(No Model.)

8 Sheets—Sheet 1.

J. HARRINGTON.

ROTARY ENGINE.

No. 332,253.

Patented Dec. 15, 1885.

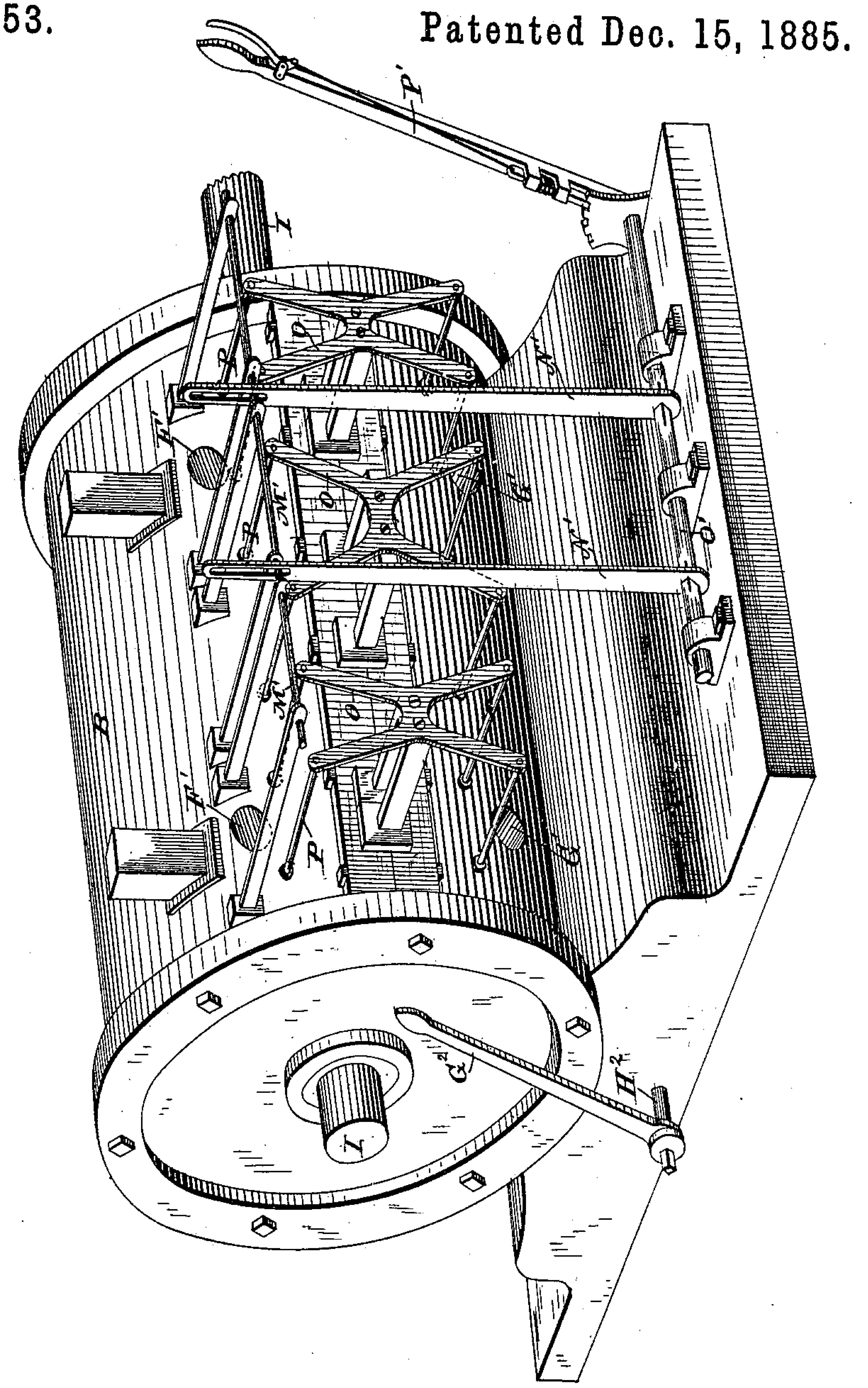

Fig. 1.

Witnesses.

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Inventor

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His Attorneys.

N. PETERS. Photo-Lithographer. Washington. D. C.

(No Model.)

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# J. HARRINGTON.

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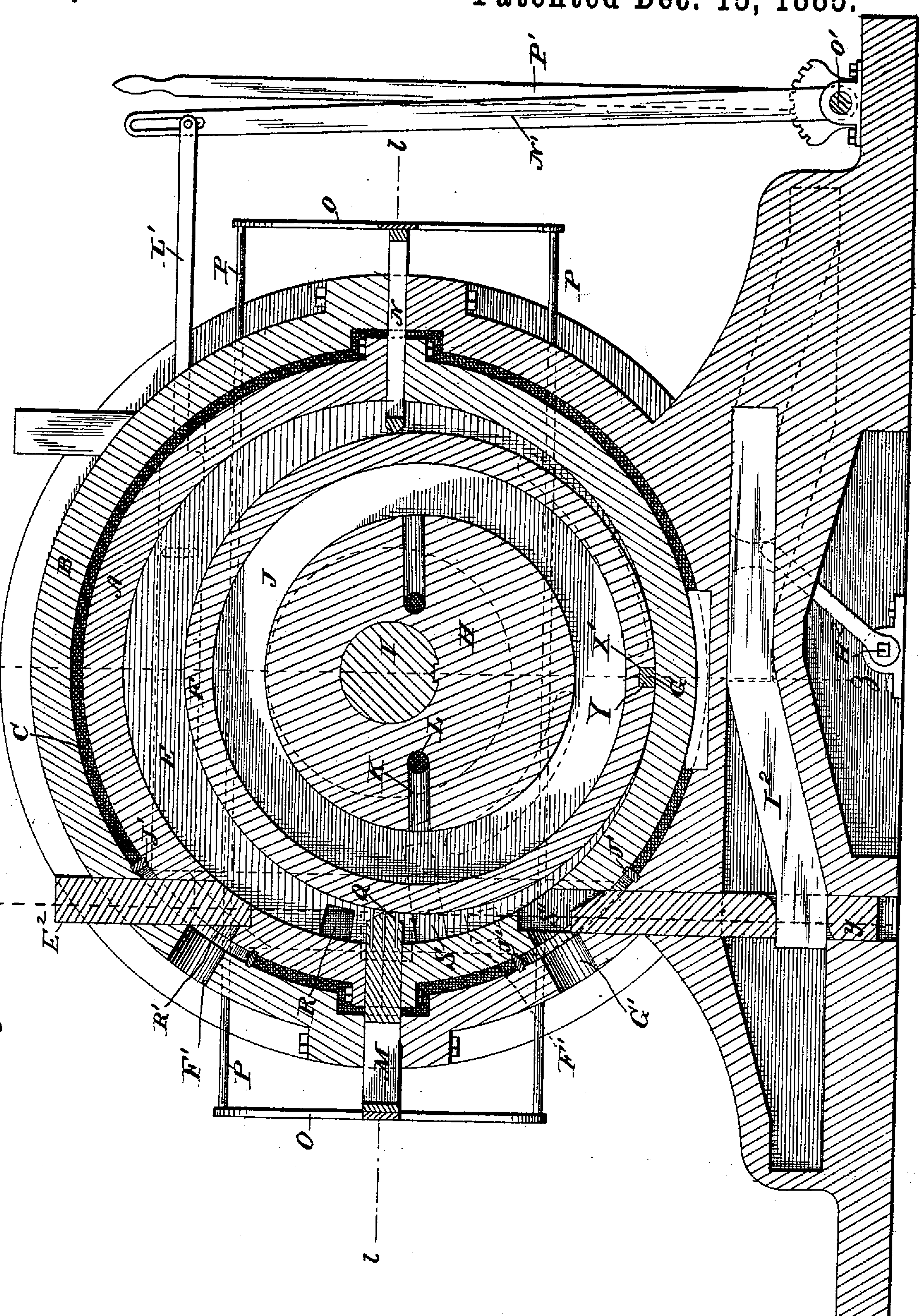

Fig. 2.

Witnesses

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# J. HARRINGTON.

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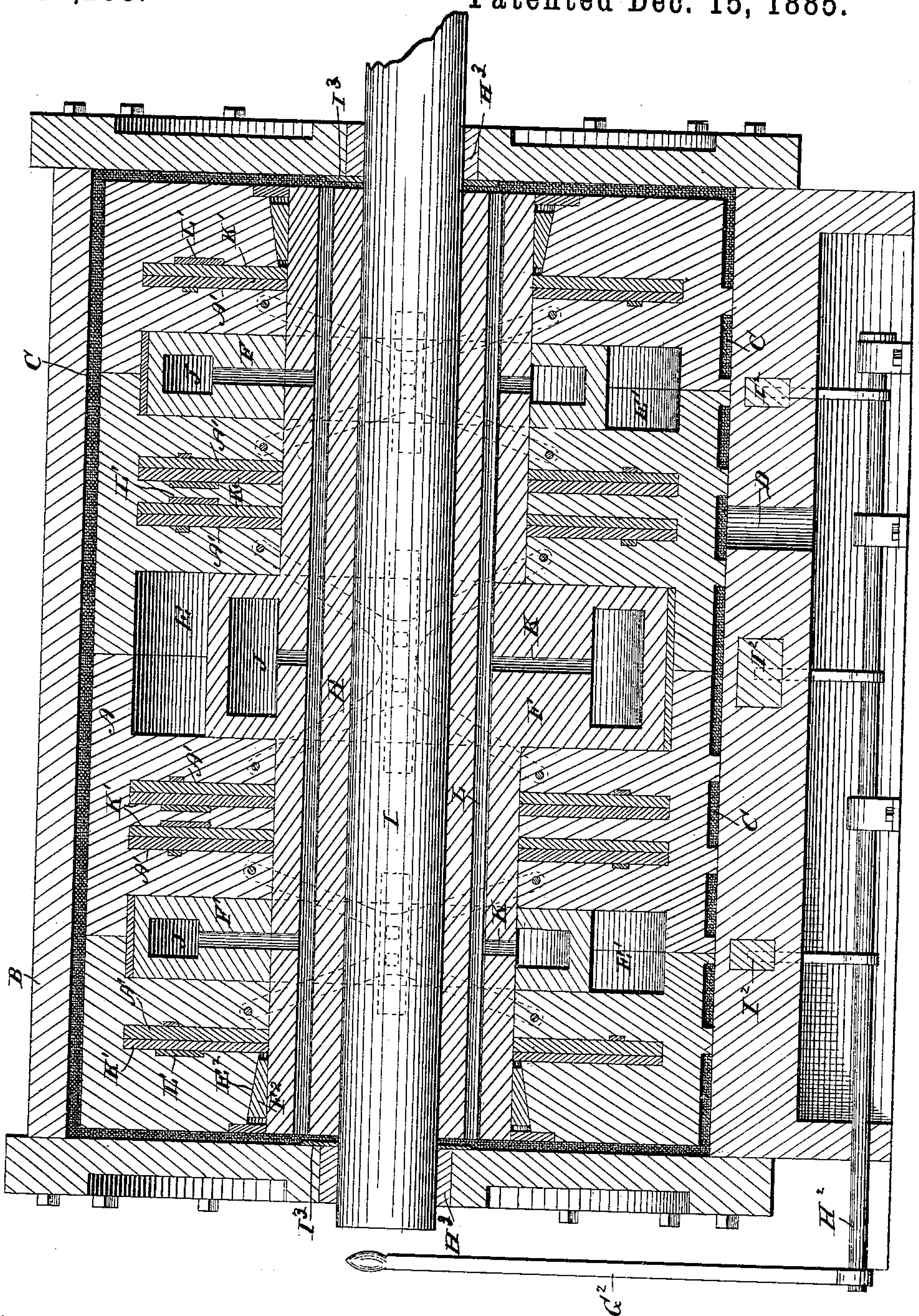

Fig. 3.

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J. HARRINGTON.

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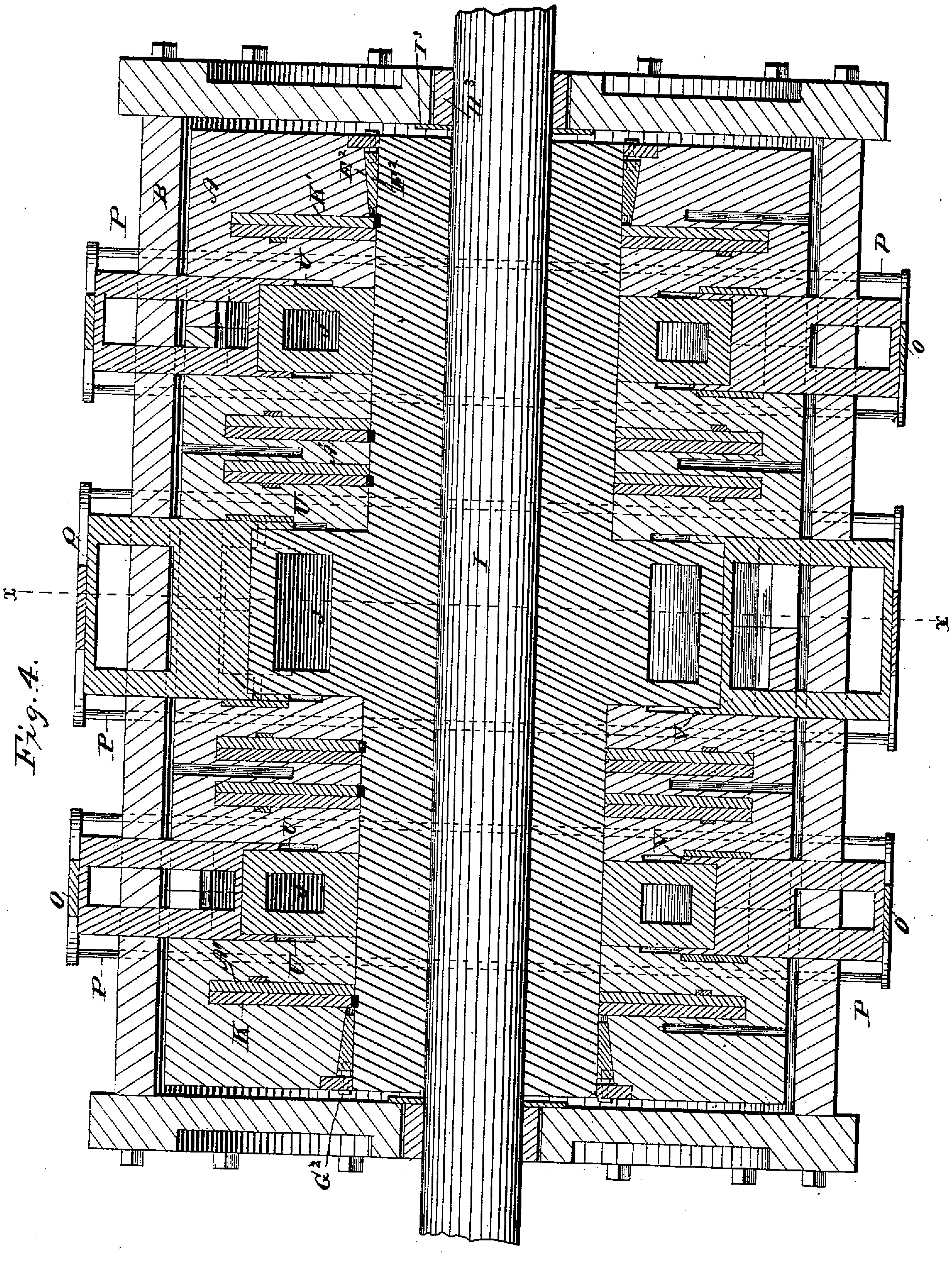

Fig. 4.

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## ROTARY ENGINE.

No. 332,253.

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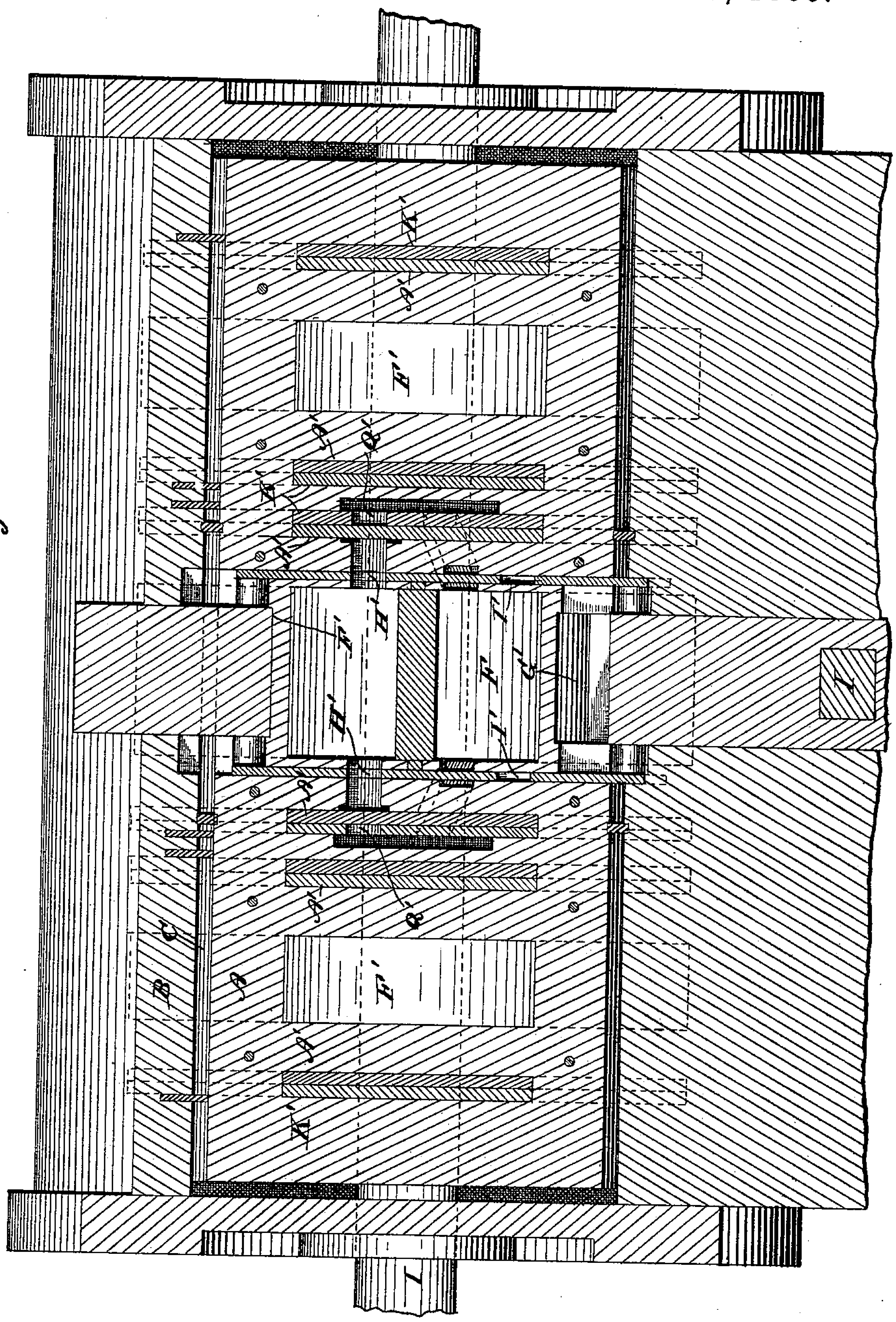
*Fig. 5.*



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# J. HARRINGTON.

## ROTARY ENGINE.

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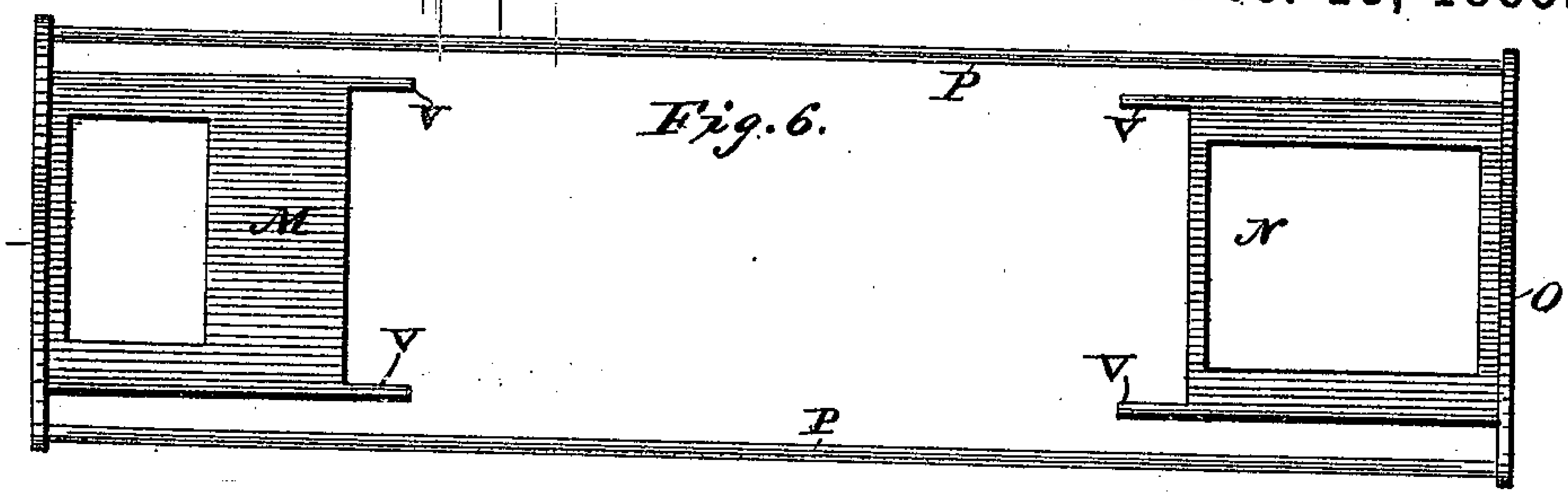


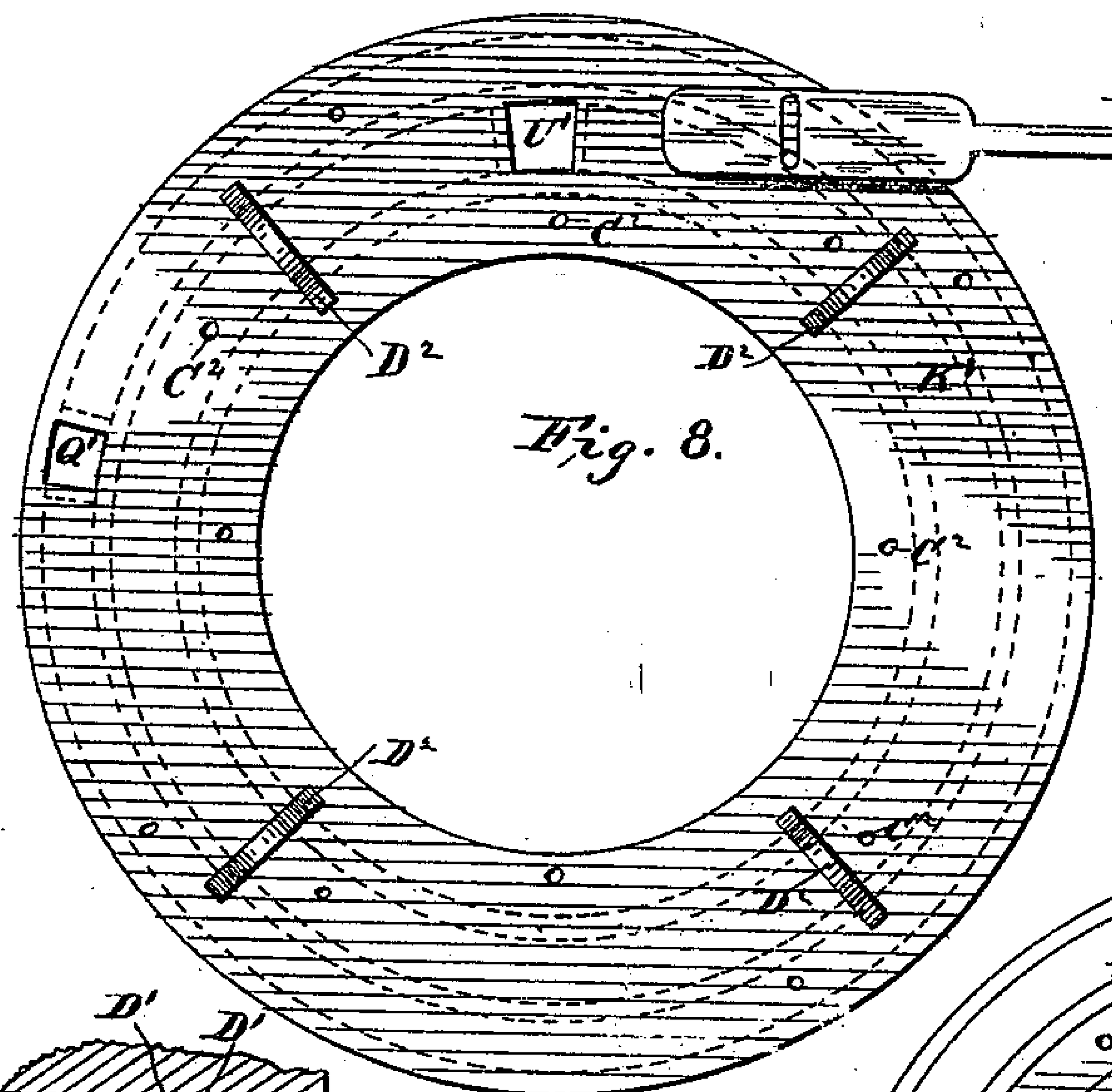


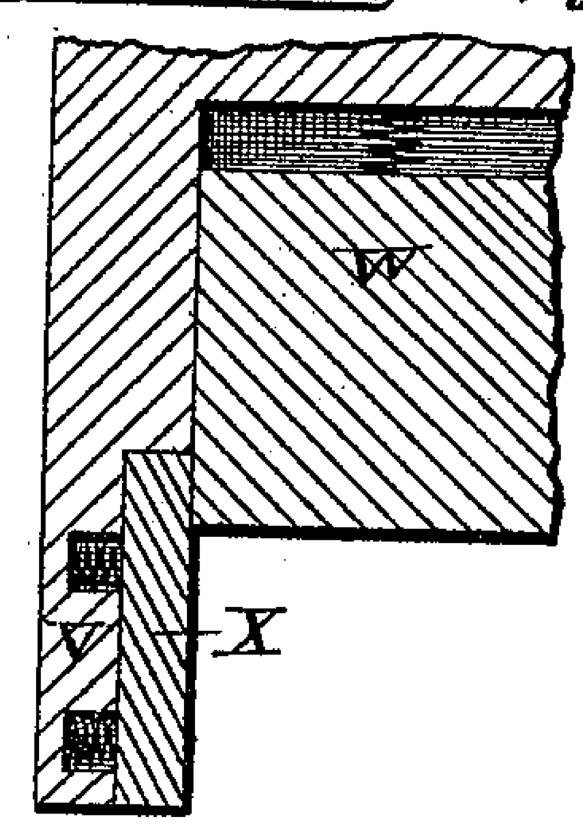


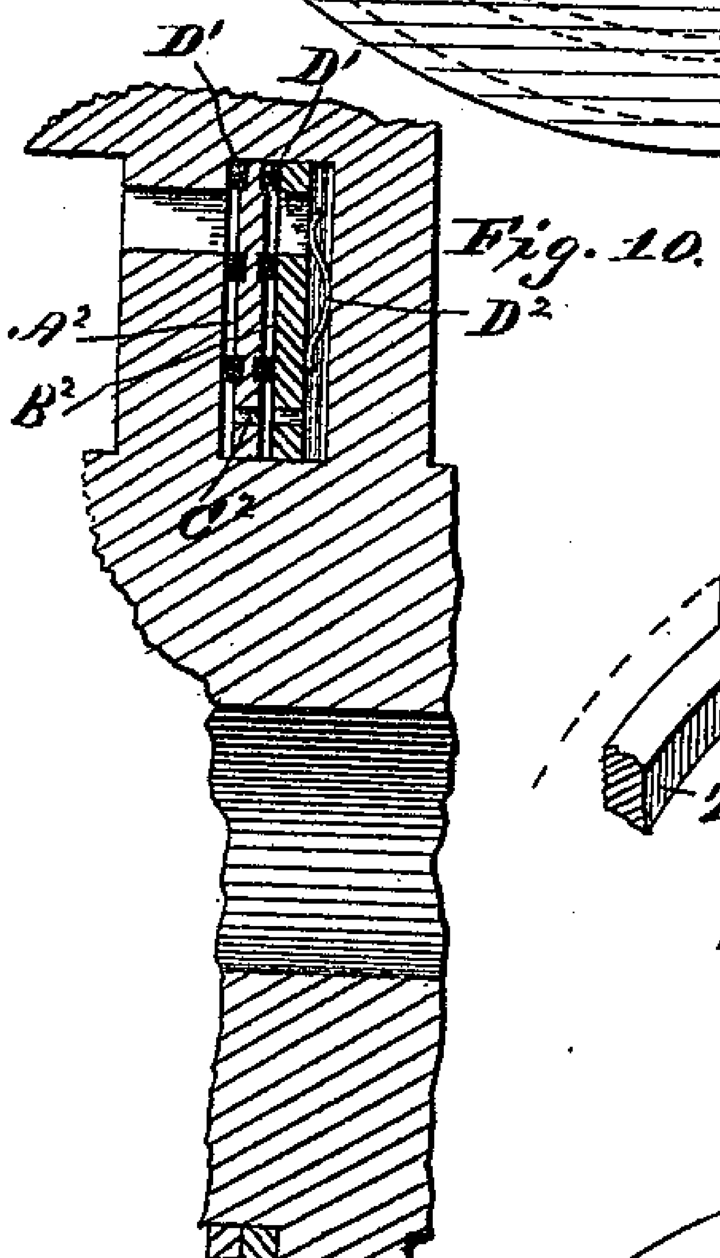


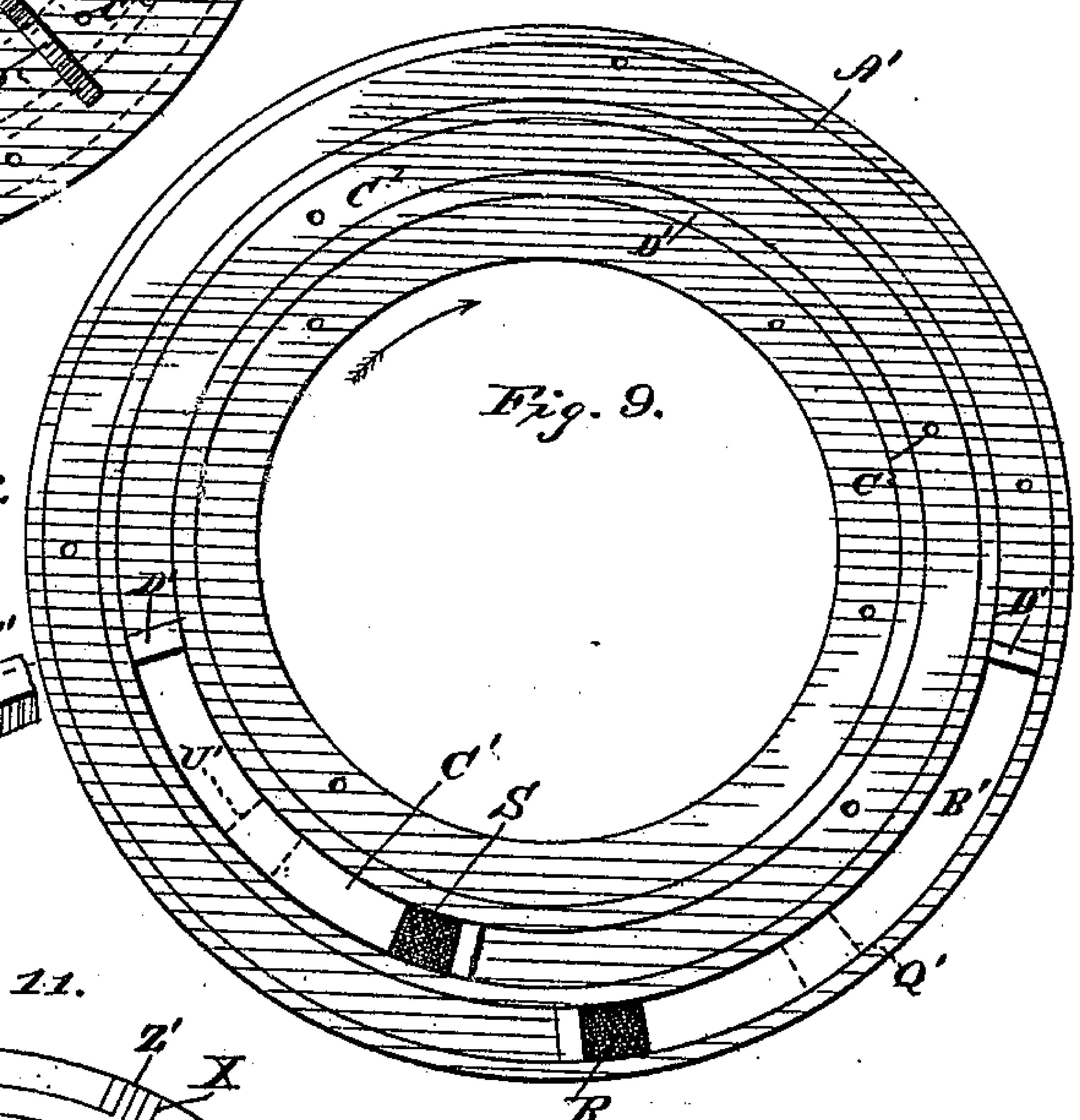


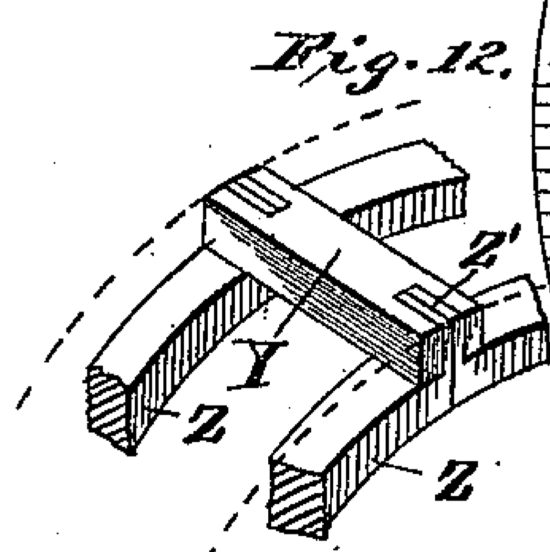



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# J. HARRINGTON.

ROTARY ENGINE.

No. 332,253.

Patented Dec. 15, 1885.

Fig. 14.

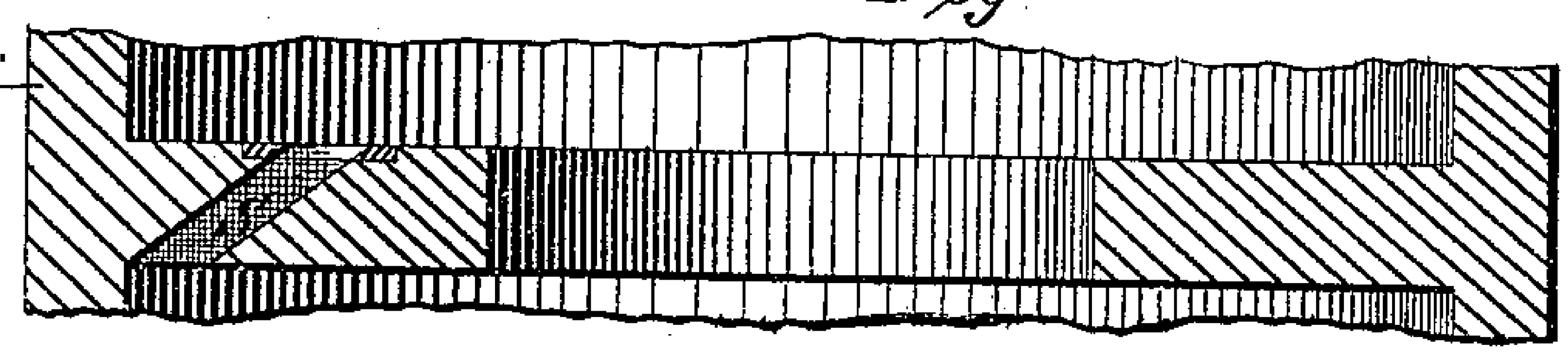



Fig. 13.

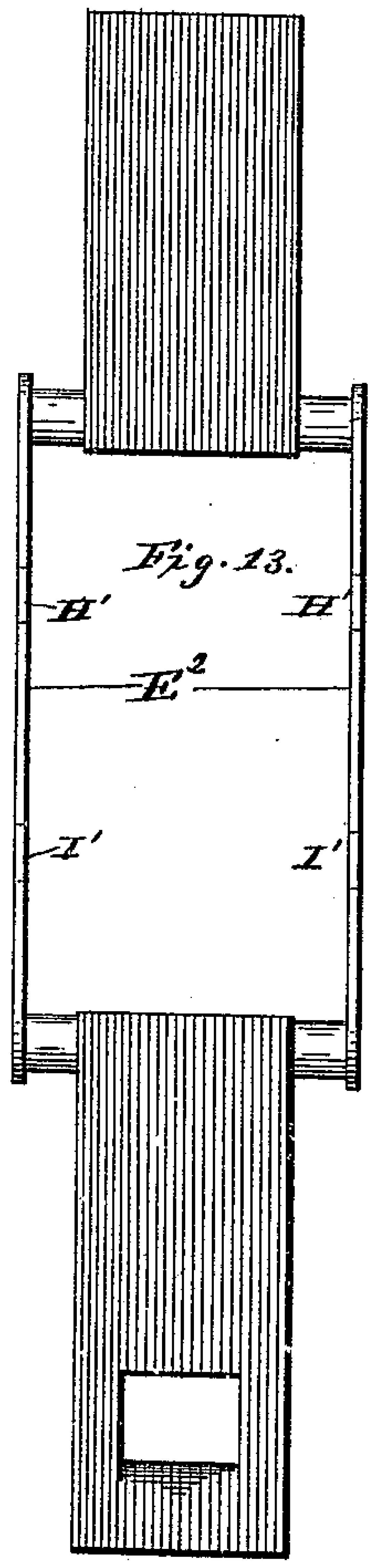



Fig. 18.

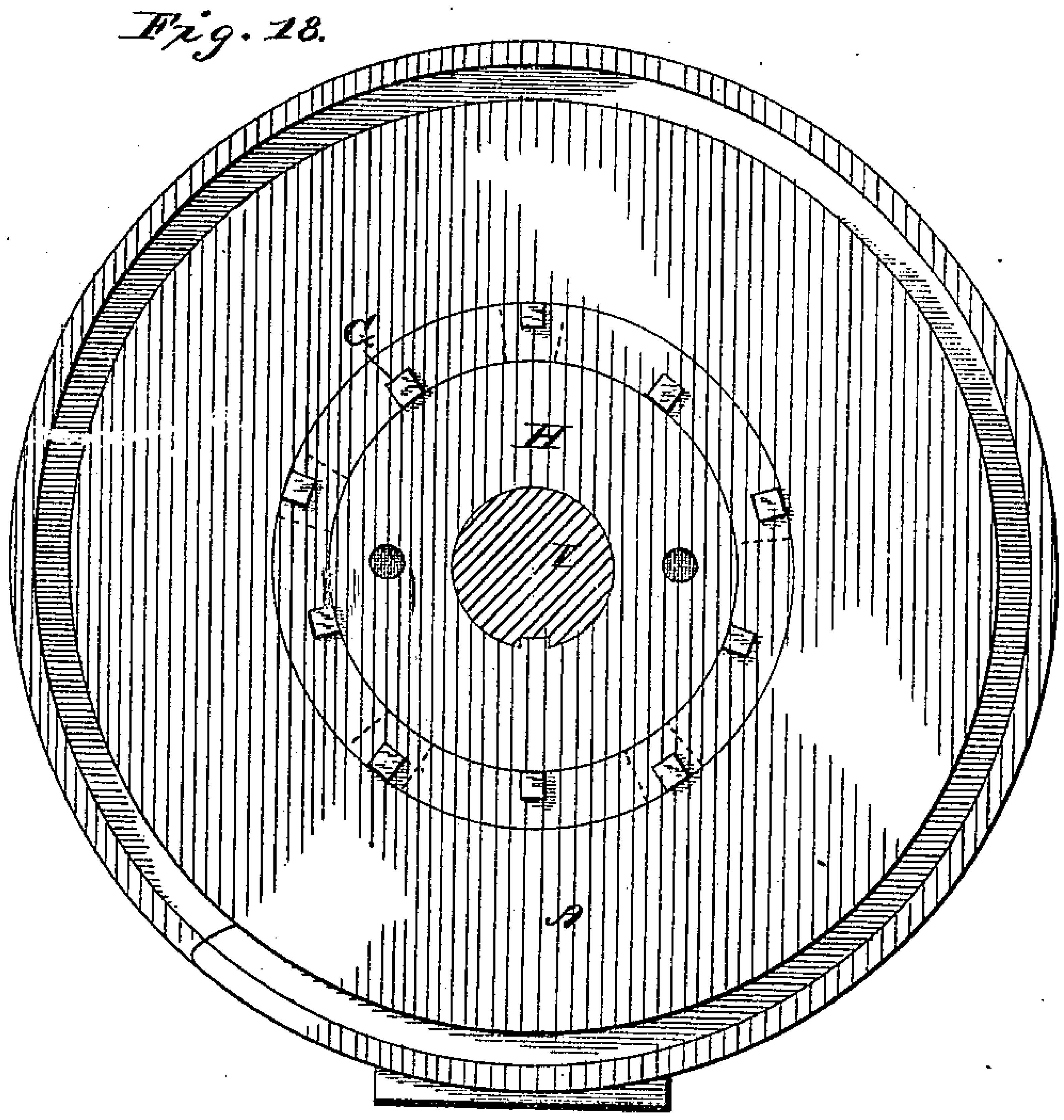



Fig. 19.

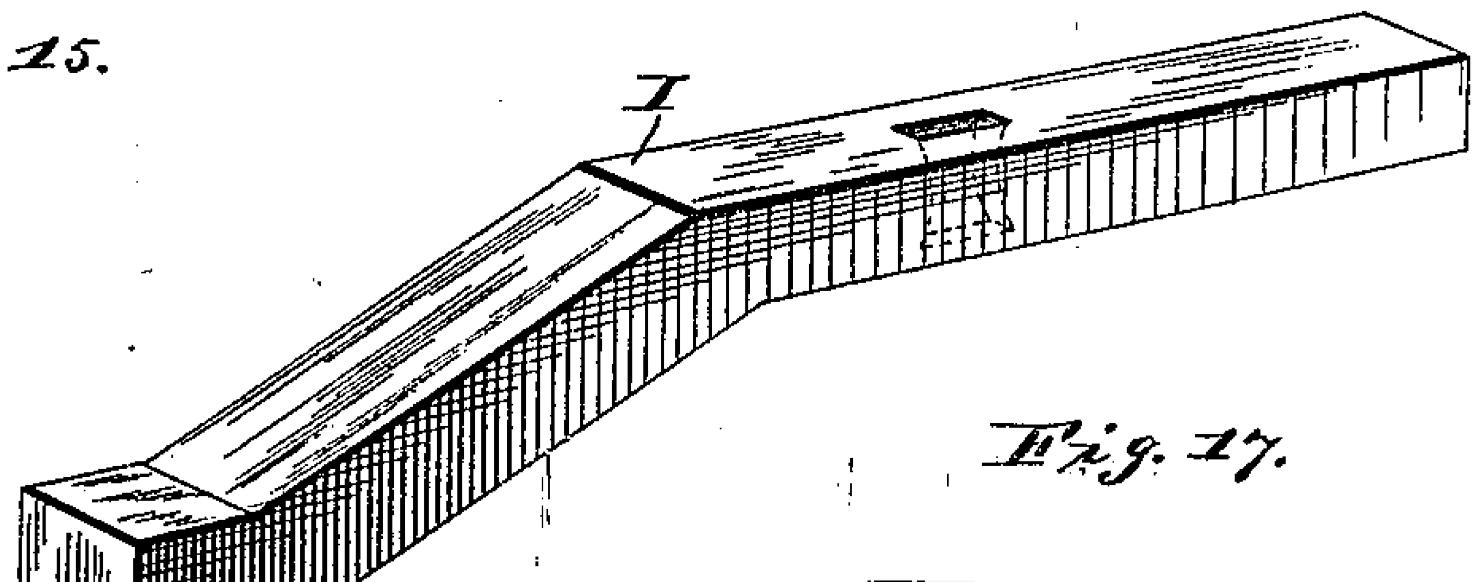



Fig. 15.

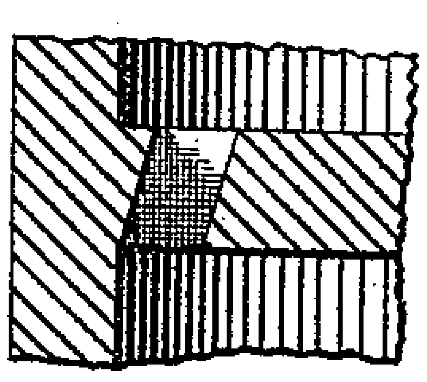
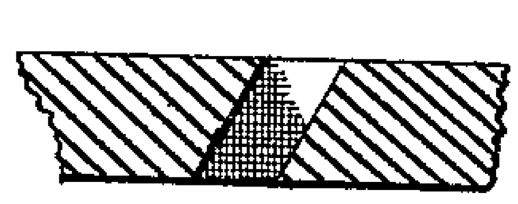


Fig. 17.

Fig. 16.



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8 Sheets—Sheet 8.

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ROTARY ENGINE.

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Fig. 20.

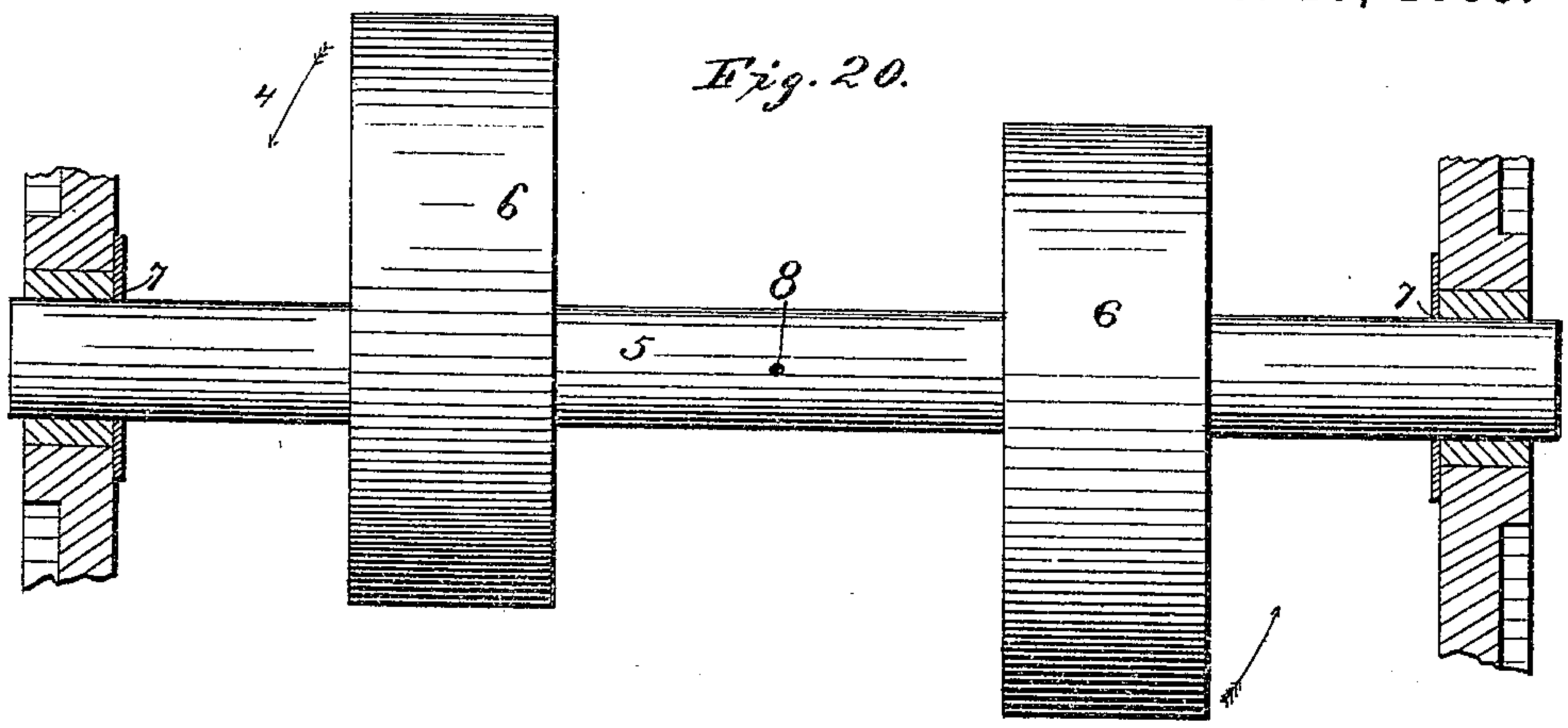
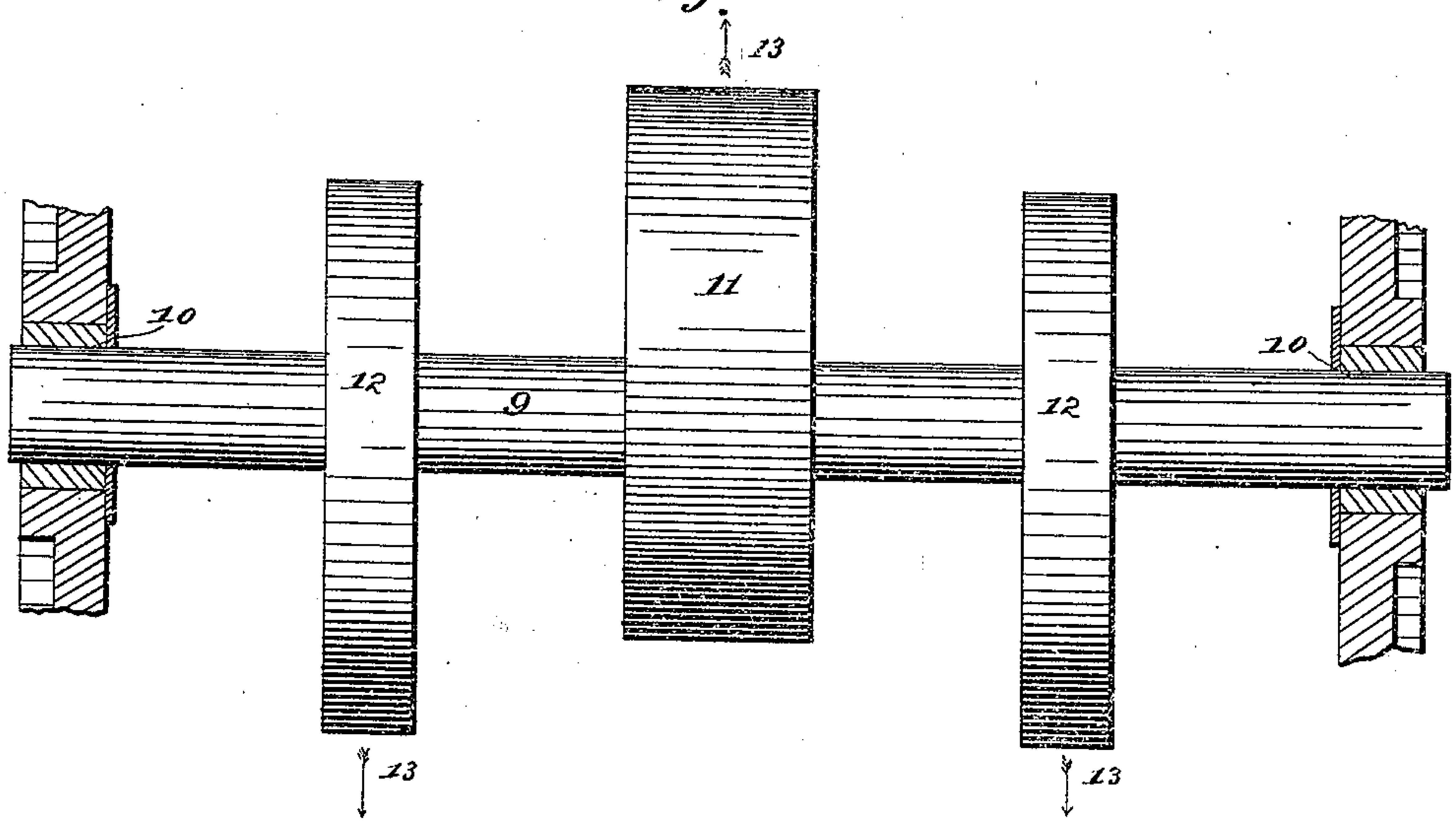



Fig. 21.

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# UNITED STATES PATENT OFFICE.

JOHN HARRINGTON, OF CALDWELL, KANSAS.

## ROTARY ENGINE.

SPECIFICATION forming part of Letters Patent No. 332,253, dated December 15, 1885.

Application filed March 18, 1885. Serial No. 159,317. (No model.)

*To all whom it may concern:*

Be it known that I, JOHN HARRINGTON, of Caldwell, in the county of Sumner and State of Kansas, have invented certain new and useful Improvements in Rotary Engines; and I do hereby declare the following to be a full, clear, and exact description of the same, reference being had to the accompanying drawings, forming a part of this specification, and to the figures and letters marked thereon.

"Rotary engines," so called, may be divided into two general classes—namely, first, those in which the pistons, abutments, valves, and, in fact, all the moving parts, are given rotary motion, and which may be termed true "rotary engines;" and, secondly, those in which the piston alone or the piston and some one or more, but not all, of the valves or other moving parts are rotated, and which may be termed, with more propriety, "mixed engines." To the latter class my engine particularly relates. I have entered upon its construction after a somewhat careful examination of the state of the art, and with the belief that, profiting by the failures of others, through a close examination of the causes thereof, I could produce a machine measurably free from the defects developed in prior structures.

In order that others skilled in the art may be able to fully understand the construction and operation of my engine, I will first describe it with reference to the accompanying drawings, and will then in the clauses of claim at the end of this specification endeavor to point out what I deem to be its essentially novel features.

In said drawings, Figure 1 represents a perspective view of my engine; Fig. 2, a transverse vertical section of the same, taken on the line *x x* of Fig. 4. Fig. 3 is a longitudinal vertical section taken on the line *z z*, Fig. 2. Fig. 4 is a horizontal section taken on the line 1 1 of Fig 2. Fig. 5 is longitudinal vertical section taken on the line *y y* of Fig. 2. Fig. 6 is a view of the sliding abutment detached. Fig. 7 is a detail view of a portion of a modified form of abutment, in which the parts which bear upon the eccentric piston are rendered self-adjusting. Fig. 8 is a view of the governor-valve for controlling the admission of steam to the eccentric piston. Fig. 9 is a view of the rotary cut-off valve. Fig. 10 is a sectional view of a portion of the inner cylinder or casing and the governor and cut-off valves. Figs. 11 and 12 illustrate a mode of packing the eccentric piston. Fig. 13 is a detached view of one of the valves which controls the inlet exhaust-ports of the engine. Fig. 14 is a view of a portion of the casing of the engine, designed to show the increased inclination of one of the inner steam-ports through the same, leading from the cut-off valve to the chamber in which the piston works. Fig. 15 is a similar view, showing one of the outer steam-ports. Figs. 16 and 17 are views illustrating the opposite inclination of the ports through which the steam alternately passes to the chamber containing the piston when the engine is worked direct and reverse. Fig. 18 is a view illustrating the means for centering the shaft and inner case. Fig. 19 is a perspective view of the means for shifting one of the valves that control the exhaust; Figs. 20 and 21, diagrams illustrative of the balancing of the pistons.

Similar letters in the several figures indicate like parts.

There are two casings to my engine—an inner casing, A, and an outer casing, B. Both these casings are stationary, and between them, and almost entirely surrounding the inner casing, is a space, C, into which the steam employed to run the engine is admitted through an inlet-port, D, as shown in Fig. 3, being thence conducted through certain passages in the walls of the inner casing, controlled by suitable valves, to the chambers E E′ E′, in which the rotary pistons are located, and being exhausted thence in a manner to be further on explained. The pistons are preferably three in number, and comprise a large middle one, F, and two smaller ones, F′ F′, arranged on opposite sides of it, as shown clearly in Figs. 3, 4, 5. Each of them is of eccentric form, as shown in Fig. 2, and its sides are fitted as accurately as possible to the sides of its circular chamber, while its periphery is adapted at one point to slide in contact with the inner circumference of its said chamber, as shown at G in said last-mentioned figure. By preference, I form the large middle piston, F, with a long hub, H, that extends from end to end of the inner casing, A, and upon this extended hub I mount and rigidly secure the two smaller pistons F′ F′. The hub of the middle piston is in turn mounted upon and keyed or otherwise fastened to the main driving-shaft I of the engine. The two end pistons, F' F', are set oppositely to the middle piston, F, and though all three of the pistons are of the same diameter the width of the middle one equals the united width of both the other ones. By this construction and arrangement the pistons and shaft are put in what I term "mechanical balance"—that is to say, a state of equilibrium, whether at rest or in motion.

The broad idea of applying several rotary eccentric pistons to a common shaft is not new with me; but never before, to my knowledge, has there been observed that relation of size, weight, and location of pistons found in my engine, which alone renders the accurate mechanical balancing of the parts possible. Others, for instance, have placed two eccentric pistons of equal weight and diameter oppositely at different points on a common shaft; but in such an arrangement the centrifugal force resulting from rotation causes the two pistons to tend to fly off tangentially in opposite directions, and to cause a gyration of the shaft on a center midway between such two pistons, the result being a deflection of the shaft and increased friction at and undue wearing of its bearings. This may be illustrated by the diagram Fig. 20, wherein 5 represents the shaft, 6 6 the two eccentric pistons of equal weight, and 7 7 the bearings of the shaft, and 8 the center between the pistons upon which there is a disposition of the shaft to gyrate when in rotation. The arrows marked 4 4 4 represent the direction in which the pistons would tend to travel under the influence of centrifugal force. This deflection of the shaft in my construction is entirely obviated for the tendency of the middle portion to carry the shaft in one direction is resisted by the tendency of the two smaller pistons exerting together equal force on opposite sides of it to carry the shaft in the opposite direction, the result being the establishment of a perfect equilibrium and the even and regular running of the shaft in its bearings, no more friction being imposed upon the bearings than is due to the weight of the parts. The diagram Fig. 21 illustrates this, 9 being the shaft, 10 10 its bearings, 11 the large middle piston, and 12 12 the smaller piston. The arrows marked 13 13 13 show the direction in which the centrifugal force of the several pistons would tend to carry said pistons. It will be observed that all the arrows travel in parallel lines.

In order that the temperature of the pistons may be kept as nearly as possible uniform throughout, and that there may be an equal expansion of the parts, I preferably form an annular chamber, J, in each of them and connect them by channels K to longitudinal channels L in the hub H, that communicate with the steam-space between the inner and outer casings.

Each of the chambers in which the rotary eccentric pistons work is provided with a sliding abutment, M, which passes through both the outer and inner casings and bears against the face of the piston, as shown in Fig. 2. Opposite each of these abutments and bearing upon a corresponding portion of the periphery of the piston is a sliding false abutment, N, which is connected to the sliding abutment by means of frames O, and through rods P, as shown in Figs. 1 and 2. From this construction it will be seen that as the eccentric piston rotates, the abutment will be moved positively in both directions—outward by the direct action of the piston, and inward indirectly, though with equal positiveness, by means of the arms, rods, and false abutment N. The inner end of the abutment is preferably provided with suitable packing—such, for instance, as shown at Q in Fig. 2—for the purpose of preserving at all times a tight joint between it and the periphery of the piston, and where found desirable the false abutment N is rendered adjustable, so as to compensate for wear.

Opening into each piston-chamber above the sliding abutment are two steam-induction ports, R R, and two eduction or exhaust ports, R' R', one induction and one exhaust port being arranged in each side wall of the casing, oppositely. Two pairs of similarly-arranged induction and exhaust ports, S S', open into said piston-chamber below the abutment.

In engines of this class as heretofore constructed sliding abutments have been arranged to slide in fixed guides to and from the piston, or else have been arranged within the piston so as to rotate with it and slide in and out toward the inner circumference of the piston-chamber; but in both such arrangements the projected portion of the abutment upon which the pressure of the steam is exerted has been unsupported, and the result has been that the steam, acting with leverage upon such extended portion, has caused more or less binding of the abutment in its bearings. In my engine I have avoided this difficulty by letting the lateral edges of each abutment into guiding-grooves in the walls of the casing, as shown at U U in Fig. 4. More than this, I have extended the lateral edges V V of the abutment even beyond that portion upon which the steam-pressure is applied, as seen in Fig. 6, and in this way I support the abutment throughout its entire length, rendering it impossible for the steam to act with leverage upon it, so as to cause it to bind in its bearings.

To provide against leakage of steam at the corners of the pistons—a somewhat difficult place to pack—I may in some instances face the end of the abutment with a spring-seated block or face-piece, W, as shown in Fig. 7, and provide the extended portions V V of the abutment with other similar spring-seated face-pieces, X, overlapping the face-piece W as also shown in said Fig. 7. By this construction tight joints are maintained.

It is essential, of course, that not only should the joints between the eccentric pistons and their sliding abutments be kept tight, but also that close joints be preserved between said pistons and the inner peripheries of the chambers at the point of contact. I have therefore formed a transverse recess, X′, in the periphery of each eccentric piston, and have filled the same with a suitable packing material, Y, as shown in Fig. 2. I have furthermore let into the opposite faces of each piston, near its periphery, a split ring, Z, having offsets or tongues Z′, which project into the ends of the packing, as shown clearly in Figs. 11 and 12, and hold it firmly in position.

Mounted upon the extended hub H, and keyed rigidly to the same, so as to rotate therewith, are a series of cut-off valves, A′, which operate within the inner casing, A, of the engine to cut off and admit the steam supplied to the piston-chambers through the steam-induction ports R and S. As there are four induction-ports opening into each piston-chamber—that is to say, two, one on each side above the sliding abutment, and two similarly located below the abutment—it follows that for each piston-chamber there are two rotary cut-off valves, one on each side thereof. This is clearly shown in Figs. 3, 4, 5.

One of the cut-off valves A′ is represented detached in Fig. 9, and in dotted lines in Fig. 2. As will be seen from these figures, it is provided with two curved ports, B′ C′, the former being the outer and longer one and the latter the inner and shorter one. The port B′, when the valve is rotated, travels over the outer steam-induction port, R, that opens into the piston-chamber above the sliding abutment, as shown in Fig. 2, while the inner port, C′, travels over the inner induction-port, S, below the abutment. Around the edges of each of the ports B′ C′, on both sides of the valve, is arranged a suitable metallic packing, D′.

Besides the rotary cut-off valves just described, each of the piston-chambers is further provided with a reciprocating slide-valve, $E^2$. (See Figs. 2 and 13.) This valve has an upper exhaust-port, F′, and a lower exhaust-port, G′, and upper and lower steam-induction ports, H′ I′, as shown in Fig. 13. When it occupies the position shown in Fig. 2, it closes the upper exhaust-ports, R′, of the piston-chamber and opens the lower exhaust-ports, S′, thereof, while it opens the upper steam-induction ports, R, and closes the lower steam-induction ports, S. The reverse operation of this takes place when the valve is shifted to its limit in the opposite direction.

Provision is made for shifting all the reciprocating slide-valves of the engine simultaneously into the desired position by manipulating a handle, $G^2$, secured to a crank-shaft, $H^2$, that operates laterally-sliding inclined shifting-bars $I^2$, constructed to co-operate with and act positively upon the lower portion of the slide-valves, as shown in Fig. 2. The steam-space between the inner and outer casings is bridged at the exhaust-ports of the piston-chambers by means of packing-rings J′, interposed between said casings and forming a continuation of the exhaust-ports, as seen in Fig. 2.

From the foregoing description of the valves it will be evident that when the reciprocating slide-valve is adjusted to the position shown in Fig. 2, for instance, steam will pass from the steam-space between the two casings into the passages in the inner casing, controlled by the rotary cut-off valves, and will be alternately admitted to and cut off from the piston-chambers by the operation of said cut-off valves in a manner that will be readily understood—that is to say, the piston-chambers will take steam while the elongated ports B′ in the valves are passing their respective ports in the casing, and steam will be cut off therefrom during the remainder of the revolution of said valves. By this construction of valves a full port of steam under nearly boiler-pressure is admitted directly into the piston-chambers on each side thereof, thus fully utilizing the initial pressure and reducing the amount of clearance to the minimum. If, now, the reciprocating slide-valves be shifted to their fullest extent in the opposite direction, so as to close the induction-ports above the sliding abutments and open those below the abutments, and at the same time open the exhaust-ports above and close the exhaust-ports below, the inner ports, C′, of the rotary cut-off valves will become operative and will deliver or cut off steam to or from the piston-chambers below the sliding abutments thereof, thereby causing a reversal of the engine.

Of course, it will be understood that the steam, when admitted to the piston-chambers, will operate first by direct pressure, and afterward, when cut off, expansively upon the projecting parts of the eccentric pistons, and cause the latter and the shaft to which they are attached to rapidly revolve in one direction or the other, according as the steam is admitted above or below the sliding abutments.

The arrangement of valves thus far described will be found to suffice for ordinary engines; but, by preference, I also employ in addition a set of "governing-valves," so called from the fact that they are designed to co-operate with the rotary cut-off valves in a manner to effect the almost instantaneous cutting off of the steam at any desired point, according to the load or desired speed of the engine. These governing-valves are represented in section in Figs. 3, 4, 5, and are lettered K′. A side view of one of them is also shown in Fig. 8. They are all mounted so as to turn freely upon the hub H in close proximity to the rotary cut-off valves, and each one has connected to it a rod, L′, which passes out through both casings and is connected to a bar or shaft, M′, common to all. The bar M′ in turn passes through slots in the upper portions of vertical bars N′

N′, mounted upon a rock-shaft, O′, to which a hand lock-lever, P′, is also secured. By the operation of this hand-lever the position of all the governing-valves can be shifted as desired and locked in their adjusted positions. Each of the governing-valves has two ports, Q′ U′, located at different points and at different distances from the center, as shown in Fig. 8, the outer port, Q′, being arranged so as to co-operate with the outer port, B′, of the corresponding rotary cut-off valve, and the inner port, U′, with the inner port, C′, of said cut-off valve.

The manner in which the governing-valves co-operate with the rotary cut-off valves will be readily understood if the attention is directed to Fig. 9, wherein a side view of one of the cut-off valves is shown in full lines, the steam-inlet ports of the adjacent piston-chamber by the cross-lined spaces lettered R S, and the ports of the governing-valve by the spaces inclosed by dotted lines and lettered Q′ and U′, respectively. Assuming the rotary cut-off valve and the shaft and piston with which it co-operates to be rotating in the direction indicated by the arrow in said Fig. 9, and that by reason of the position of the reciprocating slide-valve the inlet of steam to the inner steam-induction passage opposite the port S is cut off, if the governing-valve is shifted till its outer port, Q′, (see Fig. 8,) comes opposite the steam-induction port R of the inner casing, steam will be admitted into the piston-chamber through said port Q′, (which, when once adjusted, remains stationary,) and through the outer port, B′, of the cut-off valve while the entire length of the said cut-off-valve port is passing by the said two other ports, the result being the giving of a full port of steam, the same as though the governing-valve were dispensed with and the rotary cut-off valve alone employed; but where it is desired to give only a half-port of steam, for instance, the governing-valve is shifted till its port Q′ stands at a distance from the corresponding port, R, of the casing, equal to half the length of the port or slot B′ in the cut-off valve, as shown by the dotted lines Q′ in said Fig. 9, this movement shortening up the port of the cut-valve and causing the steam to be cut off just twice as quickly as when the position of the governing-valve was at that first described. From this it will be seen that by adjusting the positions of all the governing-valves of the engine all the rotary cut-off valves may be caused to cut off steam at any given point, according to the load or speed of engine required.

On the reversal of the engine, and a consequent closure of the port R and opening of the inner ports, S, the inner port, U′, of the governing-valves will in like manner co-operate with the inner ports, C′, of the rotary cut-off valves, as will be readily understood.

Inasmuch as the outer ports of the rotary cut-off valves travel faster than the inner ports thereof, by reason of the difference in distance from the center of motion, the said outer ports are made proportionally longer, in order that they may admit the same amount of steam in the same time as the inner ports.

The packings D′ (see Fig. 10) on opposite sides of the rotary cut-off valves, while preserving tight joints between the said valves and the casing on the one hand and between said valves and the governing-valves on the other hand, leave slight intervals or spaces $A^2$ $B^2$, which would tend to create unequal pressure on the valves, were it not for the fact that I provide each valve with a number of lateral perforations, $C^2$, through which steam is admitted to both sides of the valve. Thus steam-balanced, the valves run smoothly, subject only to the friction of the packings. The governing-valves are kept properly seated against the cut-off valves by means of springs $D^2$, interposed between them and the casing, as clearly shown in Figs. 8 and 10.

In most rotary engines, owing either to the unequal expansion of the parts of the mechanism or to wear, difficulty often arises from the shaft getting out of center, and with this in view I have in the construction of my present engine essayed a distribution of steam calculated not only to steam-balance all the running parts, but also to provide for a uniformity of expansion. My plan for accomplishing this, as has been seen, includes the steam-jacketing of the inner casing in which the several operative parts of the mechanism work, the channeling and chambering of the inner casing, the hub, and pistons, so as to admit steam therein, the provisions for steam-balancing the several valves, the supporting of the inner casing so as to permit of free expansion in all directions, the packing of the sliding abutments, slide-valves, and rods in a manner to admit of expansion, &c. In fine, my aim has been to secure a free and equal expansion of the inner casing and all its contained parts from center to circumference, so that there shall be no binding or cramping at any point, and so that the expansion or contraction of the inner casing would not affect at all the inner casing. While all these provisions are believed to in a large measure, if not entirely and effectually, meet the difficulties of unequal expansion, I have still thought it advisable to provide further against such difficulties, but more particularly against wear of parts, by the employment of means for adjusting and centering the shaft, or rather the long hub of the pistons in its bearings in the inner casing. In carrying out this point of my invention I form annular tapering recesses $E^7$ $E^7$ in the outer portions of the inner case, as shown, for instance, in Fig. 4, and in such recesses I arrange a series of corresponding wedge-shaped ring-segments, $F^2$, rendered adjustable by movable bolts $G^2$. The shaft, which of course is rigidly connected to the hub H, has bearings $H^3$ $H^3$ in the outer casing, that are capable of a slight lateral adjustment in the casing, the joint between them and the outer casing being maintained at all times steam-tight by means of packing-rings $I^3$, incircling the shaft and steam-pressed outward, as shown.

When the engine is first properly centered and balanced, a circle may be struck upon the outer surface of the outer casing by means of any suitable instrument applied to the shaft and rotated with it. This circle will thereafter serve as a gage by which to determine whether the shaft is perfectly aligned. If at any time, upon a suitable instrument being applied to the shaft, it is found that a circle is made eccentric to that of the standard circle, the wedge-shaped sections $E^2$ are adjusted till a perfectly true alignment is effected. In this way an even running of the engine may at all times be assured.

Having thus described my invention, what I claim as new is—

1. In a rotary engine, a single driving-shaft and a series of eccentric pistons of the same diameter, but of unequal weight, secured to said shaft in a manner to cause the balancing of the heavier piston or pistons by two or more of the lighter pistons, in combination with chambers in which the pistons work, and sliding abutments co-operating with said pistons and supported by the walls of the piston-chambers, substantially as described.

2. In a rotary engine, the combination of a middle rotary eccentric piston having an elongated hub and two other eccentric pistons secured rigidly to said elongated hub on opposite sides of said middle portion, substantially as described.

3. In a rotary engine, the combination of a middle rotary eccentric piston having an elongated hub and two other eccentric pistons rigidly secured to said elongated hub on opposite sides of the said middle piston, and having an aggregate weight equal only to the weight of the middle piston, substantially as described.

4. In a rotary engine, the combination of an inner casing containing the piston-chambers, the rotary pistons, and the valves for controlling the admission of steam to said piston-chambers, with an outer casing, between which and the inner casing the steam for running the engine is first admitted before passing into the inner casing, substantially as described.

5. In a rotary engine, the combination, with a stationary piston-chamber, of an eccentric piston operating therein and a sliding abutment guided in the walls of the piston-chamber and moved positively in and out by direct contact with the surface of the piston, substantially as described.

6. In a rotary engine, the combination, with a stationary piston-chamber, of an eccentric piston operating therein, a sliding abutment, and a sliding false abutment guided in the walls of the piston-chamber, connected together and bearing upon opposite portions of the surface of the piston, substantially as described.

7. In a rotary engine, the combination, with a stationary piston-chamber, of an eccentric piston operating therein and the sliding abutment supported at its lateral edges in the walls of the chamber and actuated by direct contact of its end with the periphery of the eccentric piston, substantially as described.

8. In a rotary engine, the combination, with a stationary casing having a series of piston-chambers and a series of eccentric pistons arranged in said chambers and mounted upon a common shaft, of a series of sliding abutments, one for each piston-chamber, said abutments being supported in the walls of the stationary casing and bearing upon the peripheries of their respective pistons and receiving positive motion therefrom, substantially as described.

9. In a rotary engine, the combination, substantially as described, of the stationary outer casing and the stationary inner casing, having the steam-space between them, with the middle piston, its elongated hub, and the two smaller pistons secured to said hub, all said pistons and said hub having internal passages for steam in communication with the steam-space between the inner and outer pistons, for the purpose specified.

10. In a rotary engine, the combination of a stationary inner casing formed with piston-chambers, rotary eccentric pistons arranged in said piston-chambers, and valves for controlling the inlet of steam to said piston-chambers, also contained within said inner casing, with an outer casing, between which and the inner casing is a live-steam space surrounding the inner casing at both sides and ends, whereby the inner casing and all its contained parts are kept at all times at a substantially uniform temperature, and are permitted to uniformly expand without liability of binding.

11. The combination, with the inner and outer casings, having the steam-space between them, of the piston-chambers within the inner casing, the rotary eccentric piston, the sliding abutments, and the reciprocating valves for simultaneously opening the steam-induction ports and closing the exhaust-port on one side of the abutments, and closing the steam-induction ports and opening the exhaust-port on the opposite side of the abutments, substantially as described.

12. The combination, with the inner and outer casings, having the steam-space between them, of the circular packing-rings interposed to form part of the exhaust-passages, substantially as described.

13. The combination, with the inner casing and its piston-chamber and rotary pistons, of the series of reciprocating slide-valves and the handle, crank-shaft, and shifting-bars for simultaneously operating said valves, substantially as described.

14. The combination of the rotary eccentric pistons, sliding abutments, and the inner casing having piston-chambers in which the ro-

tary pistons work, and provided with two opposite steam-inlet ports on each side of the abutments, substantially as described.

15. The combination, with the eccentric piston, having the transverse slot in its periphery for the reception of packing, of the split rings let into the sides of the piston, and having the offsets or lugs for holding the packing in position, substantially as described.

16. The combination, with the casing having the piston-chambers, of the rotary eccentric pistons, the sliding abutments, and the rotary cut-off valves having the inner and outer elongated ports co-operating with the steam passages or ports in the casing, substantially in the manner described.

17. The combination, with the casing having the piston-chambers, of the rotary eccentric pistons, the sliding abutments, and the rotary cut-off valves arranged in pairs, one on each side of every piston-chamber, and controlling the admission of steam to such piston-chambers, substantially as described.

18. The combination, with the casing having the piston-chambers, of the rotary eccentric pistons, the sliding abutments, the rotary cut-off valves arranged in pairs, one on each side of every piston-chamber, and controlling the admission of steam to the piston-chambers, and the reciprocating cut-off valves co-operating with the steam supply and exhaust ports on opposite sides of the abutments, in the manner described, and for the purpose specified.

19. The combination, with the casing having the piston-chambers therein, of the rotary cut-off valves having the elongated segmental ports, and the adjustable governing-valves having inner and outer ports co-operating with the ports of the rotary cut-off valves, substantially in the manner specified, and for the purpose described.

20. The combination, with the inner casing and its steam ports or passages, of the rotary cut-off valves having the elongated ports, and the packing surrounding said ports on both sides of the valves, and the adjustable governing-valves, substantially as described.

21. The combination, with the inner casing and its ports, of the rotary cut-off valves and the governing-valves, constructed as described, and pressed against the cut-off valves by means of springs, substantially as described.

22. The combination, with the inner casing and its steam-ports, of the rotary cut-off valve, the governing-valve, and the reciprocating cut-off valves, all constructed and arranged substantially as described.

23. The combination, with the inner casing and its steam-passages, of the rotary cut-off valves, the governing-valves, and the described means for simultaneously adjusting the governing-valves, so as to cause them to cut off the steam sooner or later for all the piston-chambers, substantially as described.

24. The combination, with the elongated hub rendered adjustable in the inner casing, as described, of the shaft to which the hub is secured, the bearings for said shaft having a slight play in the outer casing, and the outwardly steam-pressed packings for preserving the joint between the said bearings and the outer casing, substantially as described.

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Witnesses:
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