Dec. 23, 1958 E. M. NUTTING 2,865,570

METHODS AND MEANS IMPROVING CONVEYING AND SIZE SEGREGATION DURING CRUSHING

Filed June 29, 1953 2 Sheets-Sheet 1

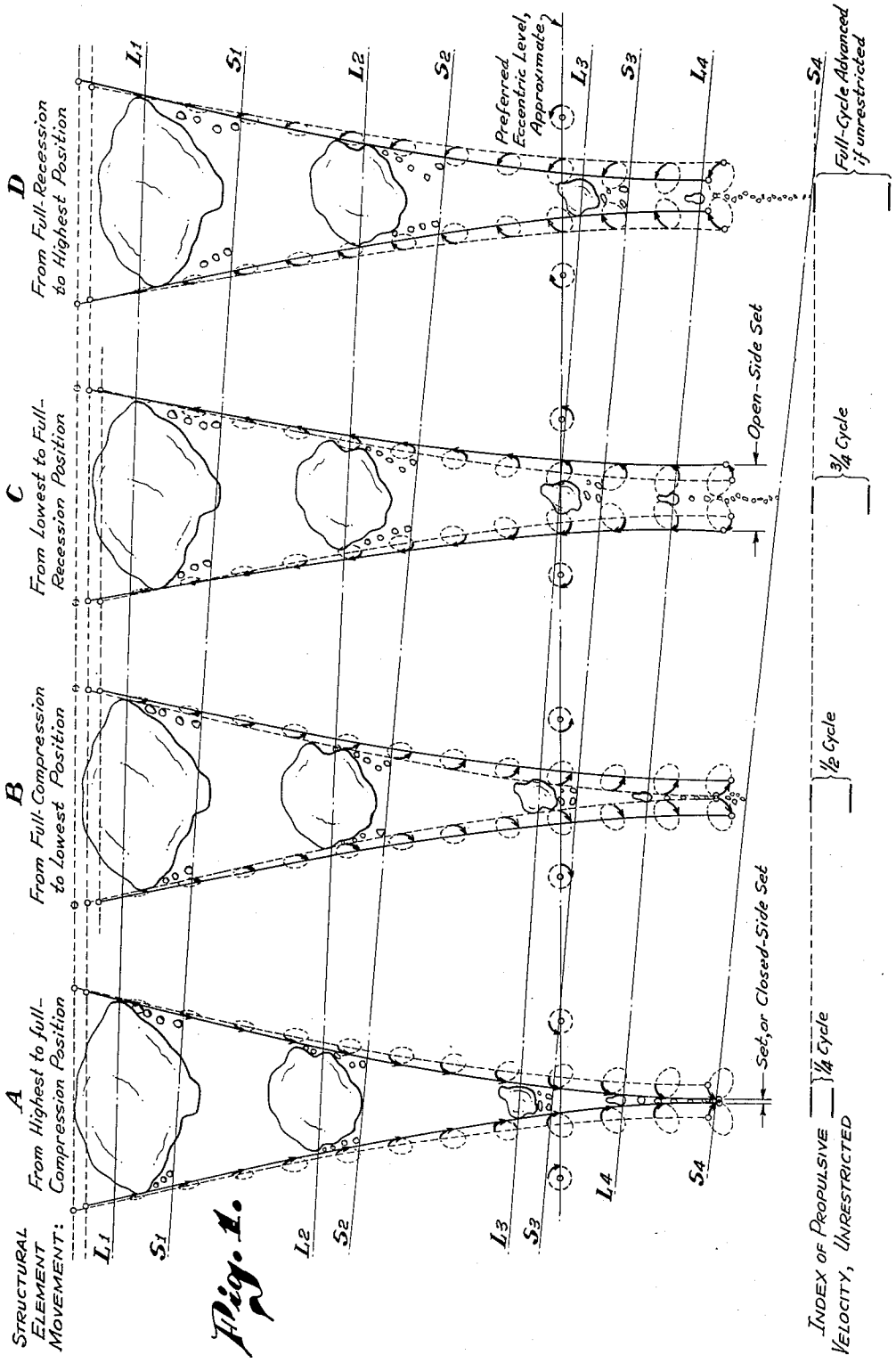


Fig. 1.

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METHODS AND MEANS IMPROVING CONVEYING AND SIZE SEGREGATION DURING CRUSHING

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Fig. 2.

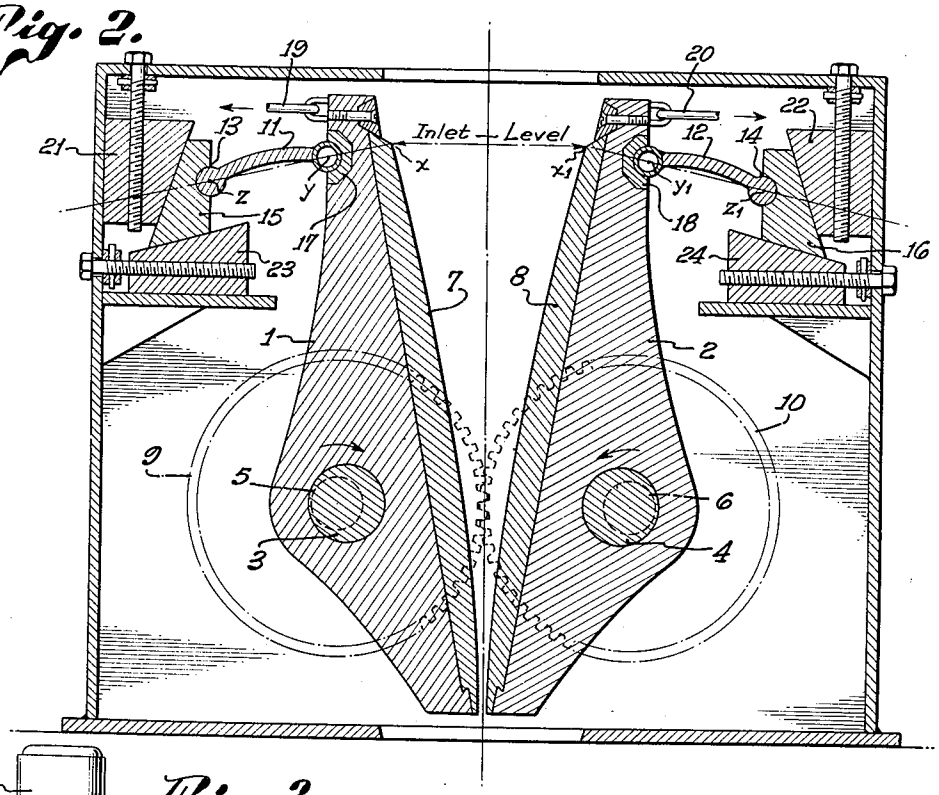


Fig. 3.

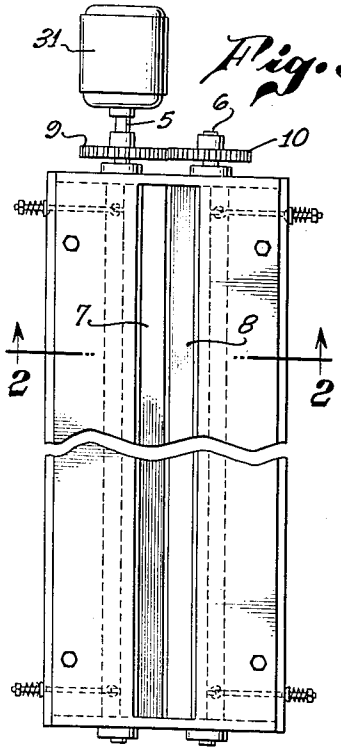


Fig. 4.

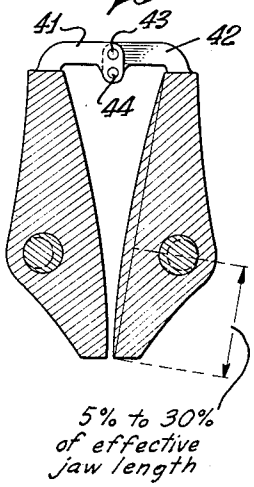
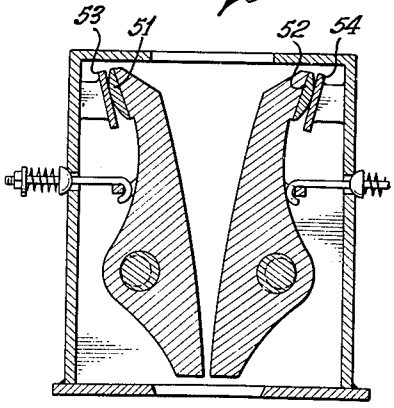


Fig. 5.



United States Patent Office 2,865,570
Patented Dec. 23, 1958

2,865,570

METHODS AND MEANS IMPROVING CONVEYING AND SIZE SEGREGATION DURING CRUSHING

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Application June 29, 1953, Serial No. 364,689

14 Claims. (Cl. 241—24)

This invention primarily relates to the art of conveying and screening mixed sizes of fragmentary and friable materials during crushing operations. It especially seeks improvement through beneficiating a stream of such materials during crushing, by establishing and controlling therein: (1) generally continuous and progressive acceleration of the material stream as a whole; (2) selective acceleration of finer fractions faster than coarser; and (3) screen-size control of the selective segregation as thus affected.

Further improvement is sought through co-ordination and regulation of the three features above, so as to coact fully with each other, and in the manner best adapted to aid in securing high efficiency in the concurrent application of any compressive forces to increase percentages of fines appearing at successive stages.

My invention is deemed especially applicable in the handling of minerals and ores, either homogeneous or heterogeneous in kind, and to those of very low or widely varying densities, since reliance on the pull of gravity can be substantially eliminated in its use; also to overcoming difficulties such as those due to the extremely wide variations often encountered matters of hardness, toughness, brittleness, cleavage, particle shape, adherent tendencies, and like factors, chiefly because the selective-acceleration and size-segregation features are attained principally by fragment-thickness controls, largely analogous to consecutive slotted screens.

Methods of this invention permit extremely high screen-effect frequencies with screen sizes governed by the cyclic frequency used; also extremely high throughput velocities; they are also especially adapted to combination with concurrent crushing-force applications in ways conferring important new benefits in fine comminution processes.

A principal disadvantage of typical systems is that they permit natural forces to affect desired results adversely. Fine powders and small fragments constantly originate in handling friable materials. Such surface forces as friction, air resistance, and adherence cause these finer fractions to lag behind accompanying larger fragments, relatively more affected by mass forces under usual conditions. Any low-density fractions present also tend to lag behind high-density fractions. Such lag results in detrimental overcrowding, or congestion, particularly at critical points or minimal cross-sections. This lag and congestion is also a disadvantage in ordinary separate screening operations. Its elimination is here a major purpose, particularly by changing fines lag to fines acceleration, with respect to velocities of accompanying larger fragments, and by conveying all densities at like velocities during combined crushing and screening.

Lag of fines, finished sizes and low-density fractions is deemed particularly detrimental and difficult to eliminate in industrial crushing and comminution; that is, in operations where every compressive-force application generates some smaller fragments and fines. Such fines range down to micron sizes, even in coarse rock breaking, and they originate at all levels and stages. Particle sizes and other

conditions are constantly changing. The disruptive forces initiate movements that are substantially uncontrolled as to velocity and direction. Fines occupy extremely valuable space which in crushing necessarily lessens at lower levels, and they cushion larger fragments against the crushing-force applications required for complete fragmentation. The conveying and size-segregating functions of crushing need much improvement before the fragmentation function can be fully utilized; but only satisfactorily fine products should be discharged.

In typical processes for beneficiating ores and minerals, the fines and finished sizes are ordinarily removed after crushing by separate screening systems dependent on gravity for size separation. Such screening is relatively slow. It requires additional conveying systems, and large screen areas to segregate moderate quantities. Difficulties increase rapidly with fineness increase, low-density factors, or moisture content. Oversize scalped off in such screening ordinarily cannot be returned to the crushing circuit within economic limits, because of the congestion and incipient impaction which characterizes fine crushing at full capacity.

In using my invention, the improved conveying permits efficient comminution to be accomplished in the same zone in which efficient size segregation, equivalent to screening, is being effected. All three functions are concurrent, effected at new high velocities, without necessary reliance on the force of gravity as a factor in the process, and without essential need for any separate conveying or screening mechanism. Both screen analysis of product and output capacity are governed by the cyclic frequency used.

Undesirable limitations in crushing performance are many and severe. To understand and remove these limitations requires that the three separate functions comprising crushing be clearly distinguished. The limitations emphasized are deemed imposed—not by the unavoidably high resistances of the materials crushed when correctly presented and properly subjected to compressive forces—but by clearly avoidable faults and failures of the conveying and screening functions. Spatial limitations are severe, and the fragments still oversize must be retained for further breaking. High-velocity conveying and screening are required for best crushing.

A major purpose of this invention is to improve conveying in crushing particularly by setting up high-speed screening effects to assure more efficient use of the limited space available, thereby to enable the use of crushers within economic limits either to make superfine products from any suitable feeds, or to handle all-small feeds satisfactorily, both heretofore impossible.

Other objects and purposes with a preferred means for their attainment, will become apparent from the drawings, the description relating thereto, and the appended claims.

In the accompanying drawings, all more or less diagrammatic:

Figures 1A to 1D are movement diagrams, illustrating in four consecutive phases or quadrants, a preferred manner of applying forces to friable material to secure combined conveying, screening and fragmentation;

Figure 2 is a sectional-elevational view of a preferred mechanical combination comprising structural elements for applying forces in the manner shown in Figure 1;

Figure 3 is a plan view of the combination shown in section in Figure 2;

Figures 4 and 5 illustrate other structural combinations for supporting, guiding and restraining inlet ends of force-applying elements, alternative to those shown in Figure 2.

The improvements of this invention inhere in the modes of applying forces to more or less friable materials;

various embodiments can be used, provided the forces are applied in the manner heredescribed.

Preferred mechanism for applying forces in the manner of this invention comprises a pair of spaced vertically extending force-applying elements, or jaws, presenting opposed surfaces or faces for applying to the material varying pressure combined with frictional propulsion alternating with frictional retardation during parts of the cycle; the said faces form a crushing zone, or throat, that is downwardly convergent, at least when the jaws are in positions of full compression; powered means such as eccentrics simultaneously oscillate the jaws at points adjacent their lower ends while their upper ends are restrained, supported and guided so that points on the jaw faces move through paths having vertical components substantially equal at all levels for a full 360 degree cycle, but with horizontal components minimal at inlet while maximal at outlet levels. Since eccentric movement is preferred, movements of jaw faces can best be described with reference to four quadrants of eccentric rotation.

The essential forces are applied at contact surfaces between material and force-applying elements. Preferred profiles of such contact surfaces are shown in the four diagrams, Figures 1A to 1D. Each shows movement during about one quarter of the operating cycle, assumed regularly recurrent.

In each diagram, the profile moves from dotted-line to solid-line position. Paths of points on profiles are shown in solid lines for the quadrant illustrated in each case with dotted lines indicating paths during other quadrants.

Circles representing paths of eccentric actuation of structural elements are also diagrammatically shown, with the particular quadrant similarly accentuated.

Major inventive essentials directly relate to both dynamic frictional and compressive force effects exerted at the surfaces where material contacts structural elements. Frictional and compressive forces are there inter-dependent. The paths travelled by points on the profiles representing those surfaces are important in my invention, particularly in matters of substantial linearity at inlet, approximate ovals at lower levels, and direction of longest axis or movement at different levels.

For best results in use, each of these features should differ widely at inlet level from the same feature at outlet level, and be characterized at intermediate levels by gradual and progressive change.

Travel of a point on such profile at inlet level should be preferably substantially along a straight or slightly arcuate line or path—both upwardly and downwardly for each element—with minimal difference of lateral position between upward and downward travel—preferably less than $\frac{1}{20}$ of the longitudinal movement there effective; particularly operations may require slight difference, but in any such case the inlet paths should be sharp-pointed at their top extremities.

The direction of this inlet travel is preferably substantially parallel to the profile at the same level, and the distance between jaw faces at the inlet should there be just sufficient to admit largest feed fragments, so that inlet paths on profiles of like opposed elements preferably are very little further apart at uppermost than at lowermost positions, and the effective horizontal amplitudes and rates of approach and recession at the inlet are the least possible in value, which does not cause lessening of output capacity under the other operating conditions being used. This also minimizes the shock and stress required to break largest feed fragments.

Such inlet paths insure substantially continuous contact between the material and the force-applying elements at near-inlet levels, as required for best use of this invention, particularly to insure that retardation be relatively high with respect to propulsion at such upper levels.

At the eccentric level the paths are preferably substantially oval, with their long axes inclined as shown at about 45 degrees to the profile at that level, and the amplitude of withdrawal and approach is there substantially equal to the diameter of the circle of eccentricity. Contact between material and element at and below eccentric level extends throughout a much lesser portion of the cycle than at the inlet. The center of eccentric movement are best positioned between 5% and 30% above the outlet ends of the jaws, and not more than $\frac{1}{3}$ the jaw length from the adjacent profile.

This jaw extension below eccentric augments the amplitudes and rates of approach and withdrawal to values which are substantially greater than like values at the eccentric level, and maximal with respect to the minimal values of the amplitudes and rates effective at the inlet level.

The long axes of the outlet paths are more nearly perpendicular to the material stream than would result if the element terminated at the eccentric level, and the ratio of long to short axes is greater; these features, in turn, augment the short, sharp, impact effect—with contact between material and jaw face near-oulet levels preferably occupying but a very limited portion of the cycle—followed by early, wide and rapid withdrawal, all desired near the outlet. Duration and effectiveness of any retardation exerted at near-outlet levels are also at minimal values, particularly in relation to the duration and effectiveness of retardation at the inlet.

I have found by tests that location of the eccentrics in the jaws within the limits indicated permits use at the very high operating speeds made possible by the improvements of this invention, and also good use of the jaw-extension advantages disclosed, without necessitating greater reciprocating weights, more complicated mechanisms for proper control of the inlet ends of the jaws, and the much slower toggle replacements resulting from such changes.

Paths of points at the same level on opposed contact profiles are preferably in mirror-counterpart relation to each other; opposed elements are preferably actuated at the same rotational speed and in synchronous relation, i. e., equal-level points on both attain their positions nearest the median line at the same instant in the cycle. Operated in this relation, there is no attritional movement, or rubbing component, between the elements; this greatly lessens energy requirement and steel wear, the major cost factors in superfine crushing and grinding operations.

The stated differences between paths at inlet and at outlet are considered essential. Extension of these differences to sensible extremes suiting each operation will contribute to the beneficial results attained.

Figure 1A illustrates preferred movement during the first quadrant. Contact profiles representing the jaw faces move from highest to mid-height positions, at which point maximum propulsive velocity is effective at all levels; compression is increasing at inlet, while passing through its peak at outlet. This serves to bring fragments and particles of all sizes, densities, and types, situated at all levels, under substantially unitary control, to accelerate the material stream as a whole to high velocity toward the outlet with substantial momentum or inertia values tending to maintain velocity in that direction. Chiefly during this quadrant, the compression also serves to effect any additional fragmentation desired, with due regard to the level of its occurrence. Crushing movement is preferably minimal at inlet but maximal at outlet.

The angle of nip should be as low as the operation permits—preferably between 0 and 3 degrees at the outlet level, and not over 10 degrees at the eccentric level, both at full-compression positions—to effect best frictional propulsion, and graduated retardation later disclosed.

Figure 1B shows preferred profile movement during the second quadrant—from mid-height to lowest positions. During this quadrant withdrawal of jaw faces from material therebetween is preferably early, wide and rapid at outlet, but less early, less wide, and less rapid at each successively higher level.

This differential, or pressure release graduated with the level or stage, imposes limits on velocities dependent on both particle thickness and the level at which the particle is then situated. Particles of thicknesses less than the set, i. e., the least inter-element distance shown in Figure 1A, proceed at substantially the maximum propulsive velocity of the force-applying elements, while effective release of fragments that are larger, or situated at higher levels, occurs at instants successively later in the cycle.

This stage-graduated release is aided and extended by the fact that the downward component of the structural element velocity is decelerating rapidly during this quadrant. Later released particles are therefore slowed down to, and released at, varied velocities all less than the maximum propulsive velocity. Such slowing down of material is retardation, graduated with the level, both by the later effective release at higher levels and by the progressive widening of the angle of nip at higher levels, which lessens the distance the typical oversize fragment can advance between the structural elements at any given instant in the cycle.

Figure 1C illustrates preferred movement of profiles during the third quadrant. Movement is upward from lowest positions to about mid-height. The upward component of structural element velocity is here accelerating, and in opposition to material flow. At the upper levels where it is still operative during this quadrant, graduated retardation of material velocities is therefore more dynamic and more effective than during the preceding quadrant, in which the retarding effect is substantially that of a brake.

During this third quadrant the material-retarding effect of the structural elements is—in sharp contrast—substantially nil at near-outlet levels. The profiles are withdrawing to the widest inter-element distance there effective during the cycle, termed the open-side set. At preferred cyclic frequencies the width of the material stream here being discharged occupies but a very minor percentage of the open-side set. Much energy loss and abrasive steel wear through needless friction is saved thereby, and the desired variations of material velocity with the level are greatly augmented.

Figure 1D illustrates preferred profile movement during the fourth and concluding quadrant, in which movement is upward from mid-height position. As this movement begins, full recession, or open-side set, is available for unrestricted material discharge at near-outlet levels, but the material flow is drastically restricted, impeded and retarded at near-inlet levels; in effect, retardation increases at each successively higher level.

This marked and essential difference between outlet and inlet flow restricting conditions preferably continues during this quadrant, while the upward component of element velocity is decelerating. It is accompanied by pressure increase, more effectively retarding the material at higher than at lower levels, particularly by reason of lesser amplitude of approach required for the jaws to exert retarding frictional force on the material and the wider nip angle effective at consecutively higher levels. The angle of nip is the angle included between lines tangent to the profiles at equal-level points.

In actual operating tests I have discovered that use of this principle, especially during the fourth quadrant, is markedly better than operations based on the principle of permitting the force-applying elements to complete their upward movement before initiating compression, as heretofore considered obviously more advantageous. In effect, this pushing up while compressing the material

stream, operates to screen out, segregate and delay generally coarser as against generally finer fractions, allowing the finished sizes and fines to proceed at relatively high velocity through interstitial spaces, to and through the system outlet, under their own momentum accelerated by the force of gravity.

Figure 1 also shows a scale below the movement diagrams representing approximate propulsive velocities. The advance per cycle shown at the right is equal to the periphery of the circle travelled by the eccentric center. This represents the propulsive or maximum downward velocity of the force-applying elements, with the eccentrics in positions indicated in Figure 1A, and approximately the maximum velocity of material discharged at the outlet. Small fragments are assumed substantially free from retarding forces throughout the cycle.

All retarding forces, being applied with greater effectiveness at each higher level and on larger as against smaller fragments at the same level, are subtractive from these maximum propulsive velocities.

An attempt is made to illustrate roughly the relative velocities of different material sizes in the four quadrants by the varying distances relatively larger and relatively smaller fragments advance during the cycle. Obvious difficulties prevent accurate illustration, and the intent is merely to indicate approximate results to aid in applying the basic principles of the invention.

Figures 1A, B, C, and D show the cycle as a whole. The gradient lines L_1—L_1, L_2—L_2, L_3—L_3, and L_4—L_4 roughly represent the relative advance of larger fragments during the cycle. At each consecutively lower level the gradient is steeper, i. e., the net advance—propulsive velocity less retardation—increases progressively at successively lower levels.

Similar relations also exist in the relative advances of smaller and finer fragments, roughly indicated by gradient lines S_1—S_1, S_2—S_2, S_3—S_3 and S_4—S_4; but the gradient increase at lower levels is greater for smaller than for larger fragments; larger fragments are retarded more than smaller at the same level, chiefly by reason of earlier and longer contact with force-applying elements during their application of the differential retarding forces described above.

These beneficial velocity differentials are further augmented during major portions of the cycle when—after being accelerated to maximum propulsive velocity—the smaller fragments are free from retarding forces, and therefore subject to added acceleration by the force of gravity, while larger fragments are forcibly retarded by the structural elements, and cannot be accelerated by gravity.

The screening process exerted by force-applying elements moved as indicated is exerted at all levels, and it varies markedly with the cyclic frequency. Screening at all levels is effected, at high frequencies by the elements at about the positions shown in Figure 1A, at low frequencies by the elements in about the positions shown in Figure 1C. The extremes of this variation are clear. More particularly, the thickness of largest fragments in the product discharged is substantially equal to the open-side set, as in Figure 1C, at cyclic frequencies below about 200 cycles per minute, but substantially equal to the closed-side set, as shown in Figure 1A, at cyclic frequencies above about 600 cycles per minute.

At cyclic frequencies between those limits of 200 to 600 cycles per minute, thickness of largest fragments discharged varies approximately in inverse ratio to the cyclic frequency used. Broadly, the entire range of product-size finenesses, increases faster than the frequency increase. This is believed due to the controlled high impact jaw velocities—terminating between substantially parallel spaced jaw surfaces—made feasible at lower levels by the improved conveying, size segregation, rapid discharge of fines, and the higher cyclic frequencies thereby permitted.

Maximum compression ratio is here considered the

ratio of greatest to least outlet width during the cycle, i. e., the ratio of open-side set shown in Figure 1C to the closed-side set shown in Figure 1A.

In operating tests of this invention, maximum compression ratios up to 100 to 1, and even in excess of 150 to 1, have been used without apparent increase of shock, stress or energy requirement, in crushing toughest available rocks exceeding 1 inch in thickness, without inter-element attritional movement. Applicant is informed that known crushing devices cannot use maximum compression ratios in excess of 10 to 1, even with the aid of attritional movement. In these tests, closed-side set was less than 0.01 inch wide.

Use of the above principles aids expeditious discharge of fines and finished sizes, avoids cushioning of fragments still oversize, aids in permitting large fragments to wedge firmly between elements at or near full-recession position, and provides ample space for their spreading. This prevents congestion and impaction, reduces resistance to crushing force, and diminishes requirements for energy and replacement of abrasive steel wear.

The resulting diminution of material resistance to rapid application of compressive and propulsive forces, particularly at lower levels, permits cyclic frequencies to be increased several hundred percent as against operating speeds of like devices known to applicant, with output-capacity increase derived from each operating-speed increase; it also permits the crushing force to be there applied at rates amounting to impact between generally parallel surfaces, approaching to within controlled distances of each other at new high velocities, thereby to effect fine comminution without attritional movement.

In my preferred methods, impact velocity increases directly with cyclic frequency at lower levels, without substantial increase in the rate at which crushing pressure is applied to material at inlet levels, where material resistance is unavoidably high because there in large fragment form.

Figure 2 illustrates in sectional elevation a preferred mechanical combination for applying forces in the manner shown in Figure 1, and in accord with the principles and mode of operation explained in the accompanying disclosure. This combination is intended to show the best mode and means, and to make apparent the best method, contemplated by applicant for effecting principles and essential purposes of this invention.

In Figure 2, force-applying elements here designated jaws **1** and **2** are preferably alike, mounted on and actuated by eccentrics **3** and **4**, mounted on and rotated by shafts **5** and **6**, which shafts are in turn rotated by any suitable known means such as meshed gears **9** and **10**, and supported in any suitable known bearings. The direction of rotation is preferably inwardly and downwardly, the speed of rotation the same for both eccentrics, and their relation preferably synchronous, in the sense that points at the same level on the opposed jaws attain nearest approach to the median plane at substantially the same instant in the cycle, so that there is no attritional movement.

Jaws **1** and **2** are preferably fitted with wear plates **7** and **8**, presenting to the material contact profiles preferably curved as above described and shown in Figure 1. Contact profiles of the wear plates preferably terminate at top-corner points X and X_1, and the common level of these points defines the inlet level referred to herein.

The upper ends of jaws **1** and **2** are guided and supported, preferably by half-toggle struts **11** and **12**, mounted with their outer ends fitted to oscillate in hinge bearings **13** and **14**, in preferably adjustable hinge-bearing blocks **15** and **16**, respectively, and with their inner ends fitted to swing in half bearings **17** and **18** mounted in jaws **1** and **2** respectively, adjacent their inlet ends substantially as shown.

The centers of movement at the inner and outer ends of half toggles **11** and **12** are respectively designated Y—Z and Y_1—Z_1; it is preferable that points X, Y and Z, be in substantially straight-line relation when the eccentric **5** is nearest the median plane, that this X—Y—Z line then slope inwardly and upwardly, and that the slope be such that the point X approaches, but does not pass below, the common level of the outer hinge points Z and Z_1 when eccentric **5** is at its lowest position; also that the opposite counter parts be arranged to function in the same relation.

Restraining means **19** and **20** may be of any suitable type, such as spring actuated retractor hooks fitted with means for tension adjustment, so that jaws may be held in continuous operative contact with their supporting half toggles, but preferably fitted for ready replacement of toggles, as with others of different effective lengths, or different compressive strengths.

For best use in handling the widely varying sizes and types of materials, and for best attainment of the many different objectives that become of paramount importance in beneficiating friable materials, adequate provision for altering the positions of outer hinge centers Z and Z_1 is preferred.

Any suitable means can be used for this purpose, such as screw-adjusted wedge blocks or bearing members **21**—**23**, and **22**—**24** forming a part of the frame assembly; it is preferable that these be of types permitting liberal adjustment during continuance of operation.

In each force-applying assembly, such as **1**, **3**, **5**, **7** and **11**, it is preferable that the throw of eccentric **3** be less than $\frac{1}{24}$ of the effective length of wear plate **7**, and less than $\frac{1}{18}$ of the distance between centers of shaft **5** and swing bearing designated Y. It is also preferable that the effective length of the half-toggle, Y—Z, be at least 4 times the eccentric throw. These dimensional relations have been found satisfactory while operating at 900–1280 R. P. M.

Half toggles have been found satisfactory in severe crushing tests of this invention when constructed with their inner ends consisting of steel tubes having wall thicknesses $\frac{1}{16}$ to $\frac{1}{8}$ of their outside diameters, as indicated. This illustrates the extent to which shock and stress have been reduced. Such tubular ends provide convenient means for overload relief and for lightening reciprocating weights. All reciprocating parts of each force-applying assembly are preferably made up in welded-assembly form, to reduce reciprocating weights at the high frequencies made practicable by the principles disclosed.

Figure 3 shows in plan view the preferred mechanical combination. The sectional elevation shown in Figure 2 is indicated at the line **2**—**2**.

In this Figure 3, structural members also shown in Figure 2 are designated by the same numbers. Motor **31** is also indicated, as a means driving the combination; this motor may be connected to the assembly by any suitable means. The motor is preferably of the variable speed type, since operating speed, or cyclic frequency, here serves particular purposes in control of material propulsion and its all-important modification by graduated retardation, and speed must preferably be coordinated to the other factors that essentially affect frictional forces desired at the material-to-element contact surfaces, to the end that best operating results can be attained.

Length of eccentric shafts and corresponding assembly is not deemed a matter of essentiality. Overload relief and special worm-gear drive, such as shown in my earlier application Serial No. 391,255, or chain drive as one means to permit adjustment of inter-shaft distance. can be used as desired by those versed in the art.

Figures 4 and 5 both illustrate alternative means for restraining, guiding and supporting the inlet ends of pairs of opposed jaws actuated by eccentrics located in the jaws at lower levels and driven in manner shown in Figures 2 and 3.

In Figure 4, arms **41** and **42** are attached to the jaws of each side, so as to clear the inlet area for admission

of feed; the arms at each side, only one pair being shown, are preferably joined by a hinge pin, secured in either of the holes 43 or 44. This hinge action is preferably located at about the inlet level, so that the path of profile movement at that level is sharp pointed at its top, with upward and downward movement substantially in the same line. No separate retracting means, such as 19—20, is here required.

Figure 5 shows a second alternative means restraining, guiding and supporting the inlet ends of pairs of opposed jaws similarly actuated by eccentrics. Here suitable members 51 and 52 attached exteriorly to the jaws, slide upwardly and downwardly on members 53 and 54, supported by the frame.

Paths of points on profiles at the inlet level here again move upwardly and downwardly in a substantially linear manner, and amplitudes through which structural elements approach toward, and recede from the material at the inlet are minimal with respect to corresponding amplitudes at the outlet level.

Basic reasons exist for the extremes of amplitude differences I have discovered advantageous for operation in the modes of this invention. In typical crushing systems, peak shocks and stresses can appear either at inlet level, or alternatively, at the outlet level, depending on whether or not congestion and incipient or actual impaction is permitted to occur at lower levels, where space must be sacrificed to secure positive application of crushing pressure. Crushable materials are generally incompressible in the absence of voids. Congestion approaching impaction can cause shock and stress at outlet to exceed that effective at inlet, although the highest unavoidable peaks occur in the inlet, where largest blocks of feed set up maximum irreducible resistances. The modes of this invention, by eliminating congestion and incipient impaction, permit outlet stress and shock to be reduced below that unavoidably effective at the inlet, even though the work rate is greater at the outlet. This reduction of shock and stress permits far higher operating speeds to be used.

Crushing systems limited to low-speed operation—as by reliance on intermittent gravity fall or congestion of material—cannot use minimal crushing amplitudes at inlet level without lessening output capacity or product fineness. In their use, decrease of crushing amplitude at inlet demands corresponding increase of that amplitude at outlet, to maintain the same total area swept by the jaw profile, which is the index of quantitative fragmentation per cycle. This required increase of outlet crushing amplitude then causes degradation of the product, by oversize fragments falling through the outlet, at the low operating speeds to which such systems are limited.

Proper use of this invention can so improve efficient use of the very limited space available at near-outlet levels that major portions of the products can be scalped off and returned to the crushing circuit, thus increasing product fineness without diminution of output capacity. Such procedure is deemed impracticable in other crushing systems, without lessening of feed rate, even at the low speeds to which they are generally limited.

To insure best results in using this invention for combined improvement of conveying, screening and comminution, particularly in superfine crushing to very fine product sizes, the user should make correlated adjustments of (*a*) approach-recession amplitude at the inlet level, (*b*) timing lag of like impulses at inlet as against outlet, and (*c*) operating speed to regulate propulsive and retarding velocities at the contact surfaces, until as by repeated determinations, the number of reduction tons actually being accomplished per unit of energy imput attains its maximum value.

Operating at predetermined values of these factors tends to insure not only lowest energy requirement, but minimal abrasive steel wear, shock, stress, and maintenance costs.

Obviously those skilled in the art may make various changes in the details and arrangement of parts without departing from the spirit and scope of the invention as defined by the claims hereto appended, and I therefore wish not to be restricted to the precise construction herein disclosed.

The term thickness, as used herein in relation to a fragment dimension, is intended to signify the least of its three dimensions, viz., length, breadth and thickness.

The term dynamic, as used herein to modify friction, signifies frictional force intentionally directed to the production of a useful result.

This application is in the nature of a continuation in part, diminished, with respect to my pending application, Serial No. 2,288, filed January 14, 1948, now abandoned, and my application Serial No. 391,255, filed May 1, 1941, now abandoned, pending on January 14, 1948 and included by reference in Serial No. 2,288.

Having thus distinguished my invention, explained its principles and the best mode contemplated for carrying out its purposes, and described a specific embodiment thereof, what I desire to secure by Letters Patent of the United States is set forth in the following claims.

I claim:

1. A reciprocating and oscillating mechanism for cyclic propulsion of rock-like materials during their progressive fragmentation for continuous segregation of generally-finer particles and powdered sizes from the accompanying generally-coarser fragments, and for accelerating such finer fractions through interstitial spaces between such coarser fragments to and through the mechanism outlet at velocities higher than the velocities of the accompanying coarser fragments, the said mechanism comprising: a pair of spaced movable jaws presenting opposed force-applying faces forming a downwardly-extending material-treatment zone downwardly convergent during at least a portion of the cycle, power means associated with the jaws for actuating the same, means oscillating lower extents of said opposed faces so that points thereon move in substantially oval paths with the concurrent movements of like points of corresponding extent but proceeding in directions relatively reverse to each other, means supporting and guiding upper extents of said jaws for generally reciprocating movement in substantially linear upward-and-downward paths approximately in the planes of said faces at about the inlet level, all said means co-acting during normal and usual operation to exert on the material between said jaws in each cycle: forces compressing, fracturing, and dynamically propelling toward the system outlet material of substantially all sizes and all densities at all levels at high and generally equal velocities during downward jaw movement, then dynamic upwardly-directed frictional forces effective to retard the downwardly-accelerated generally-coarser fragments more in contact with said faces, said upwardly-directed forces being effective in magnitudes greater at higher levels, where fragments are relatively larger and present in higher percentages, than at lower levels.

2. In a method of accelerating finer fractions of rock-like material that are repeatedly changed in size during reciprocating-pressure crushing, for augmenting the mean throughput velocity and improving the void-to-solid relations in the material before applying the next crushing force, which method comprises supplying said material to the inlet of a force-applying system, then passing such material downwardly between opposed force-applying elements in a relatively continuous stream, then applying to both opposed sides of the material stream generally-concurrent inwardly-and-downwardly directed forces in which compression is combined with dynamic friction, so as to accelerate material generally of all sizes and all densities at all levels to high velocity toward the

system outlet while fracturing oversize fragments, then applying to both sides of the material stream generally concurrent upwardly-directed frictionally-retarding forces which exert on the downwardly-accelerated coarser fragments more in contact with said elements, dynamic frictional retardation more effective at higher than at lower levels, so that finer fractions may proceed through interstitial spaces between larger fragments under their own momentum to and through the system outlet during the application of upward forces, and then repeating said alternating forces with cyclic regularity with paths of movement of points in the planes of material-to-element contact confined to approximately linear reciprocation at proximate inlet levels substantially in the plane of the jaws and to substantially oval forms at lower levels with the long axes thereof inwardly and upwardly inclined at the outlet.

3. The method of claim 2, in which the inclination of said long axes attains angles approximately 45 degrees to the median plane in the lower third portion of the jaws.

4. The method of claim 2, in which said alternating force applications are applied at regular cyclic frequencies substantially in excess of 650 cycles per minute, for greater increase of the mean throughput velocity and greater relative effect of the upward forces on the downwardly accelerated material.

5. The method of beneficiating a stream of rock-like material, during its passage through a crushing system having opposed force-applying elements forming a material-treatment zone downwardly convergent during at least a portion of its cycle and in which the approach of force-applying elements for fragmentation alternates with recession thereof to permit material advance, by establishing and controlling between the inlet and outlet of the system: progressive acceleration of the material, selective acceleration of finer fractions faster than coarser, and size-selective control of largest fragment sizes in the product by frequency of impact between spaced force-applying elements, which method comprises the following steps: supply the material to the inlet of the system; pass the material downwardly between the said elements in a substantially continuous stream; apply to both opposed sides of the material stream generally-concurrent, inwardly-and-downwardly directed forces which combine compression for added fragmentation with dynamic frictional force for material propulsion, so as to fracture oversize fragments and concurrently accelerate material of all resulting sizes and all densities at all levels to high and generally-equal velocities toward the system outlet; withdraw both said force-applying elements in directions away from each other, in such manner that withdrawal shall be earlier, more rapid and wider at lower than at upper levels, to cause release to be more effective at lower than at upper levels and on finer as against coarser fractions at the same level; apply to the material stream as it proceeds downwardly at high velocity and with substantial momentum, generally-concurrent, upwardly-directed, frictionally-retarding forces, so as to exert, on generally coarser fragments more in contact with said elements, dynamic frictional retardation more effective both at higher than at lower levels, and on generally coarser than on generally finer fractions at the same level, so as to permit such finer fractions to proceed under their own momentum through interstitial spaces to and through the system outlet; move said force-applying elements toward each other during continuance of upward movement thereof, with their approach earlier and more effective for frictional retardation at upper than at lower levels, and on coarser as against finer fractions at the same level; repeat said material-treatment steps with cyclic regularity at a rate substantially in exess of 650 cycles per minute and sufficient to cause high-frequency screening such that the thickness of largest-fragment sizes discharged is less than one-half of the maximum spread between said force-applying elements at the outlet during the cycle.

6. The method of claim 5, in which the movements of said force-applying elements are so limited that the angle of nip between the faces thereof is in a range of zero to 3 degrees at the outlet level at full compression, and substantially wider than 3 degrees at upper levels, so as to augment the effect of the upward retarding forces on the downwardly accelerated material.

7. The method of claim 5, in which the ratio of maximum to minimum spread between said elements at the outlet approximates 100 to 1.

8. The method of beneficiating a stream of rock-like material, during its passage through a crushing system having opposed force-applying elements forming a material-treatment zone downwardly convergent during at least a portion of its cycle and in which the approach of force-applying elements for fragmentation alternates with recession thereof to permit material advance, by establishing and controlling between the inlet and outlet of the system: progressive acceleration of the material, selective acceleration of finer fractions faster than coarser, and size-selective control of largest fragment sizes in the product by frequency of impact between spaced force-applying elements, which method comprises the following steps: supply the material to the inlet of the system; pass the material downwardly between the said elements in a substantially continuous stream; apply to both opposed sides of the material stream generally-concurrent, inwardly-and-downwardly directed forces which combine compression for added fragmentation with dynamic frictional force for material propulsion, so as to fracture oversize fragments and concurrently accelerate material of all resulting sizes and all densities at all levels to high and generally-equal velocities toward the system outlet; apply to the material stream, as it proceeds downwardly at high velocity and with substantial momentum, generally-concurrent, upwardly-directed, frictionally-retarding forces, so as to exert, on generally coarser fragments more in contact with said elements, dynamic frictional retardation more effective both at higher than at lower levels, and on generally coarser than on generally finer fractions at the same level, and permit such finer fractions to proceed under their own momentum through interstitial spaces to and through the system outlet; repeat said material-treatment steps with cyclic regularity at a rate substantially in excess of 650 cycles per minute and sufficient to cause high-frequency screening such that the thickness of largest-fragment sizes discharged is less than one-half of the maximum spread between said force-applying elements at the outlet during the cycle.

9. The method of claim 8, in which the movements of said force-applying elements are so limited that the angle of nip between the faces thereof is in a range of zero to 3 degrees at the outlet level at full compression, and substantially wider than 3 degrees at upper levels, so as to augment the effect of the upward retarding forces on the downwardly accelerated material.

10. The method of claim 8, in which the lateral movement of a point in the element face at the inlet level does not exceed one twentieth of the longitudinal movement of said point during the cycle.

11. The method of claim 8, in which the ratio of maximum to minimum spread between said elements at the outlet approximates 100 to 1.

12. In a crusher of the class described, the combination comprising a frame; a pair of opposed similar jaws; means connecting said jaws near their upper ends to the frame for swinging and vertically reciprocating movements, the said jaws being arranged in spaced relationship to provide a top inlet and a bottom outlet therebetween, and means connected to said jaws whereby when mixed sizes of fragmentary and friable material are introduced into said inlet the said material will

be crushed and in part conveyed downwardly between said jaws and through said outlet during a cycle of their operation and whereby (*a*) during the first part of the cycle the facing profiles of the jaws will move downwardly from their highest to their mid-height positions and at the same time move toward each other through horizontal distances which are minimal at the inlet and maximum at the outlet, (*b*) during the second part of the cycle the said profiles will move downwardly from their mid-height positions to their lowest positions and at the same time move away from each other to effect pressure release from the material graduated in extent upwardly from the outlet, the pressure release at the outlet being rapid and wide and being less rapid and less wide at the inlet, (*c*) during the third part of the cycle the said profiles will move from their lowest to about mid-height positions and at the same time move away from each other except at their upper ends, the material-retarding effect of the jaws being substantially nil at the outlet, and (*d*) during the fourth part of the cycle the profiles will move from their mid-height positions to their highest positions and at the same time move inwardly except at their upper ends, the said means including the inwardly convex curvatures of the inner faces of the jaws, and mechanism connected to the jaws near their lower portions for causing points on the jaw profiles at the level of said mechanism to move in substantially oval and synchronous paths at substantially the same speed.

13. A crusher comprising a frame, half-toggle struts, a pair of similar laterally spaced facing jaws having inwardly convex curvatures on their inner faces, and a pair of similar eccentrics, each strut being hingedly connected at one of its ends to the frame assembly at points lying in the same horizontal plane, and each strut being hingedly connected at its other end to a jaw near the top thereof, the eccentrics being journalled in the jaws at a level near the bottoms thereof to impart oval paths to points on the inner faces of the jaws at that level, and each of the struts being connected to a jaw and the frame in such manner that a straight line passes inwardly and upwardly through the centers of the hinged ends of the strut and the upper edge of the inner surface of the jaw when the associated eccentric is nearest a vertical median plane between the jaws and the angle of nip will be widest at the upper ends of the jaws and practically nil at the lower ends of the jaws, and that the point where such line intersects the upper edge of the inner surface of the jaw is above a horizontal plane passing through the centers of the hinged portions of the struts where they are attached to the frame assembly when the eccentric is in its lowest position.

14. The crusher as defined in claim 13 in which the frame comprises adjustable bearing members in which the struts are hinged, and means for adjusting said members laterally and vertically.

References Cited in the file of this patent

UNITED STATES PATENTS

45,582	Brodie	Dec. 17, 1864
49,032	Ingersoll	July 25, 1865
123,406	Learmouth	Feb. 6, 1872
264,179	Marsden	Sept. 12, 1882
434,686	Howland	Aug. 19, 1890
523,938	Howland	July 31, 1894
708,495	Robinson	Sept. 2, 1902
906,271	Palmer	Dec. 8, 1908
929,177	Watt	July 27, 1909
1,029,910	Buchanan	June 18, 1912
1,067,229	Kumplen	July 8, 1913
1,133,101	Cockfield	Mar. 23, 1915
1,620,659	Hodgkinson	Mar. 15, 1927
1,936,742	Youtsey	Nov. 28, 1933
1,967,240	Guest	July 24, 1934
2,131,801	Gruender	Oct. 4, 1938
2,257,388	Krider	Sept. 30, 1941
2,302,723	Symons	Nov. 24, 1942
2,303,923	Fahrenwald	Dec. 1, 1942
2,383,457	Anderson	Aug. 28, 1945

FOREIGN PATENTS

605	Great Britain	1876
3,696	Great Britain	Oct. 26, 1874
6,990	Austria	Mar. 10, 1902
8,386	Great Britain	1896
9,881	Germany	June 4, 1880
12,087	Great Britain	May 23, 1910
28,065	Sweden	Jan. 14, 1910
39,646	Norway	Sept. 1, 1924
43,545	France	Apr. 9, 1934
	(1st Addition to No. 740,081)	
52,728	Norway	June 26, 1933
65,467	Austria	June 25, 1914
129,279	Germany	Mar. 11, 1902
201,412	Great Britain	Aug. 2, 1923