Sept. 9, 1952 K. GAULDIE 2,609,994

POWER TRANSMISSION IN JAW CRUSHERS

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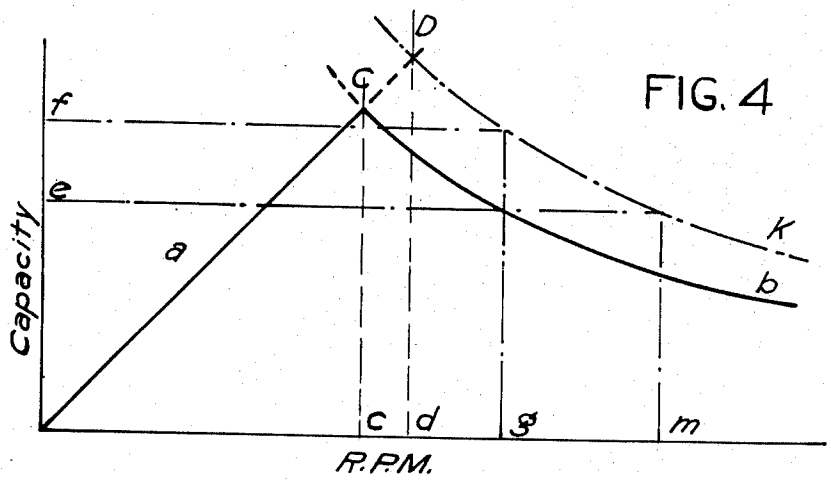


FIG. 4

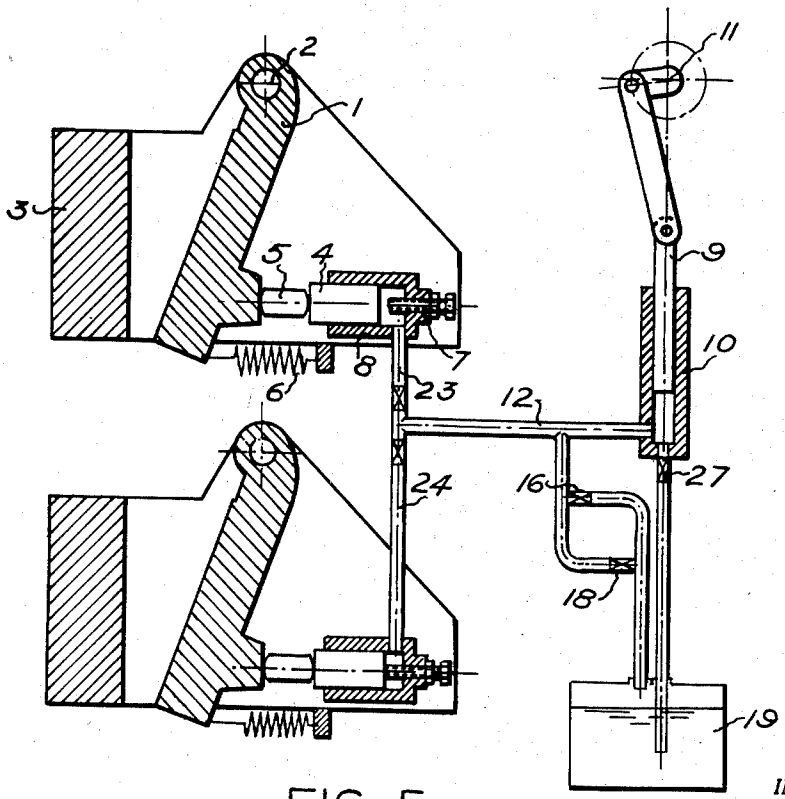


FIG. 5

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FIG. 1

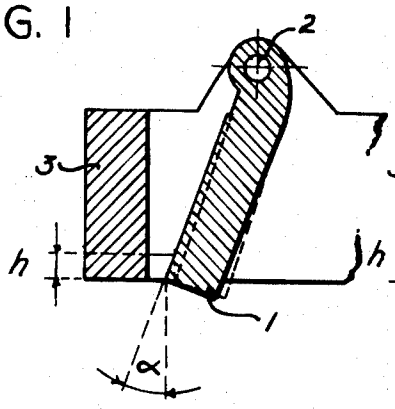


FIG. 2

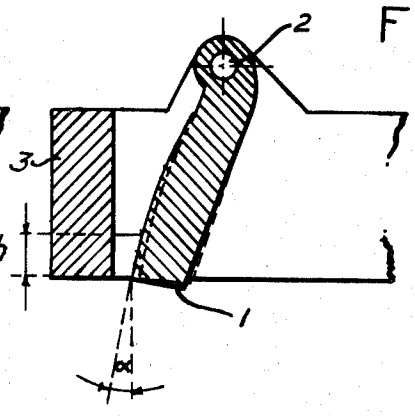


FIG. 3

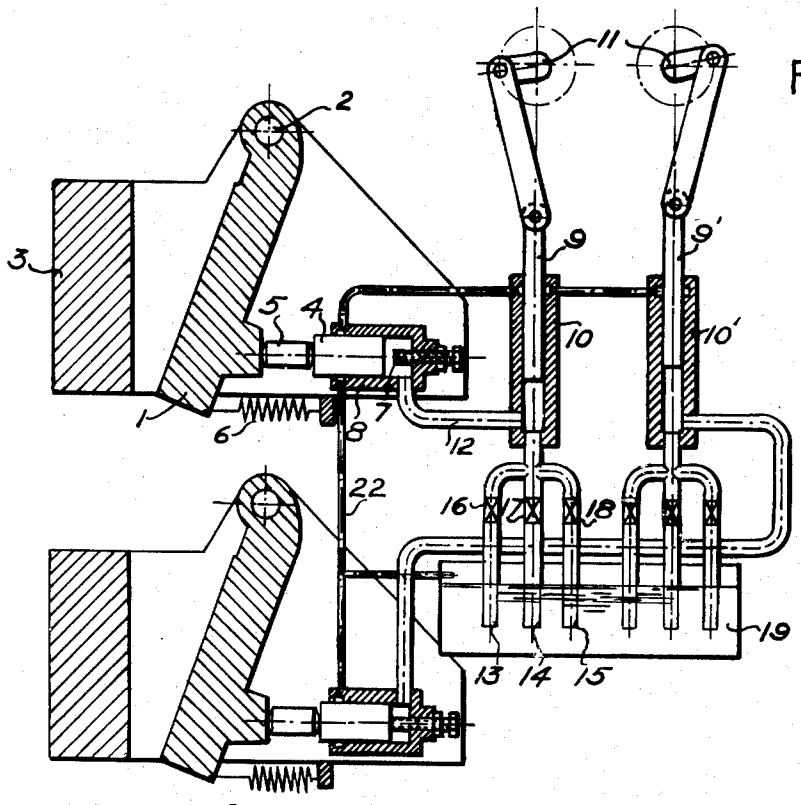
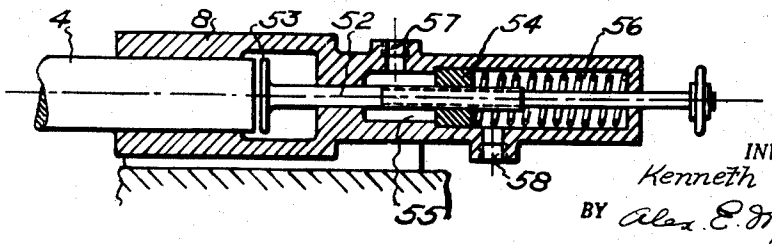


FIG. 8



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POWER TRANSMISSION IN JAW CRUSHERS

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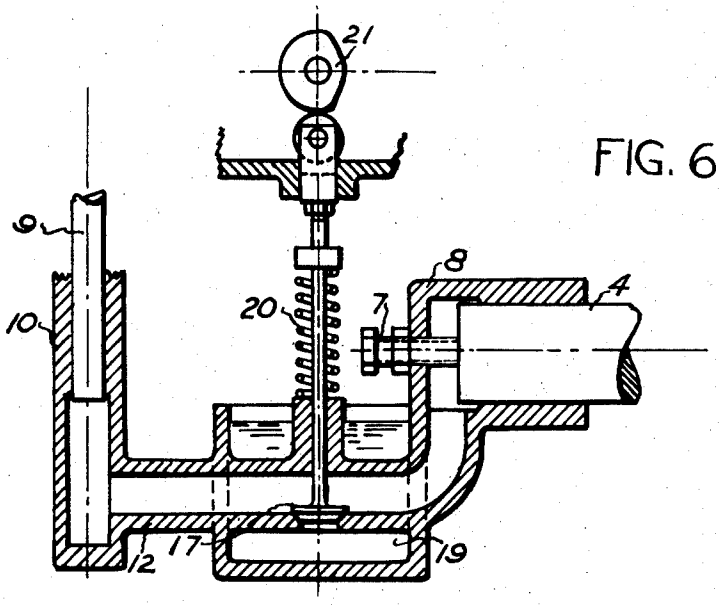


FIG. 6

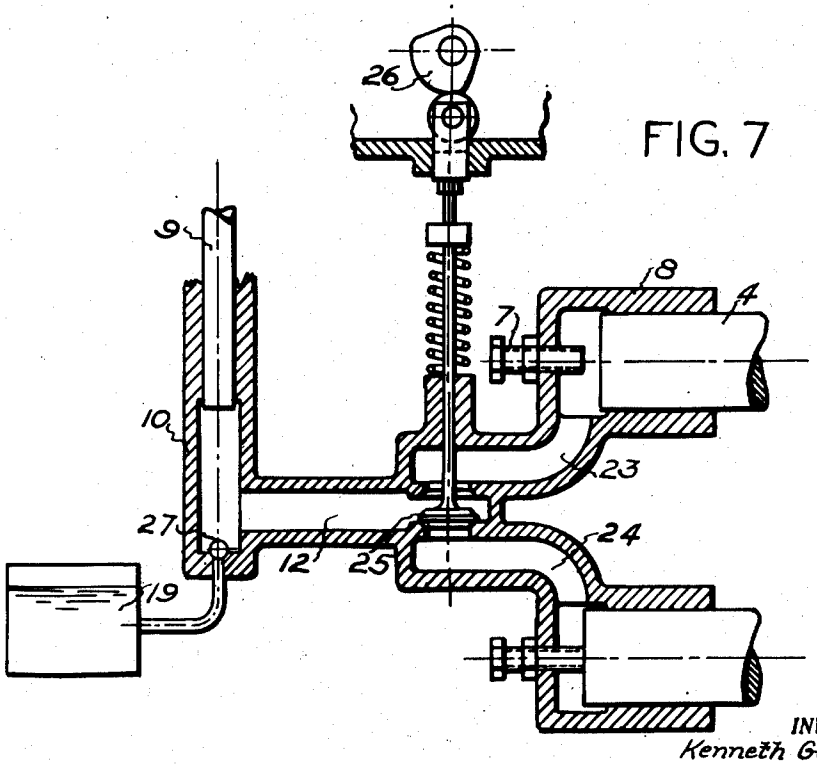


FIG. 7

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POWER TRANSMISSION IN JAW CRUSHERS

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FIG. 9

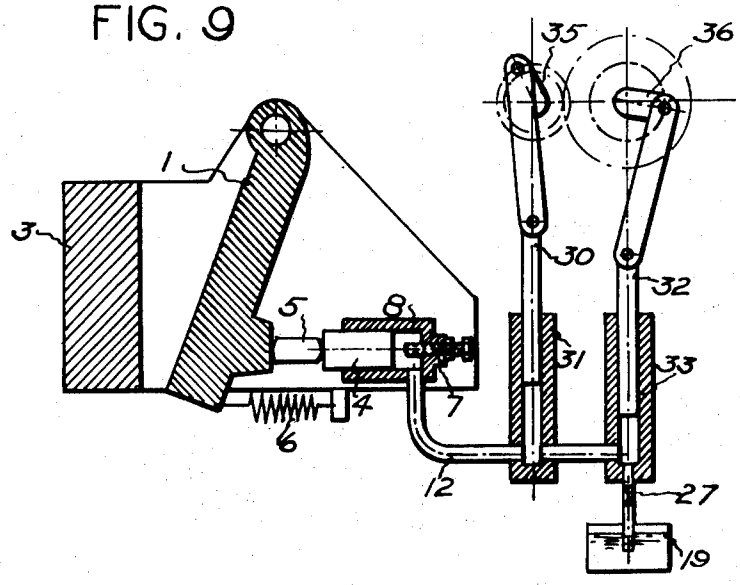
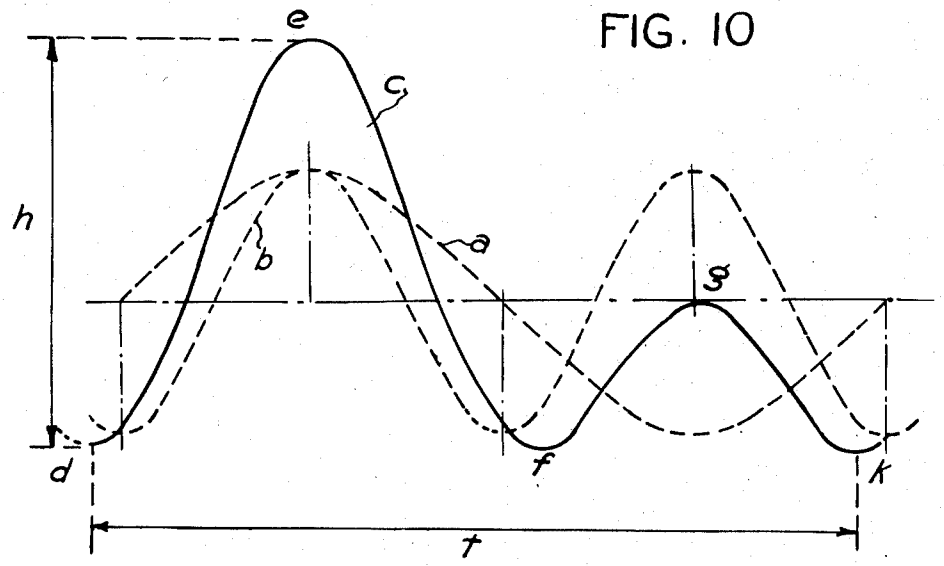


FIG. 10



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POWER TRANSMISSION IN JAW CRUSHERS

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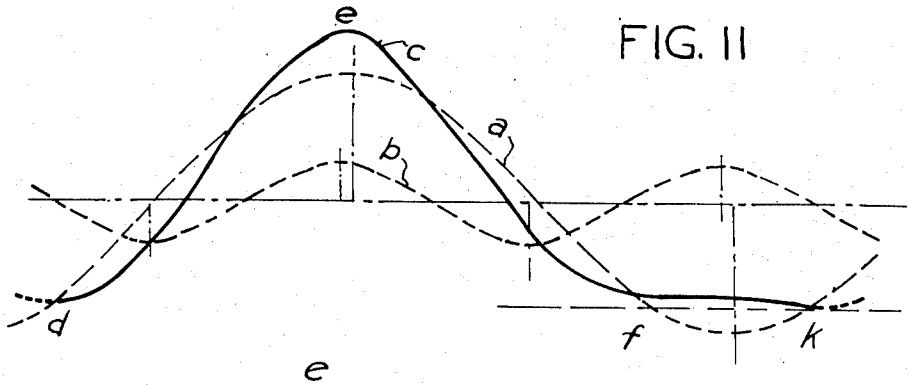


FIG. 11

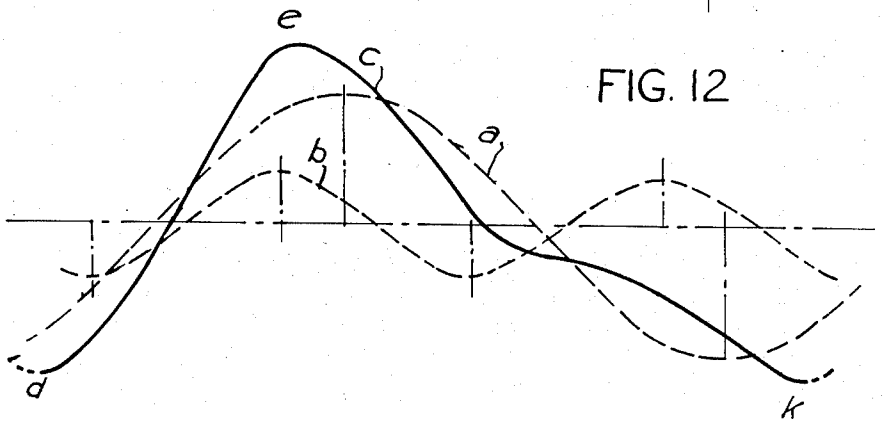


FIG. 12

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UNITED STATES PATENT OFFICE

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POWER TRANSMISSION IN JAW CRUSHERS

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Application April 9, 1948, Serial No. 20,140
In Great Britain April 27, 1947

5 Claims. (Cl. 241—148)

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The present invention relates to jaw crushers and particularly to improvements in the manner and means of power transmission to the oscillating jaws thereof of which the primary objects are to enable increased capacity, lighter construction, greater uniformity of product or a combination of these advantages to be attained.

In the conventional jaw crusher in which a jaw pivoted adjacent its top is caused to oscillate to crush material between it and a fixed jaw, the material can descend in and emerge from the crushing chamber between the jaws only during the return stroke of the swing jaw. During such return stroke, the whole charge moves downwards as the swing jaw moves backward and (provided that time is available for descent under gravity) a wedge of crushed material can emerge of which the greatest width is equal to the distance apart of the jaw tips at open setting.

During each complete oscillation of the jaw of a conventional crusher, the time available for the descent under gravity, from rest, of the crushed material is one half of the period of the oscillation. The distance through which material can fall from rest, under gravity, varies as the square of the time available for descent and therefore decreases rapidly with decrease in available time. If the speed of a jaw crusher is progressively increased from zero there will, at first, be sufficient time available during each return stroke for the whole of the potentially-emergent wedge of crushed material to fall clear of the jaws. Under such conditions, the same volume of material will emerge each revolution and the capacity of the crusher will be proportional to its speed.

As the frequency of oscillation of the jaw is increased, a "critical" speed will be reached such that the distance through which crushed material can fall from rest during the return stroke is just sufficient to clear the jaw tips at open setting.

As the speed of the crusher is further increased beyond the "critical" speed, the distance through which material can fall is progressively less than the height of the potentially-emergent wedge. That is, the volume which can emerge per stroke decreases after the critical speed has been exceeded and the proportionality which exists at speeds up to the critical no longer persists. As the speed of the crusher is increased beyond the critical, the height of each emergent wedge decreases as the square of the time occupied in a return stroke; that is, the height of each emergent wedge varies inversely as the square of the frequency of oscillation. The number of emergent wedges varies, however, directly as the frequency.

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It follows therefore that the capacity of a crusher operating above its critical speed tends to be inversely proportional to its speed.

A primary object of my invention is to provide mechanism whereby the proportion of the period of a complete oscillation of the jaw of a crusher which is available for the falling of the crushed material by gravity is increased with consequent increase in capacity or potential capacity of the crusher.

Further objects and advantages of my invention will become apparent from a consideration of the following detailed description of embodiments of my invention taken together with the accompanying drawings in which Figs. 1 and 2 are diagrammatic showings of conventional jaw crushers for the purposes of explaining the principles of my invention; Fig. 3 is a diagrammatic showing of an embodiment of my invention; Fig. 4 is a graph; Fig. 5 is a diagrammatic showing of another embodiment of my invention; Fig. 6 is a sectional view of a valve arrangement useful in the modification of Fig. 3; Fig. 7 is a valve arrangement useful in the modification of Fig. 5; Fig. 8 is a sectional view illustrating certain details; Fig. 9 is a further modification of my invention; and Figs. 10, 11 and 12 are graphs useful in the explanation of the modification of Fig. 9.

Referring to the drawings, Fig. 1 is a diagrammatic showing of the crushing elements of a conventional jaw crusher in which the movable jaw 1 is caused to oscillate about the shaft 2 and to crush the material which descends between it and the fixed plate 3. The jaw is shown in full lines at the forward end of the crushing stroke and in dotted lines at the rearward end thereof. It will be evident that a wedge of crushed material of which the maximum breadth is equal to the distance apart of the jaw tips at open setting and of which the height is represented by the letter "h" in the figure, may fall out during the back swing of the swing jaw provided that time is available for descent under gravity through such distance.

Fig. 2 is a similar conventional showing of a crusher in which the swing jaw has a curved face and in which the included angle α between the jaw surfaces at outlet is relatively low. By comparison with Fig. 1 this figure illustrates the influence of the included outlet angle on the height h of the potentially-emergent wedge and on the capacity of a crusher.

It has previously been indicated that the capacity of a crusher is proportional to its speed until a "critical" speed has been reached after

which this capacity declines as the speed is further increased. In the graph shown in Fig. 4 in which speed or R. P. M. is the abscissa and capacity is the ordinate, the proportionality of capacity to speed up to the critical point at C is indicated by the straight line *a* passing through the origin. Up to the "critical" speed, it is the height *h* of the potentially-emergent wedge which determines the volume of crushed material which is discharged during every return stroke of the swing jaw. At the critical speed, the time available during the return stroke is exactly sufficient for the fall of material under gravity through the height *h*. Beyond the critical speed, the distance through which material can fall under gravity in the time of the return stroke decreases rapidly as speed is increased; and the falling line *b* indicates the manner in which, for that reason the capacity of a crusher tends to decline at speeds above the critical.

It will be apparent therefore that the maximum capacity of a crusher depends on its critical speed. Any measure which would have the effect of increasing the critical speed (as from C to D) has consequently the effect of correspondingly increasing the maximum capacity of the crusher. Any driving arrangement for the movable jaw which increases the proportion of the period of an oscillation during which the swing jaw is being retracted, causes the critical speed to be raised and hence increases the maximum capacity of the crusher.

The effect on the capacity of a crusher of an increase in the critical speed is illustrated by comparison of the lines *b* and *k* whereby it will be evident that the capacity of a crusher at any speed *g* beyond the critical is increased if the critical speed is raised. For example at the speed *g* the capacity of the crusher is increased from *e* to *f* by the raising of the critical speed from *c* to *d*.

It will also be apparent from the diagram that the same capacity *e* will be attained at a higher speed *m* if the critical speed is increased and that the work done per stroke and the forces transmitted through the structure of the crusher may be reduced accordingly.

It will also be evident that if the capacity *f* obtainable at the speed *g* from a machine operating in accordance with the curve *k* is greater than is desired, that capacity may be reduced by corresponding reduction in the jaw movement and that the size-uniformity of the product may be improved.

The lengthening of the proportion of the period of a complete oscillation which is available for outfall of material, permits therefore by comparison with jaw crushers of conventional design, of greater capacity, or higher speed and lighter construction, or greater uniformity of product, or a combination of these advantages.

Fig. 3 shows an emboliment of my invention in which the forward crushing force, developed as a hydraulic pressure by the plunger 9, is applied to the swing jaw 1, by means of a ram 4 acting through an intermediate rocker 5. The swing jaw is retracted during its return stroke by a spring 6; but its movements are controlled by movements of the plunger 9. And when the plunger reaches the top of its stroke the ram comes quietly to rest against the adjustable stop 7 in the base of the hydraulic cylinder. The power-driven plunger 9 operating in hydraulic cylinder 10 is driven from the shaft 11, at twice the speed of oscillation desired for the jaw 1. A suitable pipe 12 delivers liquid from the bottom of cylinder 10 to the ram cylinder 8; and pipe 14 connects from the bottom of the cylinder 10 to the sump 9. The pipe 14 is equipped with a valve 17. This valve is a commutating valve, one example of a suitable form being shown in Fig. 6 and is driven at half the speed of the plunger 9 whereby successive strokes of the plunger alternately deliver liquid to the ram cylinder 8 and to the sump 19. In operation, during a rotation of the shaft 11 with the valve 17 closed (the position shown in Fig. 6) the ram 4 is forced forward on the downstroke of the plunger 9 to deliver a crushing stroke to the jaw 1 and is then retracted to its position against the stop 7 by the spring 6 on the upstroke of the plunger 9. On the next downstroke of the plunger 9 and during its subsequent return stroke, the valve 17 is open and the plunger 9 is idling, the jaw 1 being held in its open position by the tension of the spring 6. It is apparent that the period of time available for outfall of crushed material from the crusher is three-quarters of the complete period of oscillation of the jaw. It will also be apparent that, as the proportion of the time of each oscillation of the jaw during which discharge may take place has been increased, the critical speed of a crusher of which the jaw movement and outlet angle are given, has increased and that, by comparison with a conventional crusher, the capacity of the crusher has been correspondingly increased.

Fig. 6 of the drawing shows a suitable form of commutating valve 17. The valve is biased to open position by a spring 20 and is moved against the pressure of the spring by a suitable cam 21 driven at half the speed of the shaft 11. The cam is appropriately shaped to bring the valve 17 nearly into contact with its seat when the plunger 9 is at the commencement of an active stroke and to permit the valve to be open under the influence of its spring during one half of the cam's revolution.

The relief or safety valve 18 (Fig. 3) in the pipe 15 opens if the pressure in the hydraulic system exceeds a predetermined value and is provided to prevent undue strain in the crusher structure as a result of tramp steel or other uncrushable material becoming caught between the jaws. The valve 16 in pipe 13 is a manually operated valve which may be closed gradually to facilitate the start of a crusher against a full chamber.

In the diagrammatic arrangement, Fig. 3, two separate swing jaws are indicated, each with its separate crushing chamber and separate hydraulic system comprising a ram and plunger. The two plungers 9 and 9' are operated from the same crankshaft 11 by cranks 180 degrees apart; but apart from this mechanical linkage, the crushing system illustrated in this figure comprises two independent units, the swing jaws of which operate alternately.

The two crushing units are shown in the diagram as in series. Such an arrangement would be suitable if a very large reduction ratio were required from a single installation. Normally, however, the swing jaws would be mounted side-by-side in the same crushing chamber and on the same shaft 2 and would operate in parallel.

Because of the alternate operation of two half-width swing jaws, the work done per jaw (by comparison with a conventional crusher) is halved, the forces transmitted through the frame are reduced and the structure may be lightened accordingly.

I have also illustrated in Fig. 3 pipe connec-

tions indicated at 22 whereby fluid leakage past the plungers 4 and 9 is returned to the sump 19. If no leakage occurred past the rams and plungers or elsewhere, each ram and its associated swing jaw would oscillate between definite limits. Leakage cannot however be avoided and as a result of leakage the jaws would tend to oscillate between receding limits. For that reason a jaw comes to rest on its stop 7 a little before the plunger 9 has reached the end of its reduction stroke and the continued slight movement of the plunger to the end of its stroke draws liquid from the sump 19 through the semi-automatic valve 17. Irrespective of the occurrence of leakage, the hydraulic system therefore contains a definite volume of liquid when the plunger 9 is at the beginning of an active crushing stroke.

In Fig. 5 I have shown a two-jaw crusher arranged in the manner of Fig. 3 and which differs therefrom in that a single plunger 9 is provided for operating the pair of rams 4. The same references are applied to the same parts as in Fig. 3. Mechanism is provided which places the plunger chamber in alternate communication with the two rams 4. The pipe 12 leading from the plunger cylinder 10 to supply the rams has a pair of branches 23 and 24 one leading to each of the ram cylinders 8 of one of the crusher jaws. The branches 23 and 24 are provided with valves diagrammatically shown in Fig. 5. In Fig. 7 I have shown a valve mechanism suitable for controlling the delivery of fluid through the pipes 23 and 24. A single valve 25 cooperates with a valve seat in the conduit 23 when in an upper position and also cooperates with a valve seat in the conduit 24 when in its lower position. The valve 25 is spring biased to move in an upward direction and is actuated against the spring by a cam 26. The cam 26 is driven in timed relation with the plunger 9 whereby for one complete stroke of the plunger 9, the inlet to conduit 24 is closed (the position illustrated) and the lower ram 4 is idle, held against its stop 7 by its return spring 6. During this stroke, the inlet to the conduit 22 and the upper ram cylinder 8 is open. On the succeeding stroke of the plunger 9, the valve 25 is seated on its upper seat closing the inlet to conduit 23 and opening the inlet to conduit 24 whereby the lower ram 4 is actuated and the upper ram 5 is held idle against its stop 7. Make-up for leakage of fluid past the rams 4 and the plunger 9 is provided for by the check valve 27 in a pipe leading from the sump 19. In the same manner as described in the modification of Fig. 3, if due to leakage one of the rams 4 is returned against its stop by its spring before the completion of the upstroke of the plunger 9, the continued movement of the plunger 9 to the end of its stroke causes the check valve 27 to open permitting liquid to be drawn in from the sump 19. While I have shown in Fig. 7 a single valve for the control of the passages 23 and 24, it is apparent that each of the passages may be separately controlled by a valve actuated by a separate cam. In the modification of Fig. 5, I have shown other pipes leading from the bottom of the plunger chamber 10 to the sump 19 including a manually operated starting valve 16 and an automatic pressure relief valve 18 for the same purpose as the similarly numbered valves described in connection with Fig. 3.

In Fig. 9 I have shown a further embodiment of my invention in which hydraulic mechanism is illustrated whereby a quick forward stroke and a delayed return stroke is obtained without the use of control valves between the driving plunger chamber and the ram as described in the embodiments of Figs. 3 and 5. Reference character 30 represents a plunger operating in hydraulic cylinder 31, and 32 illustrates another plunger operating in hydraulic cylinder 33. The bottom of cylinder 31 is in communication with the bottom of cylinder 33 and the pipe 12 connects the ram cylinder 8 to both these plunger cylinders without intervening valves. The movement of the ram 4 is thus the resultant of the combined action of the two plungers 30 and 32. The plunger 30 is connected to be driven by a crank from the shaft 35 and the plunger 32 is connected by a crank to be driven from the shaft 36. The shaft 36 as diagrammatically shown is arranged to be driven at half the speed of the shaft 35. The plunger 30 is thus caused to reciprocate at twice the speed of the plunger 32 and by their conjoint action the two plungers provide a quick forward stroke of the ram 4 and a much longer return stroke.

The operation of the mechanism of Fig. 9 will be understood with reference to the diagram Fig. 10. In that diagram the displacement of the slow-speed plunger 32 is represented by the harmonic curve *a* and the displacement of the high speed plunger 30 by the harmonic curve *b*.

Since both plungers are in communication with each other and with the ram it follows that the displacement of the latter is the resultant of the displacements of the two plungers.

The full line curve *c*, Fig. 10, which represents the displacement of the ram, results from the compounding of the two simpler periodic curves *a* and *b*. It will be noted that the period *t* of a complete cycle of jaw movement is equal to the period of the slow-speed plunger.

The condition when the ram 4 is momentarily at rest on its stop 7 is represented by the point *d* on the curve. In the interval between the points *d* and *e* the ram is forced forward in its active, or crushing stroke, through its full amplitude *h*. During the remainder of the period *t*, (between points *e* and *k* on the curve) the ram and the swing jaw are retracted from their extreme forward positions and crushed material is, consequently, free to emerge from the crushing chamber during the corresponding interval.

As is evident by inspection, the time involved in the return stroke of ram and swing jaw is very considerably more than half the complete period of oscillation of the jaw.

The secondary forward movement of the ram and swing jaw which occurs between points *f* and *g* on the curve does not necessarily affect the capacity of the crusher in any marked degree. It does, however, affect the manner of descent of material in the upper portion of the crusher chamber, and it may or may not be a desirable feature according to the conditions of operation of the crusher. As indicated in Figs. 11 and 12 this secondary movement may be completely eliminated by adjustment of the relative displacements of the two plungers and their phase relationships.

Under the conditions of relative displacement and phase relationship indicated in Fig. 11 the rapid crushing stroke between points *d* and *e* is followed by a rapid retraction of the ram between points *e* and *f* on the curve. At the end of this period the ram has almost completed its return stroke but has not quite contacted its stop. The remainder of the period from *f* to *k* is available for the slow and gradual ap-

proach of the ram into contact with its stop. That is, the object attained by the plunger relationships indicated in Fig. 11, is the minimization of any shock which may occur when the ram contacts its stop.

Fig. 12 indicates how, by other choice in displacement and phase relationships of the two plungers, a relatively uniform velocity of ram and swing jaw during the return stroke may be attained.

It will be understood that the general principles which have been explained with reference to two plungers apply with respect to the compounding of the motions of a greater number of plungers and that three or more plungers running at different speeds may be employed in conjunction with a single ram.

In the modification of Fig. 9, check valve 27 provides for makeup fluid to compensate for leakage in the same manner as has been described in connection with Fig. 5.

In Figs. 3, 5 and 9, I have illustrated more or less diagrammatically a stop 7 against which the ram 4 comes to rest on its return stroke. In Fig. 8 I have shown stop mechanism which provides for the absorption of shock between the ram and its adjustable stop and which also provides for the automatic release of uncrushables.

This mechanism comprises a shaft 52 mounted for longitudinal reciprocation in the casing and having a head 53 of substantial area to be engaged by the end of the ram 4. The shaft 52 has a piston 54 mounted thereon for adjustment therealong and which operates in the cylinder 55. Piston 54 is backed by a compression spring 56 which is of sufficient strength to maintain the piston 54 in the position shown, against the pressure exerted thereon through the ram 4 by the return spring 6. The cylinder 55 is provided with an inlet port 57 and an outlet port 58. The inlet port 57 is connected by a pipe to the outlet port of the relief valve 18 and the outlet port 58 is connected by a pipe to the sump.

In normal operation the layer of oil between the ram 4 and the head 53 together with the spring 56 act to cushion the shock of contact of the ram with its stop at the end of the stroke of the former. If, however, uncrushable material enters between the jaws of the crusher, fluid in the hydraulic system is expelled on the crushing stroke of the plungers, through the relief valve 18 and thence through the port 57 into the cylinder 55. The pressure of fluid in the cylinder 55 drives the piston 54 against its spring till the outlet port 58 is uncovered, whereby the liquid discharges to the sump. As the stop 53 moves back with the piston 54 when the relief valve comes into operation, the swing jaw 1 is free to move back under the influence of its retracting spring until the obstruction is discharged from the crusher. The relief valve then closes and the stop moves back to its previous setting at a slow rate dependent on the rate at which liquid caught behind the piston can escape past it to the output port. The mechanism just described thus provides for the absorption of shock at the moment of contact between the ram and its stop and also provides for the automatic release of uncrushables and for subsequent, automatic resetting of the swing jaw.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In a crusher having a reciprocatable jaw, a hydraulic system for operating the jaw to produce crushing strokes thereof including a ram cylinder, a ram in the cylinder acting on said jaw, and a hydraulic power-transmitting liquid engaging said ram, and means for imparting a return stroke to the jaw after completion of each crushing stroke, a power-driven, oscillating, primary member engaging said liquid to produce pressure impulses therein, and a secondary member having a periodic movement the frequency of which is half that of the pirmary member, said secondary member engaging said liquid to transmit conjointly with the primary member, pressure impulses to the ram to force the jaw forward in crushing strokes each extending from the extreme backward limit to the extreme forward limit of movement of the jaw, said crushing strokes having a frequency equal to that of said secondary member, and the duration of each said crushing stroke being less than half the period of one cycle of movement of said secondary member.

2. In a crusher having a reciprocatable jaw, a hydraulic system for operating the jaw to produce crushing strokes thereof including a ram cylinder, a ram in the cylinder acting on said jaw, means forming a passage leading to said cylinder, and a hydraulic power-transmitting liquid filling said passage and engaging said ram, and means for imparting a return stroke to the jaw after completion of each crushing stroke, a power-driven oscillating member engaging said liquid to produce impulses of hydraulic pressure therein, means forming a space hydraulically disconnected from the ram cylinder, and a commutating valve mechanism in said passage having a port leading to the ram cylinder and a second port leading to said space, said mechanism including means for opening said first port and closing said second port during each alternate complete oscillation of said member to transmit the impulse produced by each said alternate oscillation to the ram cylinder, said latter impulse actuating the ram to impart a crushing stroke to the jaw, and for closing said first port and opening said second port during each intervening oscillation of said member to prevent transmission of the impulse produced by each said intervening oscillation to the ram cylinder.

3. A jaw crusher, comprising a reciprocatable jaw, a hydraulic system for operating said jaw including a ram cylinder, a second cylinder, means forming a passage connecting said cylinders, and a hydraulic liquid filling said passage, a ram in the ram cylinder acting on the jaw, a power-driven oscillating member in the second cylinder, said liquid engaging said ram and oscillating member, said oscillating member having a substantially uniform frequency of oscillation to produce hydraulic pressure impulses of equivalent frequency in said liquid, means for preventing transmission of each alternate one of said impulses to said ram cylinder comprising means forming a space hydraulically disconnected from said ram cylinder, a commutating valve mechanism in said passage having a port communicating with said ram cylinder and a second port communicating with said space, said mechanism including means for closing said first port and opening said second port during each alternate oscillating cycle of said member to permit passage of liquid to said space and for opening said first port and closing said second port during each other oscillating cycle of said member to cause transmission of a respective impulse to the ram cylinder, said transmitted impulse being operative to actuate the ram to apply a crushing

stroke to the jaw, and means for imparting a return stroke to the jaw at the end of each crushing stroke, said transmitted impulses thereby having a frequency half that of said member, and the duration of each said crushing stroke being thereby less than half the period of one cycle of oscillation of the jaw.

4. A jaw crusher comprising a pair of reciprocatable jaws, a pair of ram cylinders, a ram in each cylinder acting on one of said jaws, a third cylinder, a power-driven oscillating member in said third cylinder, means forming a separate passage leading to each of said ram cylinders, means forming a passage connecting said third cylinder with both said first passages, a hydraulic liquid filling said passages and engaging said rams and member, said oscillating member having a substantially uniform frequency of oscillation to produce hydraulic pressure impulses of equivalent frequency in said liquid, a commutating valve mechanism at the junctures of said second passage with said first passages and controlling communication therebetween, said mechanism being operative to place said second passage in alternate communication with one only of said first passages during each oscillating cycle of said member to cause transmission of each alternate one of said impulses to a respective ram cylinder, each transmitted impulse being operative to actuate the respective ram to apply a crushing stroke to the respective jaw, and means for imparting a return stroke to each jaw at the end of each crushing stroke, the impulses transmitted to each ram thereby having a frequency half that of said member, and the duration of each said crushing stroke being thereby less than half the period of one cycle of oscillation of each jaw.

5. In a crusher having a reciprocatable jaw, a hydraulic system for operating the jaw to produce crushing strokes thereof including a ram cylinder, a ram in the cylinder acting on said jaw, means forming a passage leading to said cylinder, and a hydraulic power-transmitting liquid filling said passage and engaging said ram, and means for imparting a return stroke to the jaw after completion of each crushing stroke, a pair of power-driven, oscillating members each engaging said liquid to produce pressure impulses therein, the frequency of one of said members being double that of the other member, said member of lower frequency acting to displace liquid into said ram cylinder while said member of higher frequency is also displacing liquid into said ram cylinder.

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