O. P. HOOD.

MEANS FOR BALANCING CRUSHERS.

APPLICATION FILED FEB. 9, 1906.

919,582.

Patented Apr. 27, 1909.

4 SHEETS—SHEET 1.

Fig. 1.

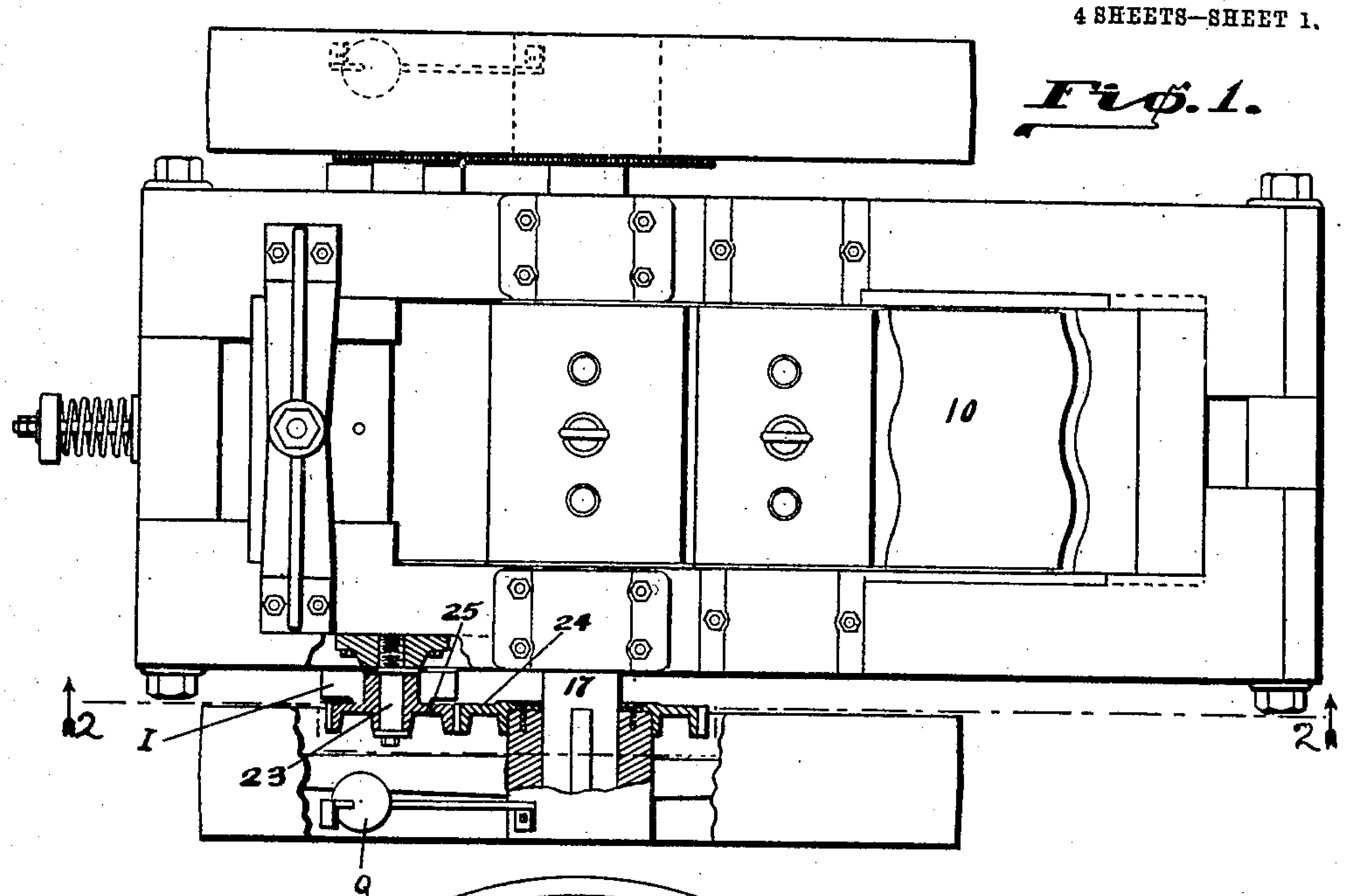

Fig. 2.

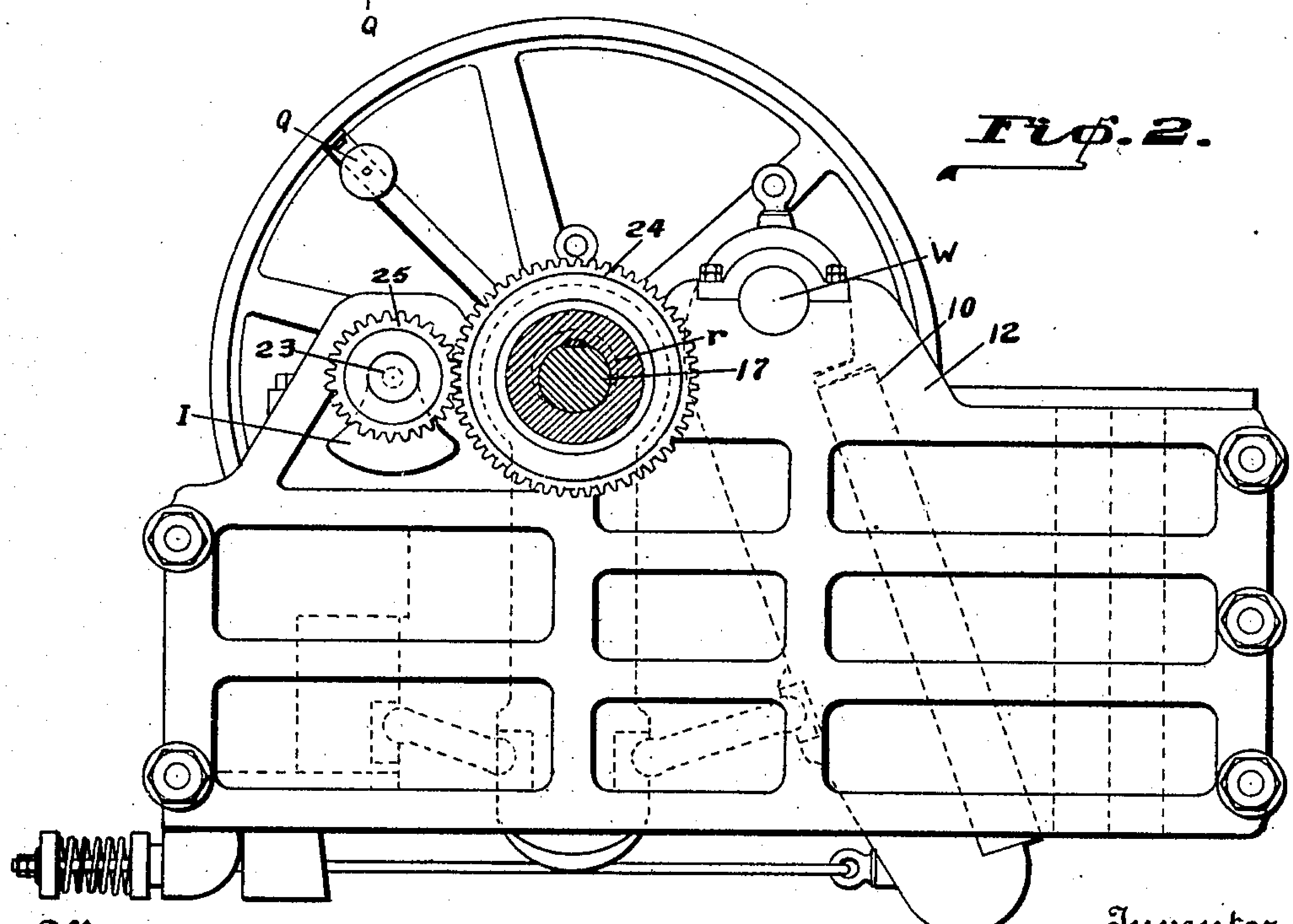

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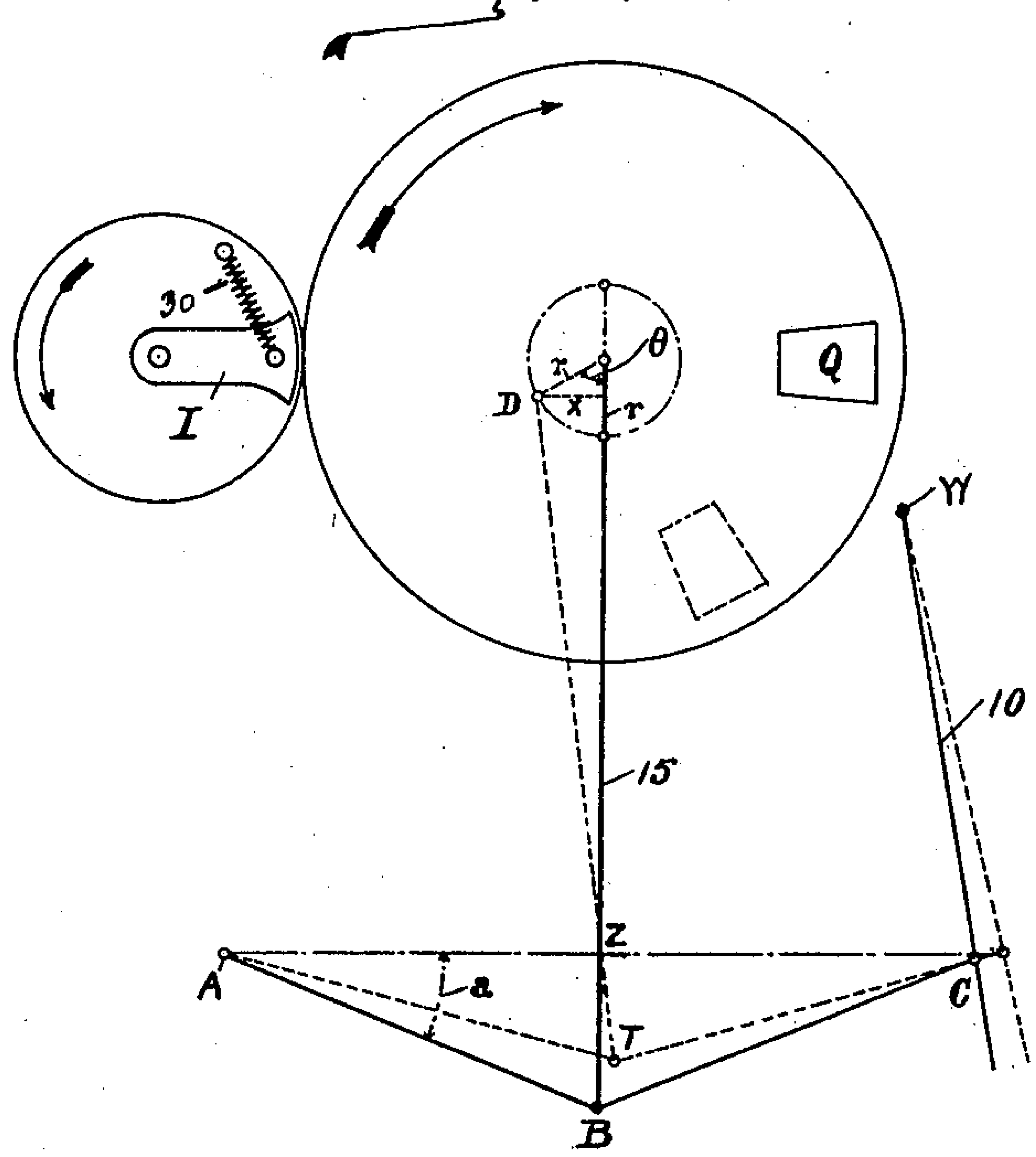
Fig. 3.



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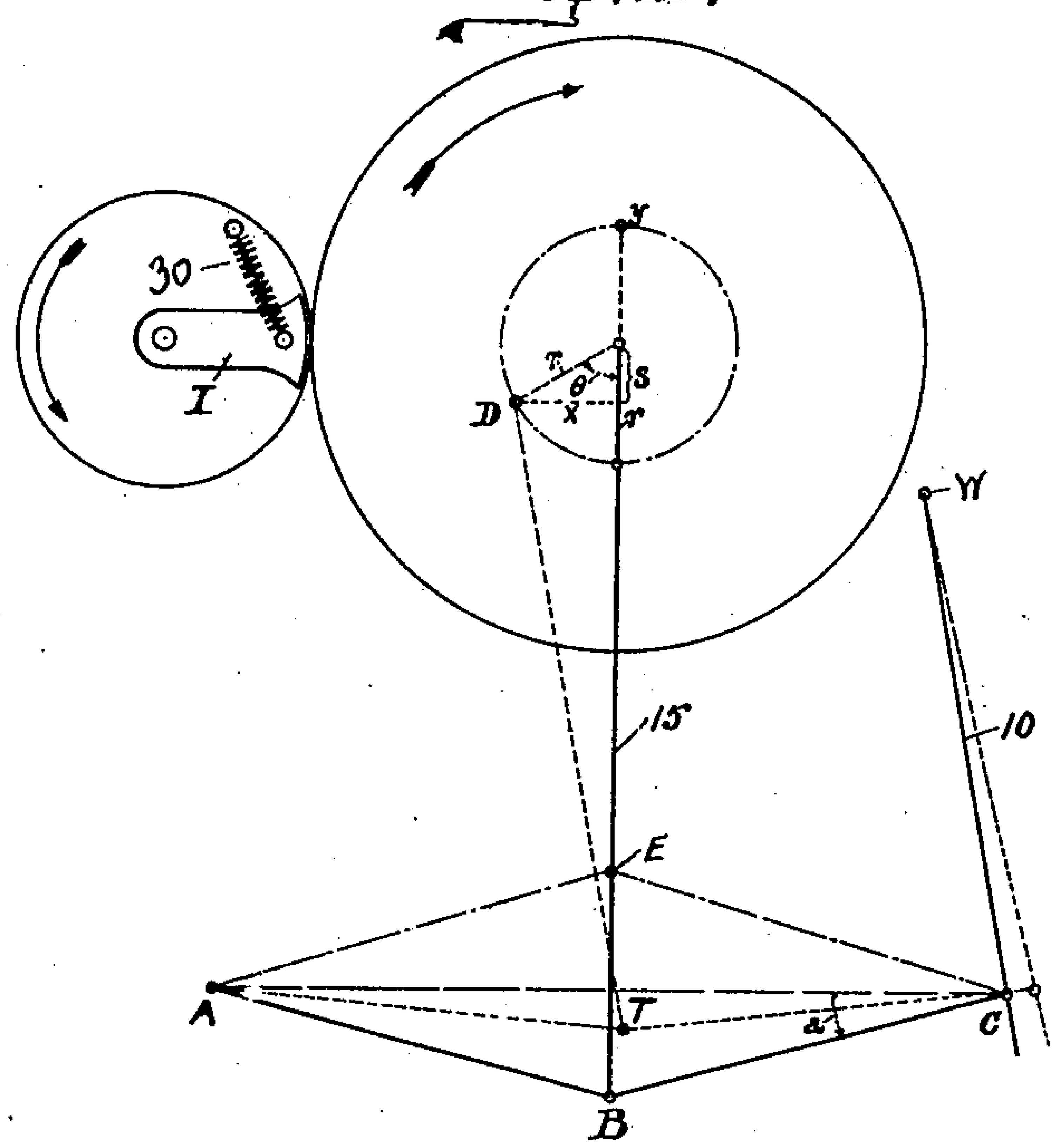
4 SHEETS—SHEET 3.

Fig. 4.



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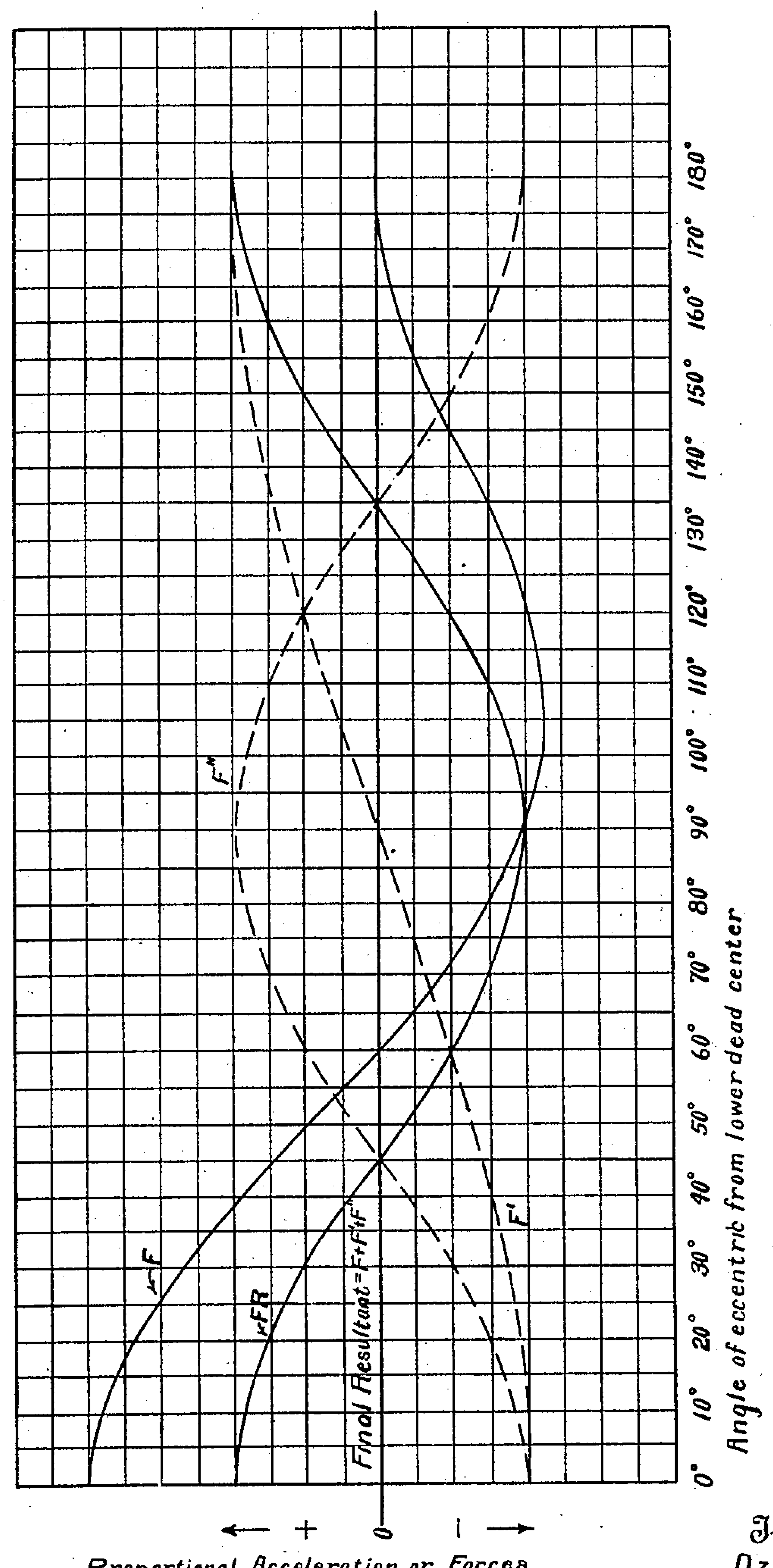
4 SHEETS—SHEET 4.

Fig. 5.



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UNITED STATES PATENT OFFICE.

OZNI P. HOOD, OF HOUGHTON, MICHIGAN.

MEANS FOR BALANCING CRUSHERS.

No. 919,582. Specification of Letters Patent. Patented April 27, 1909.

Application filed February 9, 1906. Serial No. 300,225.

To all whom it may concern:

Be it known that I, Ozni P. Hood, a citizen of the United States, residing at Houghton, in the county of Houghton and State of Michigan, have invented certain new and useful Improvements in Means for Balancing Crushers, of which the following is a specification.

In the operation of that type of crushers having a swinging jaw oscillated by a toggle there is a horizontal vibration which is not especially objectionable where a firm and solid foundation can be had, but when the crusher is arranged in the top of a rock-house, as is customary in copper mining, the horizontal vibration becomes exceedingly objectionable.

The object of my invention is to provide means for eliminating this horizontal vibration.

The accompanying drawings illustrate my invention.

Figure 1 is a plan of an ordinary "Blake" crusher equipped with an embodiment of my invention; Fig. 2 is a section on line 2 2 of Fig. 1; Fig. 3 a diagram of the construction shown in Figs. 1 and 2; Fig. 4 a similar diagram of a crusher in which the oscillating jaw is given two complete oscillations for each rotation of the drive-shaft, and Fig. 5 force curves.

In the drawings, 10 indicates the oscillating jaw, pivoted at W in the main frame 12. The jaw 10 is oscillated by means of a toggle AB, BC which is pivoted at C to the jaw 10 and at A on the main frame 12. Pivoted to the knuckle B of the toggle is one end of a pitman 15 which is connected at the other end to the eccentric, or crank r, which is carried by the main drive-shaft 17 journaled in the main frame parallel with the axis of oscillation of the crusher jaw.

The horizontal forces which require balancing will depend upon the velocity of oscillation of the crusher jaw (for instance the velocity at the point C) the mass of the oscillating parts, and their acceleration. This device balances the horizontal components of those forces generated within the machine by inertia of the parts having variable horizontal velocities. Thus the oscillating crusher jaw, having a variable angular velocity about the pivot W, will resist any change in velocity with a force depending upon the velocity of rotation of driving shaft 17, upon the mass of the oscillating parts, and their acceleration at any instant. The character of the motion imparted to the oscillating jaw 10 is such that the rate of change of movement of a point on the jaw, as C, increases while shaft 17 is revolving through one-third of its rotation and the rate of change decreases during the remaining two-thirds of the revolution. The resisting forces of inertia depend upon the acceleration or the rate of increase or decrease of velocity of the mass moved. While the mass of the jaw 10 actually moves about W as a center, its actual movement is so small that the path of any point may be considered a straight line and the acceleration as straight-line acceleration.

Curve F, Fig. 5, represents the character of the acceleration of the jaw in a machine of the type shown in Figs. 1, 2 and 3. Curve F is plotted on a field where horizontal distances represent time and for convenience in comparing with other curves to be drawn, this time is measured by the uniform angular movement θ of the eccentric imparting motion to the device. With the eccentric at the lower dead center as a starting point and calling this 0 degrees, at this time the rate of change of the velocity of the jaw is greatest and is represented by that point on the curve F vertically above the 0 of the horizontal scale. For each new angular position of the eccentric there is a new rate of change of the velocity of the jaw and this being continuously plotted, generates curve F. Since the resisting force of inertia is proportional to this acceleration, curve F can also represent, to some suitable scale of pounds, the horizontal shaking force which is to be balanced.

A partial balance may be obtained by introducing an unbalanced revolving weight Q which has the same angular velocity as the crank, but whose phase is 90° behind the crank or eccentric. In this position the horizontal movement of the weight Q is always in the opposite direction to that of the swinging jaw. The amount of this weight is so selected that, when θ equals 180°, its maximum inertia value horizontally shall be one-half the inertia of the jaw at zero degrees. Weight Q would produce horizontal forces represented by curve F′ and the combined effect is represented by curve FR which is the algebraic sum of curves F and F′. The resulting effect of applying the single unbalanced weight will be a rythmic horizontal vibration having two maximum positive values and two maximum negative values for each revolution of the crank-shaft (see curve FR). As a consequence, this rhythmic vibration may be reduced to zero by the application of a second unbalanced revolving weight having an angular velocity of twice that of the eccentric or crank, and so proportioned and related in phase (see curve F″) as to oppose and balance the rhythmic force produced by the combined action of the oscillating jaw and the unbalanced weight Q. I, therefore, provide a second unbalanced weight I which is arranged as nearly as convenient in the same vertical plane as the weight Q, and is mounted so as to rotate about an axis 23 at double the angular velocity of the shaft 17, this being readily accomplished by a pair of two-to-one gears 24 and 25 carried by the crank-shaft 17 and the shaft 23 respectively.

The equations for the several curves are found as follows:

Let P be the stress in the pitman D−T.
" R " " " at the end of the toggle
" a " " angle of the toggle link with a line joining the ends of the toggle link A and C.

Then P = 2 R sin a.

The eccentricity of the crank O−D is always small compared with the length of the pitman so that Px = the moment of P about the center o and must be equaled by the moment of the belt pull about the same center. Let the value of the belt pull reduced to the radius D−O or r be represented by B′, then $B'r = Px$. But $x = r \sin\theta$, therefore $B' = P \sin\theta$ or

$$P = \frac{B'}{\sin\theta} = 2\,R\sin a.$$

To find a value for a in terms of θ we can use the relation that the movement of the toggle joint B−Z is equal to the travel of the crank F−y and at any instant the distance $y-u$ or Z—T $= r + r\cos\theta$. But

$$\sin a = Z - T \div B - C \text{ or } \frac{r}{B-C}(1+\cos\theta).$$

Introducing this value of sin a we have

$$\frac{B'}{\sin\theta} = 2\,R(1+\cos\theta)\frac{r}{B-C}.$$

The values of r and B−C are fixed by the design and are constant so that we may take 1 for the toggle length and

$$\frac{1}{2\,r} = k.$$

Then

$$R = B'\frac{k}{\sin\theta(1+\cos\theta)}.$$

From this equation the resistance that can be overcome at the jaw is found in terms of the belt pull and the position of the eccentric.

At any instant the velocity of the jaw is inversely as the resistance it could overcome so that if for a belt pull of one pound R = the above equation then for a velocity of one foot per second of the crank point D the relative velocity of the jaw would be reciprocal or

$$\frac{\sin\theta\,(1+\cos\theta)}{k}$$

and the actual velocity of the jaw would be had by multiplying this value by the actual velocity of the crank v or

$$\text{Jaw velocity} = \frac{v\sin\theta\,(1+\cos\theta)}{k}$$

The rate of change of this velocity or the acceleration of the jaw f is given by the first differential of this velocity.

$$\begin{aligned}
f = d\frac{v}{k}\sin\theta(1+\cos\theta) &= \frac{v}{k}\Big[(d\sin\theta)\,(1+\cos\theta) + d(1+\cos\theta)\sin\theta\Big] \\
&= \frac{v}{k}\Big[\cos\theta\,d\,\theta\,(1+\cos\theta) + -\sin\theta\,d\,\theta\sin\theta\Big] \\
&= \frac{v}{k}\,d\,\theta\Big[(\cos\theta+\cos^2\theta-\sin^2\theta)\Big] \\
&= \frac{v}{k}\,d\,\theta\Big[(\cos\theta+\cos^2\theta-1+\cos^2\theta)\Big] \\
f &= \frac{v}{k}\,d\,\theta\,(\cos\theta+2\cos^2\theta-1)
\end{aligned}$$

The movement of the point D is supposed to be uniform and the space moved in $d\,t$ would be $d\theta$ and $=\frac{v}{r}$ then f becomes

$$f = \frac{v^2}{kr}(\cos\theta + 2\cos^2\theta - 1)$$

The force required to produce this acceleration in a weight W will be

$$F = \frac{W v^2}{gkr}(\cos\theta + 2\cos^2\theta - 1)$$

Let a weight Q be so placed that it is 90 degrees behind the crank r. Let its velocity be v', its horizontal acceleration f' and the angle it makes with the horizontal $=\theta'$. The horizontal velocity will be $v'\sin\theta'$ and

$$f' = \frac{v^2}{r'}\cos\theta'.$$

But cos θ may be in such phase as to give an effect opposed to the inertia of the jaw and can therefore be called $-\cos\theta$. Also $v':v=r':r$ or

$$v'=\frac{vr'}{r}$$

Therefore

$$f'=-\frac{v^2 r'}{r^2}\cos\theta.$$

If W′ be the weight of Q then the force required to produce the acceleration f' will be

$$F'=-\frac{W' v^2 r'}{g r^2}\cos\theta.$$

The weight W′ is to be so selected that the force F′ shall be one half F when each is a maximum. F is a max. when θ is zero and becomes

$$F=\frac{2 W v^2}{g k r.}$$

Therefore F′ as a max. $=\frac{W v^2}{g k r}$.

F′ is also a max. when θ is zero. Therefore

$$\frac{W' v^2 r'}{g r^2}=-\frac{W v^2}{g k r}$$

and

$$W'=\frac{W r}{k r'}=\frac{2 W r^2}{1 r'}.$$

With this value of W′,

$$F'=-\frac{W v^2}{g k r}\cos\theta$$

the resultant F_R of the two forces F and F′ will be their algebraic sum and will be

$$F_R=\frac{W v^2}{g k r}(2\cos^2\theta-1).$$

The secondary weight I has a horizontal accelerating force F″ which in amount and direction shall be equal to F′ when θ is zero. The angular velocity is to be twice that of θ. Therefore $\theta''=2\theta$. Let the velocity be v'' and radius r'' then

$$f''=-\frac{v''^2}{r''}\cos 2\theta.$$

Let the weight be W″. Then

$$F''=-\frac{W'' v''^2}{g r''}\cos 2\theta.$$

$$v''=\frac{2 v r''}{r}$$

and at zero degrees when F″ is a max.

$$\frac{W'' 4 v^2 r''^2}{g r'' r^2}=\frac{W v^2}{g k r}$$

and

$$W''=\frac{W r}{4 k r''}$$

With this value of W″

$$F''=-\frac{W v^2}{g k r}\cos 2\theta$$

which can be written in the form

$$F''=-\frac{W v^2}{g k r}(\cos^2-\sin^2).$$

Since $-\sin^2=\cos^2-1$ this can be changed to the form

$$F''=-\frac{W v^2}{g k r}(2\cos^2\theta-1).$$

Combining this value with the resultant F_R to form a new final resultant the value is found to be zero for all values of θ.

The construction just described is designed for use with that type of crusher in which the jaw is given one complete oscillation for each rotation of the crank-shaft, this being the general type. I find, however, that, where the throw of the eccentric is increased so as to swing the toggle an equal amount to each side of a line joining the outer ends of the toggle, the horizontal forces of the swinging jaw are themselves rhythmic, giving two complete alternations for each rotation of the crank-shaft. Consequently in this type of machine, as illustrated diagrammatically in Fig. 4, the unbalanced weight Q may be omitted and the horizontal forces balanced by the single unbalanced weight I having twice the angular velocity of the crank-shaft.

Referring to Fig. 4 the following equations are found. When the crank has moved θ degrees B will be at s distance from the medial line A—C. Then $s=r\cos\theta$ and $\frac{s}{c}\sin a$ or

$$\frac{r\cos\theta}{BC}=\sin a.$$

From our other demonstration $Px=B'r$ and $x=r\sin\theta$. Therefore $P\sin\theta\, r=Br$ or

$$P=\frac{B'}{\sin\theta}=2R\sin a=\frac{2Rr\cos\theta}{BC}.$$

From this

$$R=\frac{B'(BC)}{2r\sin\theta\cos\theta}$$

and using the same significance for k as before the resistance

$$R = \frac{B'k}{\sin\theta\cos\theta}.$$

As before, if $B'\ k = \frac{1}{c}$, the velocity of the jaw would be proportional to the reciprocal of this or

$$V = c\frac{\sin\theta\cos\theta}{1}$$

times the actual velocity v of the crank D. The first differential of this would give the acceleration of the jaw which is as follows.

$$\begin{aligned} dV = cvd\,(\sin\theta\cos\theta) &= cv\,(\sin\theta\, d\cos\theta + \cos\theta\, d\sin\theta) \\ &= cv(-\sin^2\theta\, d\,\theta + \cos^2\theta\, d\,\theta) \end{aligned}$$

but $d\theta = \frac{v}{r}$ and $-\sin^2\theta = \cos^2\theta - 1$. Therefore this reduces to

$$\frac{cv^2}{r}(2\cos^2\theta - 1) = \frac{cv^2}{r}(\cos 2\theta).$$

This value of the acceleration of the jaw is seen to agree with that of F_R or R'' and can therefore be balanced with the single weight revolving with the double angular velocity.

In order to protect the driving mechanism in case of sudden stoppage of the crusher it may sometimes be desirable to drive the weight I through a spring or similar yielding part 30.

I claim as my invention:

1. In a machine having a reciprocating jaw and rotating means for driving the same, an unbalanced weight revolving at an angular velocity greater than the angular velocity of the jaw-driving means, and in such phase as to oppose the maximum acceleration thereof.

2. In a machine having a horizontally reciprocating jaw and rotary means for driving the same, a revolving unbalanced weight vertically revolving at an angular velocity greater than the angular velocity of the jaw-driving means and in such phase as to oppose the maximum acceleration thereof.

3. In a machine having a reciprocating jaw, a crank-shaft, and intermediate connections between said crank-shaft and said jaw for operating same, an unbalanced weight revolving with an angular velocity equal to the angular velocity of the crank-shaft and in a phase behind the phase of the crank, a second unbalanced weight, and means for revolving said second unbalanced weight with double the angular velocity of the first unbalanced weight.

4. In a machine having a horizontally reciprocating jaw, a crank-shaft, and intermediate connections between said crank-shaft and said jaw for operating same, an unbalanced weight revolving vertically with an angular velocity equal to the angular velocity of the crank-shaft and in a phase behind the phase of the crank, a second unbalanced weight, and means for revolving said second unbalanced weight with double the angular velocity of the first unbalanced weight.

5. In a machine having a reciprocating jaw and rotating means for driving the same, a revolving unbalanced weight, and means for revolving said weight at double the angular velocity of the jaw driving means.

6. In a machine having a horizontally reciprocating jaw and rotating means for driving the same, a vertically revolving unbalanced weight, and means for revolving said weight at double the angular velocity of the jaw driving means.

7. In a crusher, a reciprocating jaw, a toggle for operating the same, a driving shaft, a crank and pitman connection between said driving shaft and toggle, a revolving unbalanced weight, and means for revolving said weight at an angular velocity greater than the angular velocity of the driving shaft and in such phase as to oppose the maximum acceleration thereof.

8. In a crusher, a reciprocating jaw, a toggle for operating the same, a driving shaft, a crank and pitman connection between said driving shaft and toggle, a vertical revolving unbalanced weight, and means for revolving said weight at an angular velocity double the angular velocity of the main drive shaft.

9. In a crusher, a reciprocating jaw, a toggle for operating same, a drive shaft, a crank and pitman connection between said drive shaft and toggle, an unbalanced vertically revolving weight revolving at an angular velocity equal to the angular velocity of the drive shaft and in the phase behind the phase of the crank thereof, a second unbalanced weight, and means for revolving said second unbalanced weight in a substantially vertical plane at double the angular velocity of the first unbalanced weight.

10. In a crusher having a jaw, a crank shaft, intermediate connections between said crank shaft and said jaw for operating the same, an unbalanced vertically revolving weight, and means for revolving said weight with an angular velocity equal to the angular velocity of the crank shaft and in a phase behind the phase of the crank.

11. In a crusher having a jaw, a crank

shaft, intermediate connections between said crank shaft and said jaw for operating the same, an unbalanced vertically revolving weight, and means for revolving said weight with an angular velocity equal to the angular velocity of the crank shaft and in a phase 90 degrees behind the phase of the crank.

In witness whereof, I, have hereunto set my hand and seal at Houghton, Michigan, this 25th day of January, A. D. one thousand nine hundred and six.

OZNI P. HOOD. [L. S.]

Witnesses:
GEO. L. CHRISTENSEN,
HARRY SHARP.