No. 720,460. PATENTED FEB. 10, 1903.

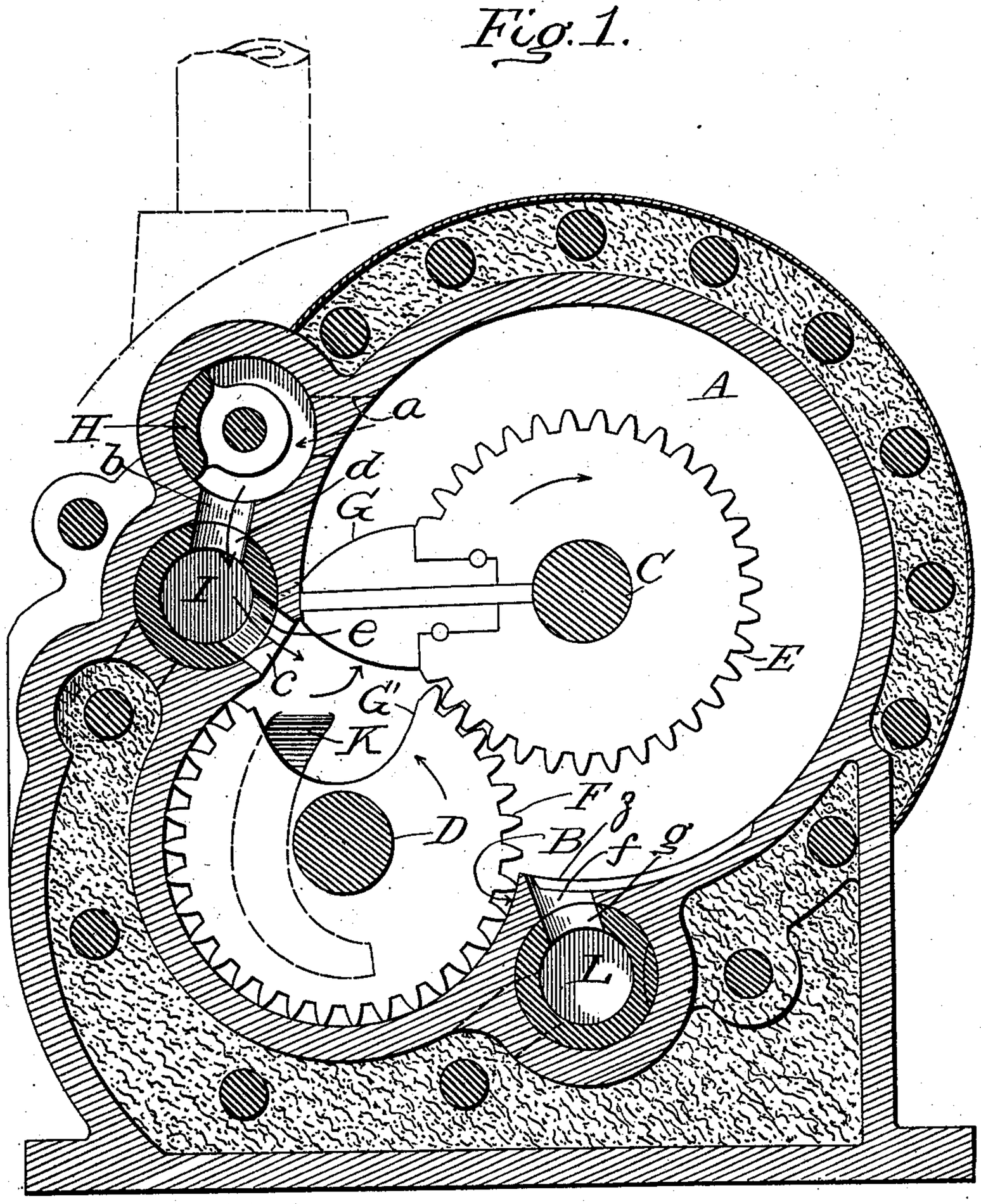
J. L. McMILLAN.

ROTARY ENGINE.

APPLICATION FILED JUNE 4, 1902.

NO MODEL. 9 SHEETS—SHEET 1.

Fig. 1.



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No. 720,460. PATENTED FEB. 10, 1903.

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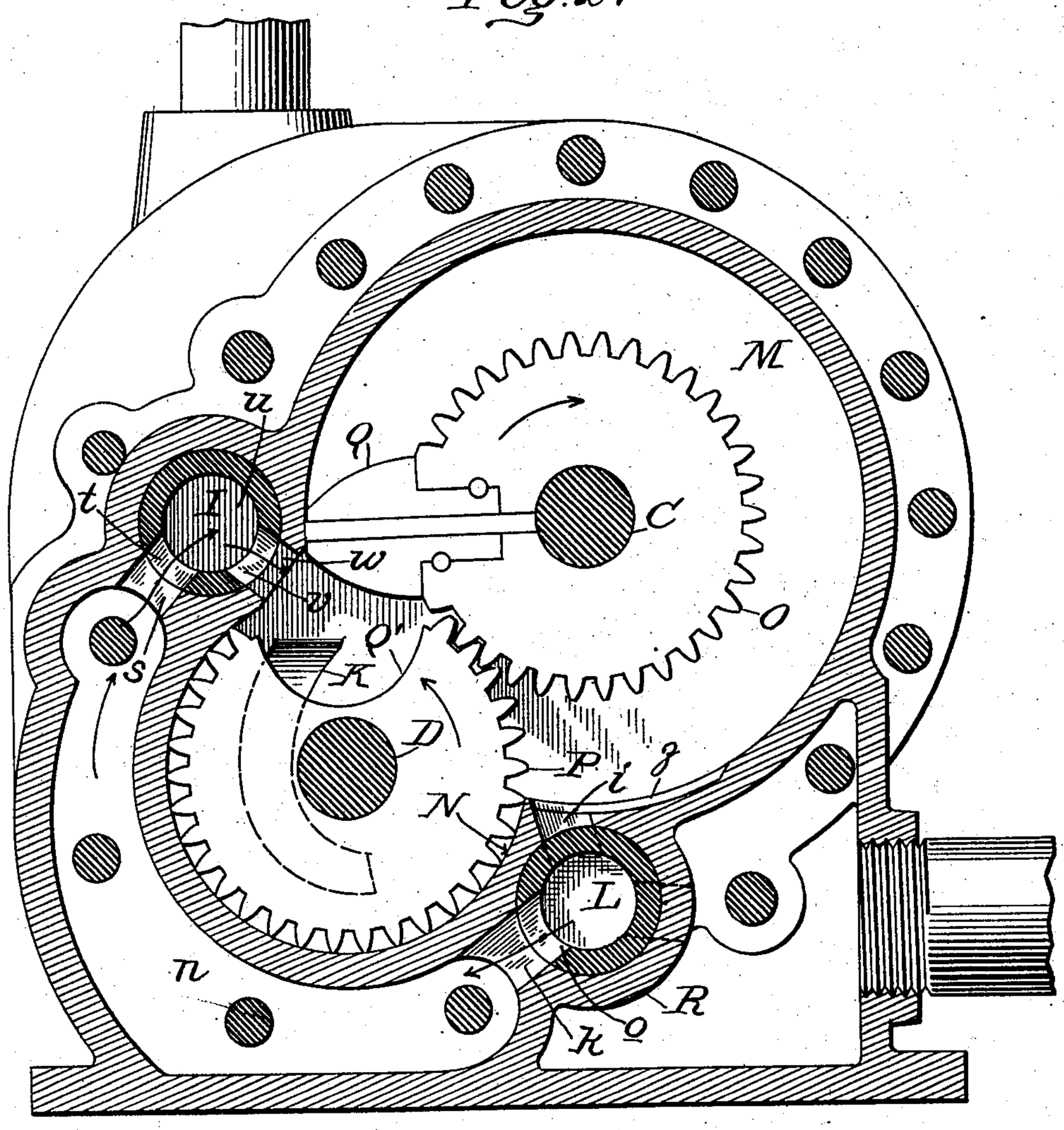
NO MODEL. 9 SHEETS—SHEET 2.

Fig. 2.



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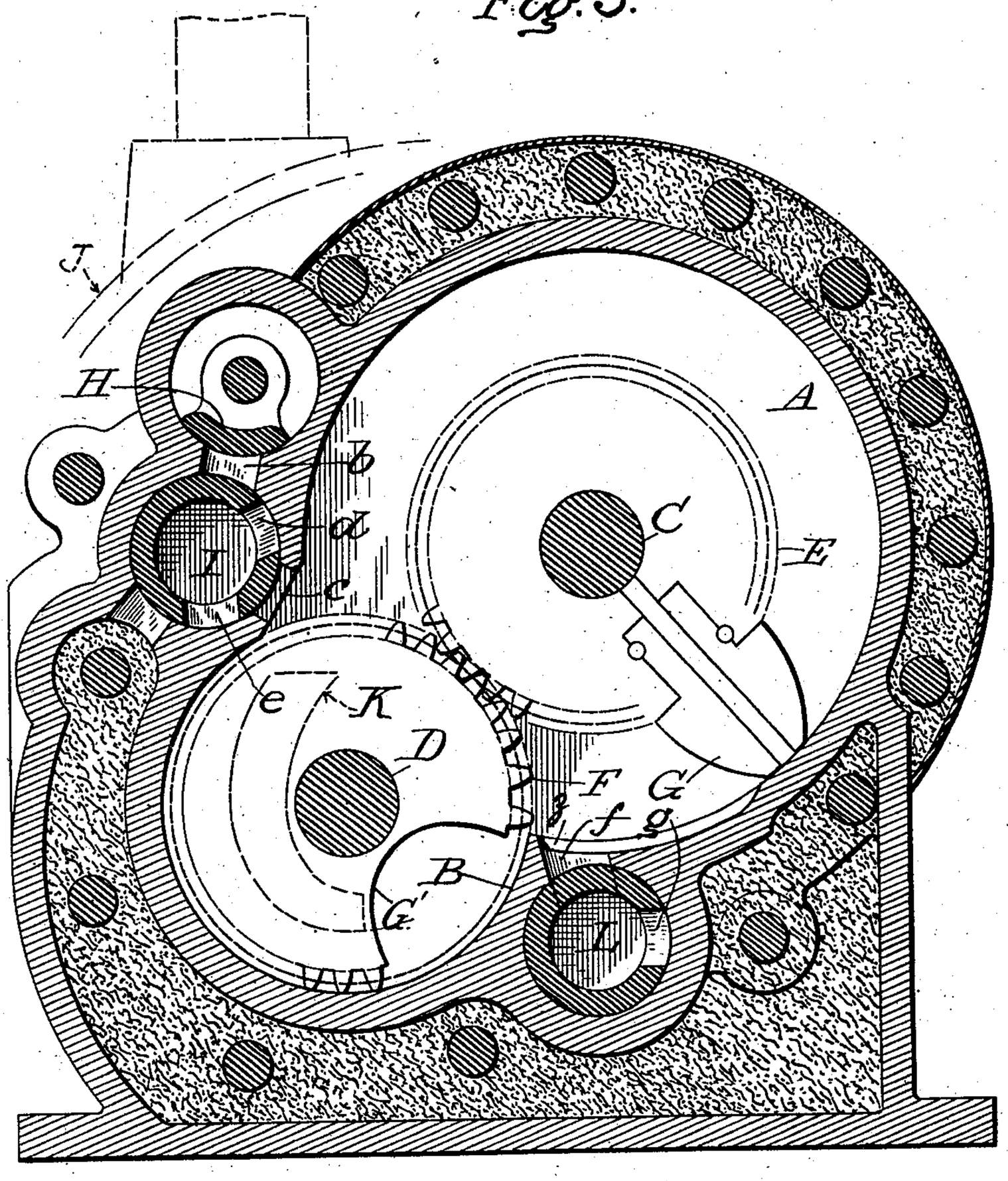
ROTARY ENGINE.

APPLICATION FILED JUNE 4, 1902.

NO MODEL. 9 SHEETS—SHEET 3

Fig. 3.



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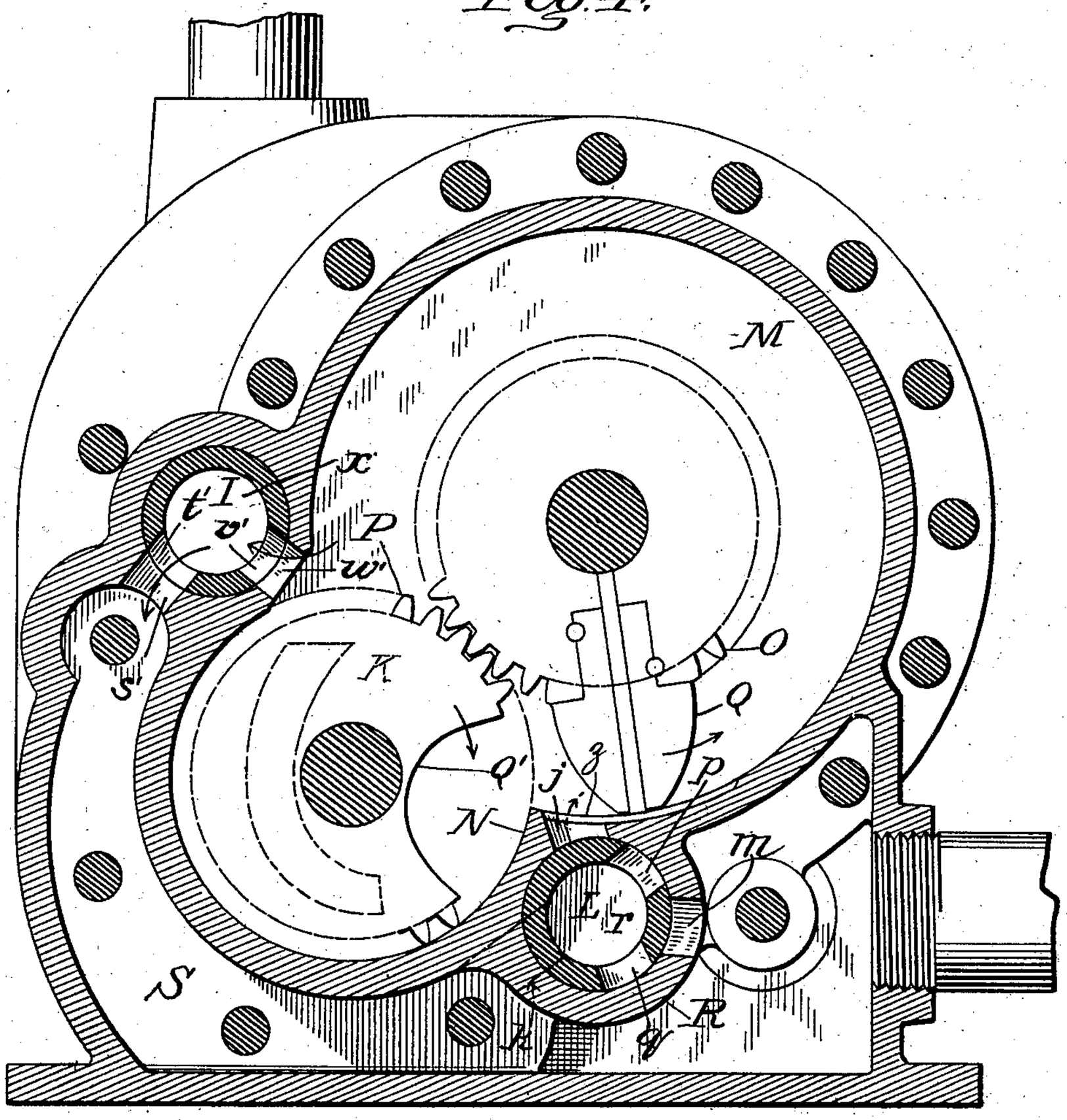
NO MODEL. 9 SHEETS—SHEET 4.

Fig. 4.



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NO MODEL. 9 SHEETS—SHEET 5.

Fig. 5

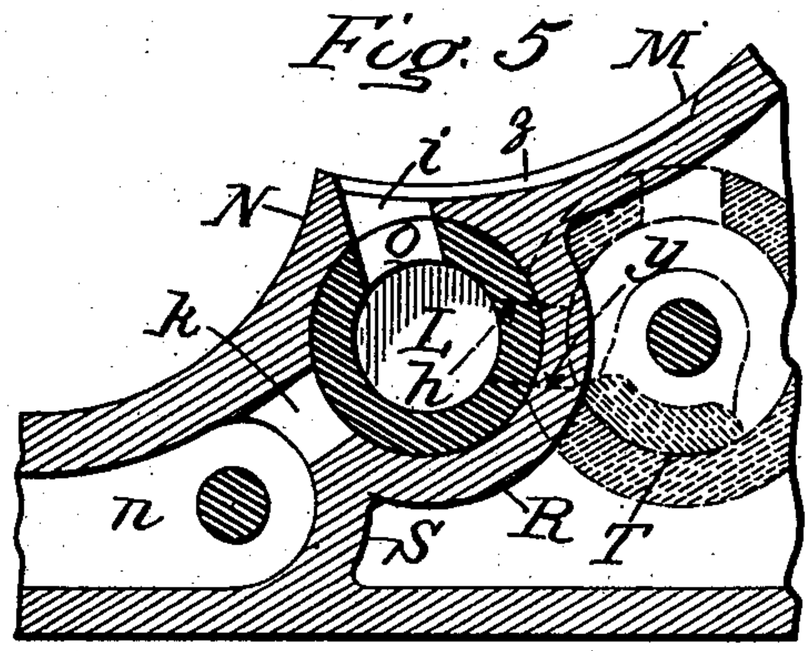


Fig. 6.

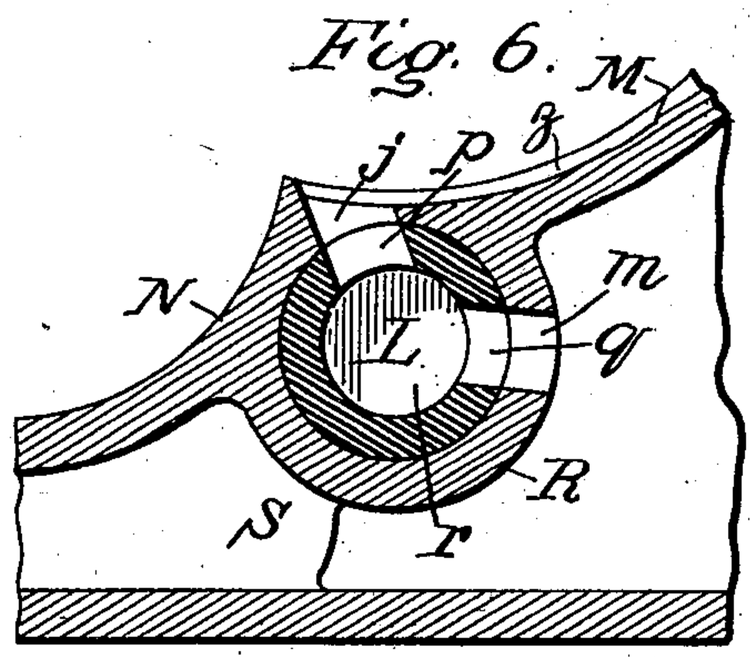


Fig. 7.

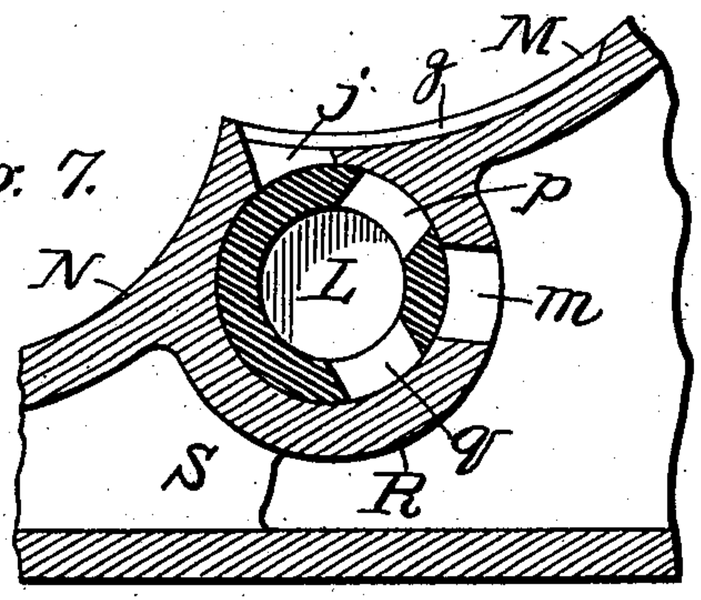


Fig. 12.

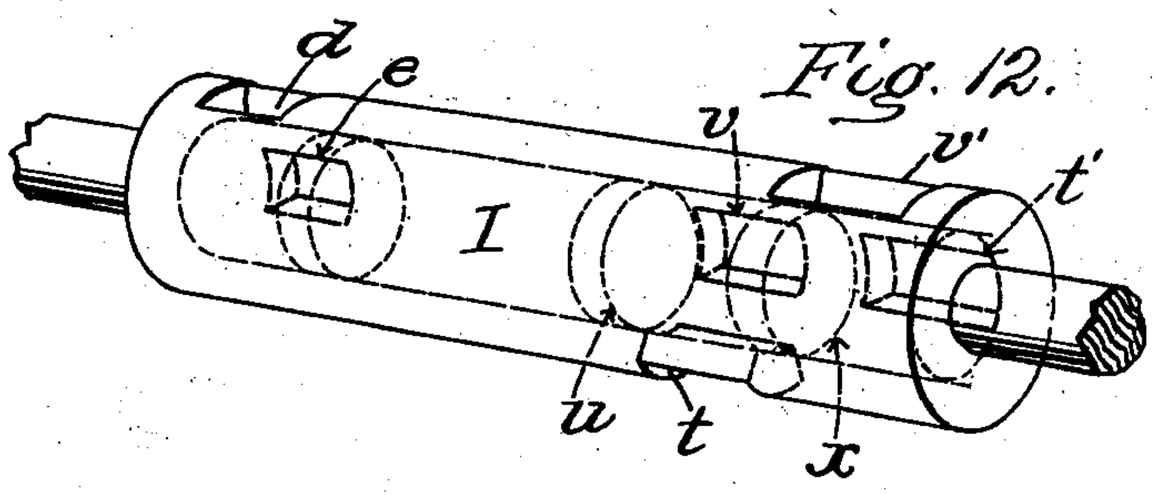
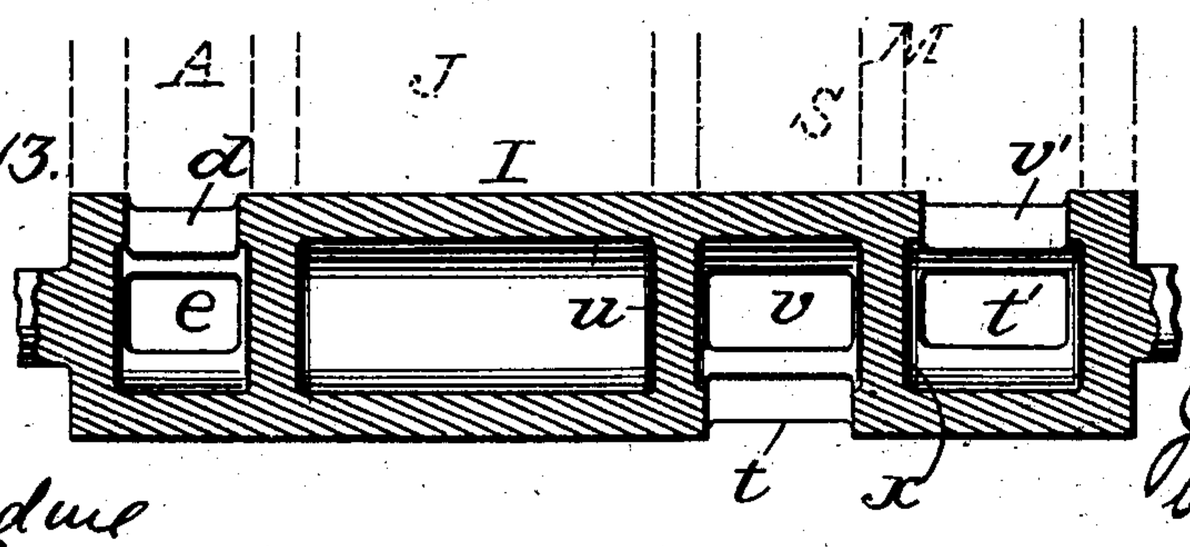


Fig. 13.



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No. 720,460. PATENTED FEB. 10, 1903.

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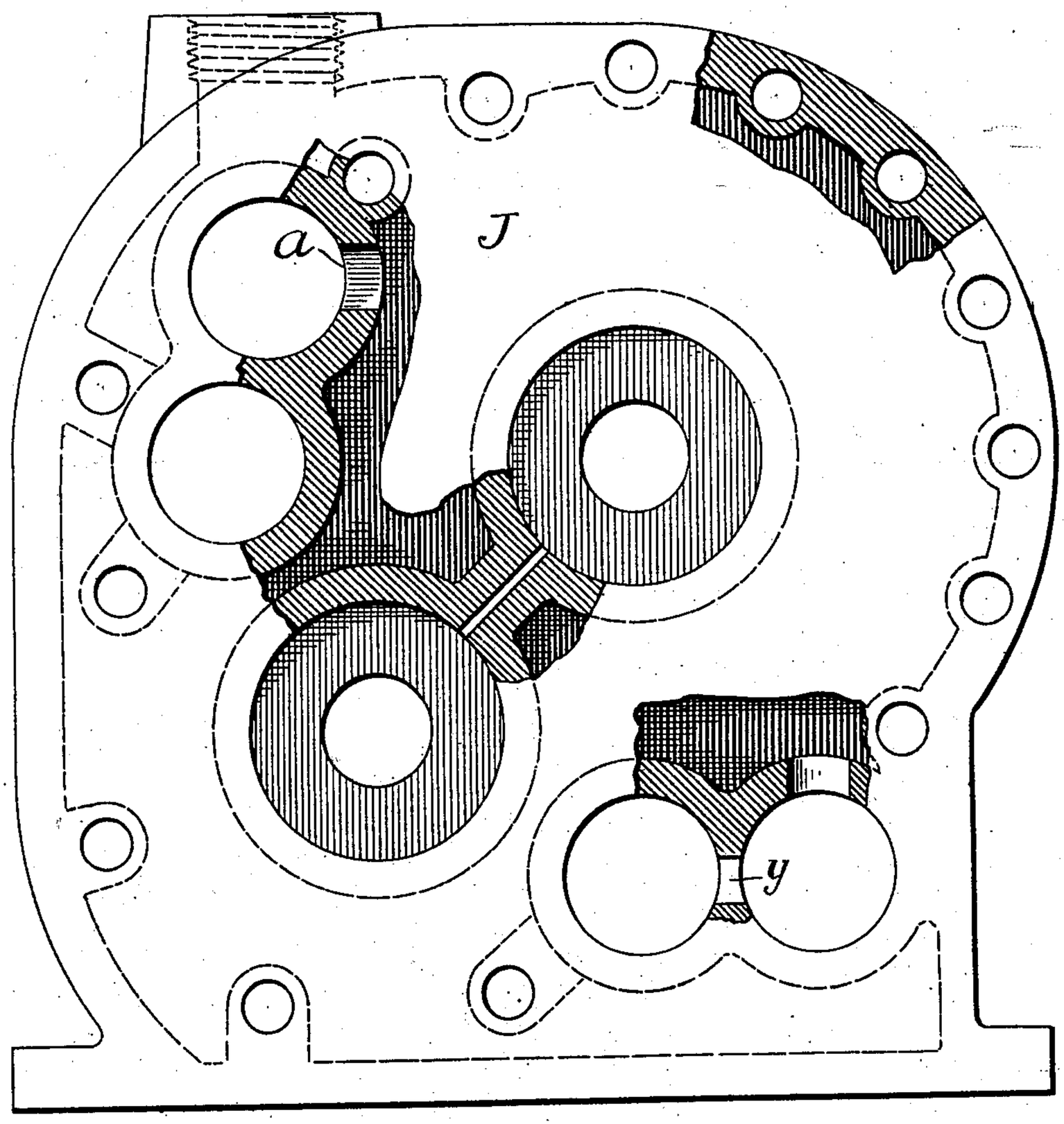
ROTARY ENGINE.

APPLICATION FILED JUNE 4, 1902.

NO MODEL. 9 SHEETS—SHEET 6.

Fig. 8.



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No. 720,460. PATENTED FEB. 10, 1903.

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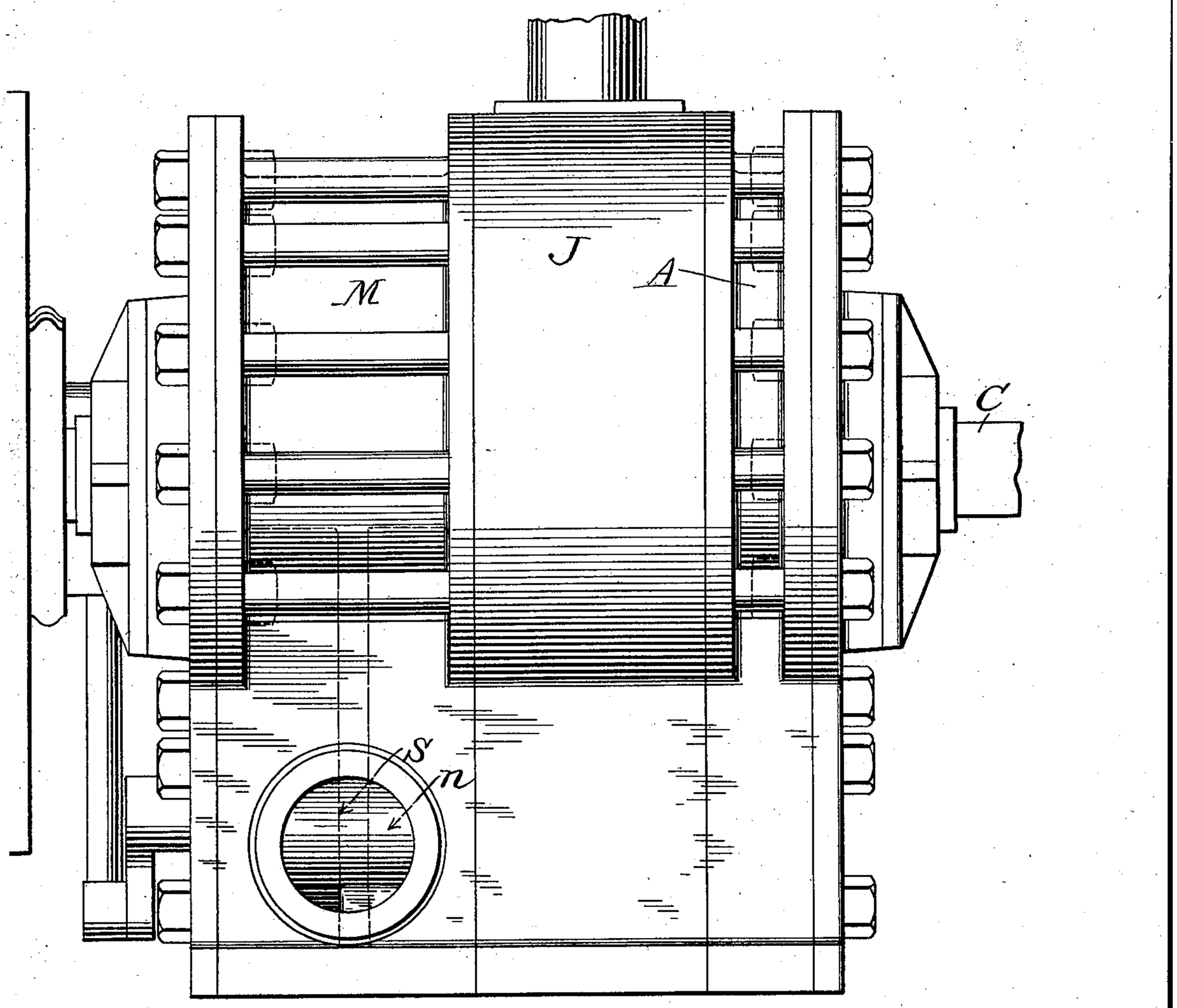
ROTARY ENGINE.

APPLICATION FILED JUNE 4, 1902.

NO MODEL. 9 SHEETS—SHEET 7.

Fig. 9.



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No. 720,460. PATENTED FEB. 10, 1903.

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ROTARY ENGINE.

APPLICATION FILED JUNE 4, 1902.

NO MODEL. 9 SHEETS—SHEET 8.

Fig. 10.

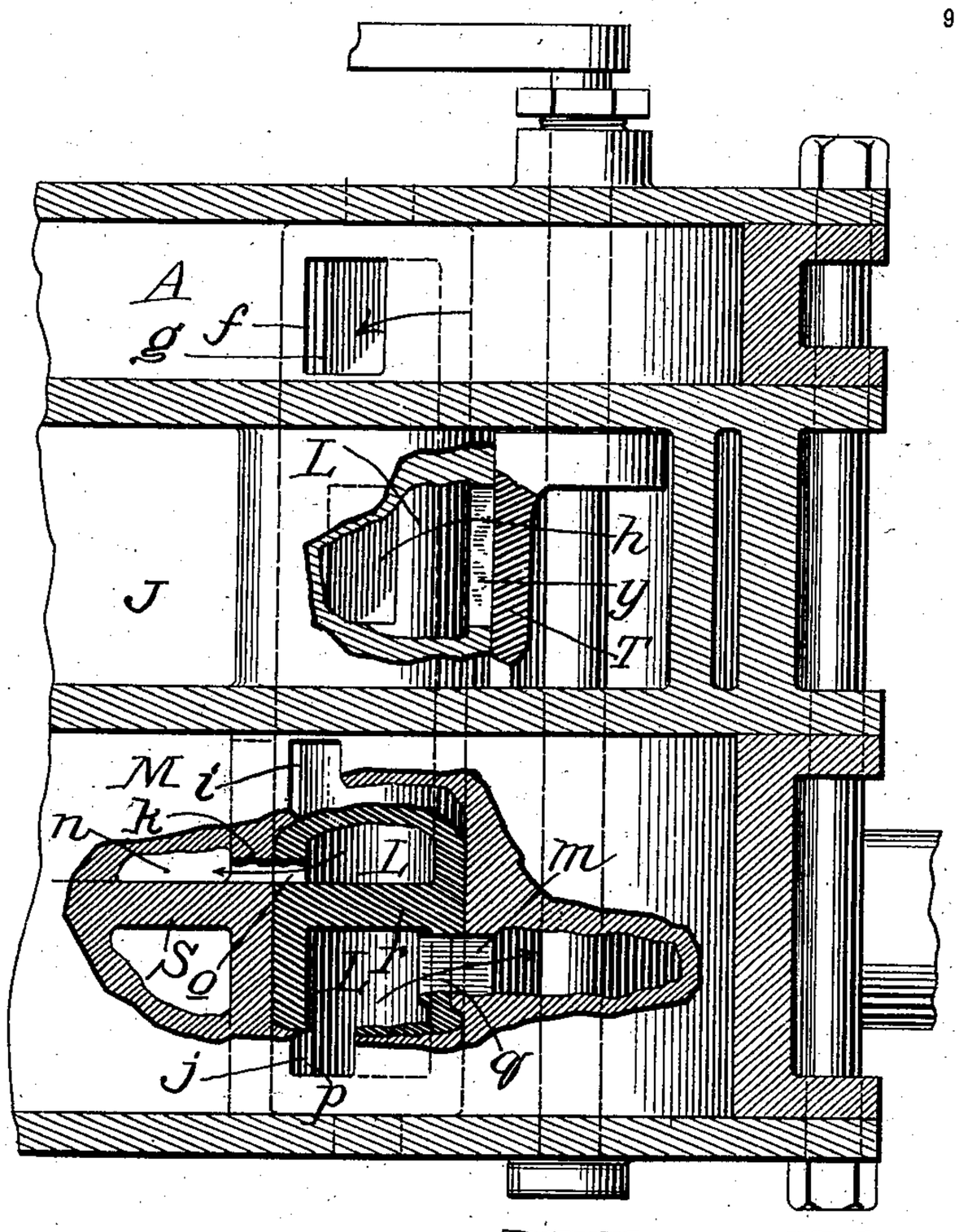
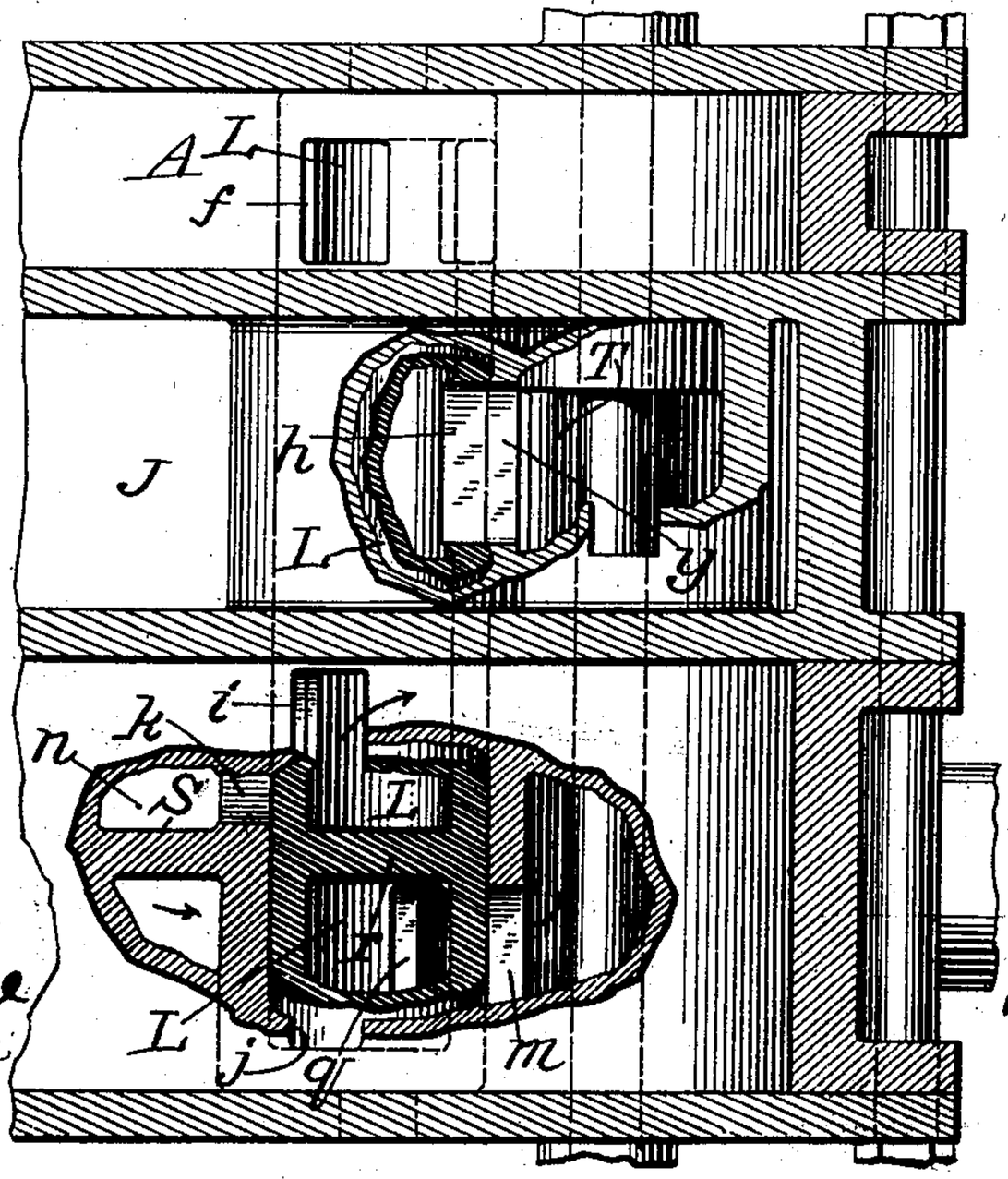


Fig. 11.



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No. 720,460. PATENTED FEB. 10, 1903.

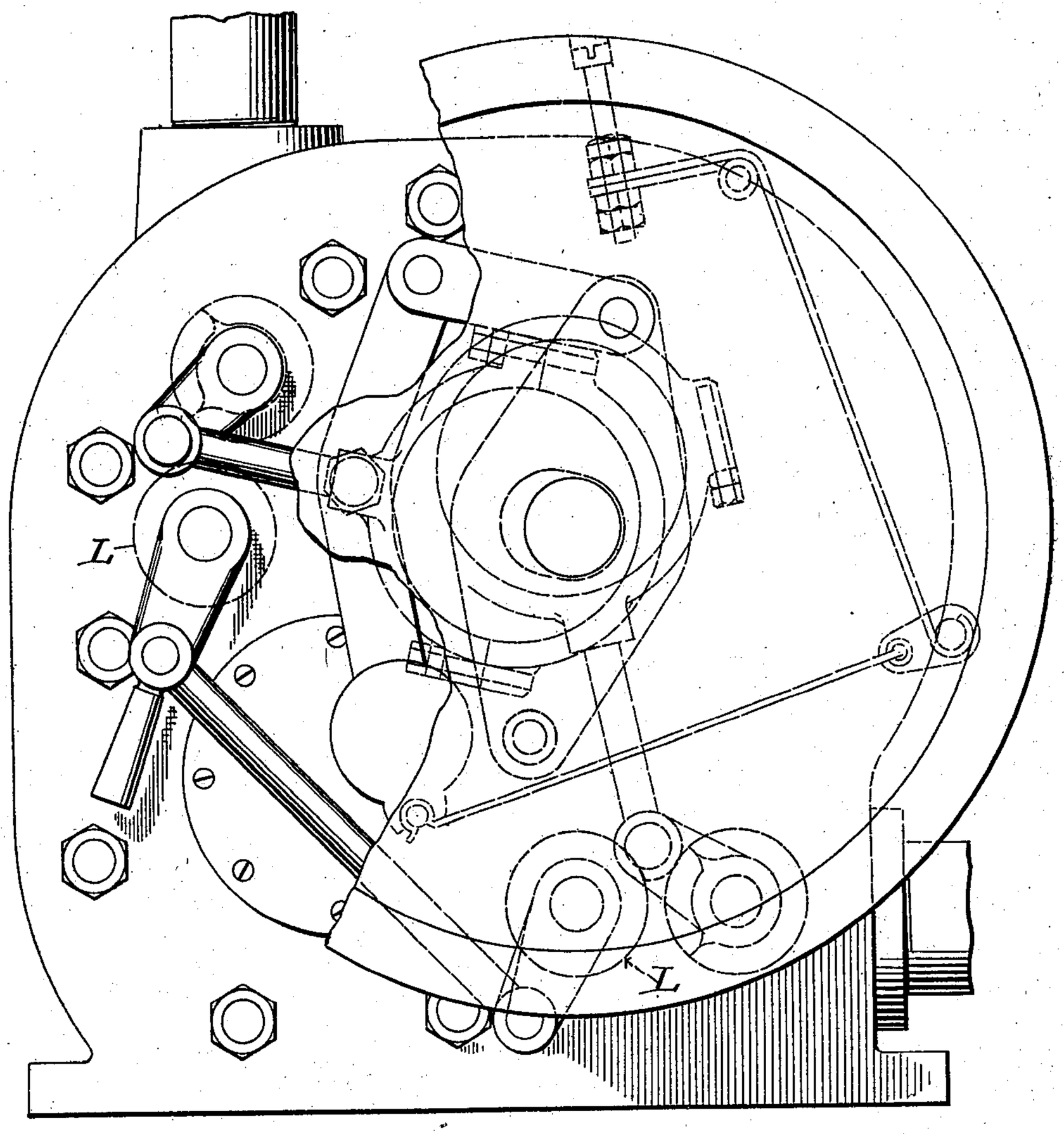
J. L. McMILLAN.

ROTARY ENGINE.

APPLICATION FILED JUNE 4, 1902.

NO MODEL. 9 SHEETS—SHEET 9.

Fig. 14.



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UNITED STATES PATENT OFFICE.

JOHN L. McMILLAN, OF SYRACUSE, NEW YORK.

ROTARY ENGINE.

SPECIFICATION forming part of Letters Patent No. 720,460, dated February 10, 1903.

Application filed June 4, 1902. Serial No. 110,217. (No model.)

To all whom it may concern:

Be it known that I, JOHN L. McMILLAN, a citizen of the United States, residing at Syracuse, in the county of Onondaga and State of New York, have invented certain new and useful Improvements in Rotary Engines, of which the following is a specification.

This invention consists in novel features and improvements in rotary engines, and is in the nature of a development or carrying forward of the invention set forth in application Serial No. 78,478, filed in the United States Patent Office in my name on the 12th day of October, 1901.

The present invention and improvements are designed to incorporate in the engine the features and advantages of compound steam-engines and to utilize more perfectly the expansibility of the steam or other fluid or gas employed.

In its general principles and construction the engine is similar to that described in the previous application mentioned, and any details of construction not fully set forth herein may be in accordance with the description therein contained. Thus, for instance, the construction and arrangement of the roller-bearings and of the governor will be omitted from the present description as not necessary to a clear understanding of those features which constitute the present invention.

In the accompanying drawings, Figure 1 is a vertical sectional view taken through the high-pressure cylinder at a right angle to the common axis of the cylinder and of rotation of the piston; Fig. 2, a similar section through the low-pressure cylinder in the plane of the inlet-port of the reversing-valve and the corresponding ports or openings in the cylinder-casting; Fig. 3, a section through the high-pressure cylinder, showing the valves set to cause backward or left-hand turning of the piston; Fig. 4, a sectional view, identical with Fig. 2, except that it is taken through the normal exhaust-port instead of through the port which serves for the induction of steam when the low-pressure piston is turned backward; Fig. 5, a sectional view through the reversing-valve of the low-pressure cylinder in the same plane as in Fig. 2, but with the valve set to produce left-hand movement of the piston; Fig. 6, a sectional view in the plane of the exhaust-ports and showing the valve set for right-hand travel of the piston; Fig. 7, a similar section with the valve set for left-hand or backward travel of the piston; Fig. 8, a side elevation of the steam-chest with internal partitions or walls shown in dotted lines and with portions broken away to show in section other walls or partitions; Fig. 9, a rear elevation of the low-pressure cylinder, showing in dotted lines the partition separating the exhaust-chamber into two compartments, one communicating with the high-pressure and the other with the low-pressure cylinder; Figs. 10 and 11, horizontal sections, essentially diagrammatic, through the lower portion of the engine and illustrating the setting and action of the reversing-valve, portions of the valve shells or casings and of the valve being broken away to better show the construction; Fig. 12, a perspective view of the reversing-valve at the upper side of the engine through which steam normally enters both the high and low pressure cylinders; Fig. 13, a longitudinal section of same; Fig. 14, a side elevation of the engine, showing the devices for operating the valves.

It will be convenient to describe first the high-pressure cylinder and its piston and valves and then to explain the like parts of the low-pressure side of the engine.

Referring first to Fig. 1, A indicates a high-pressure cylinder or chamber, which in the direction of its axis will ordinarily be relatively short as compared with its diameter, though the proportions are variable to any desired extent. At one side of the cylinder or chamber A is a second circular chamber or enlargement B, the inner circumference of which cuts that of cylinder A, as shown. Passing through and concentric with cylinder A is a shaft C, which is the main shaft of the engine, and parallel therewith and concentric with chamber B is a second shaft D. Shafts C and D carry, respectively, toothed gears E and F of like diameter and having teeth extending from end to end, thus giving long and firm engagement, and the teeth effectually barring any passage of steam between the two gears and rendering packing of any kind unnecessary between them. Gear E is provided with a piston G, represented as in the form of an enlarged gear-tooth, the outer ex-

tremity of which extends to or just clears the inner wall of cylinder A and is furnished with a packing-strip which makes close rubbing contact with said wall. To receive the piston G and permit it to pass the gear F, the latter is formed with a recess or cavity G′ in its periphery, which cavity is of semicircular form, or substantially so, though the shape may vary somewhat according to the form given to piston G. Thus far the construction is the same as in my former engine.

To control admission of steam to the cylinder A, I employ two valves H and I, the first of which is a cut-off valve directly controlling the supply of steam to the cylinder and determining at what point in the stroke or revolution it shall be cut off, it being found highly advantageous to use the steam, gas, or fluid expansively. Valve H is contained within a shell or casing communicating by a passage *a*, Fig. 8, with the interior of a steam chest or chamber J, which occupies a position between the high-pressure cylinder A and a low-pressure cylinder hereinafter described, but of essentially the same form as the high-pressure cylinder. Valve I is of tubular form and is contained within a shell or casing cast in or as a part of the high-pressure cylinder A, which casing contains two ports *b* and *c*, the former controlled and alternately covered and uncovered by the valve H, which is oscillated by an eccentric or cam carried by the shaft C, as in my former engine and as is well understood. The valve I has within the length or axial measurement of cylinder A two ports or openings *d* and *e*, which may be carried into or out of register with ports *b* and *c*, as desired, by partially rotating said valve. In Fig. 1 the ports *b d* and the ports *e c* are shown as registering, so that when port *b* is uncovered by oscillation of valve H steam or other pressure fluid will pass from steam-chest J through opening *a* and by ports *b*, *d*, *e*, and *c* to the interior of cylinder or chamber A.

Valve H and its actuating eccentric or cam are so set in practice as to cause port *b* to be opened or uncovered when piston G occupies the position (shown in Fig. 1) immediately above the port *c*. Steam or other fluid will then enter and fill the space between gear F and piston G, filling the cavity or recess G′ of the latter, and being prevented by the gear F from passing downward it will press against the piston G and force it around in the direction of the hands of a clock. The meshing of gears E and F will cause the latter to turn in an opposite direction and to carry the cavity or recess G′ downward to the left. After the piston has traveled a predetermined distance, advisably about one-fourth of a revolution, valve H closes port *b*, steam is cut off, and the further travel is effected by expansion of the steam or fluid and by momentum of the parts, a fly-wheel being used to give steadiness of motion, as usual.

As in my former engine, provision is made for utilizing the live steam contained in the cavity or recess G′, which, if merely discharged without utilization, would entail a serious loss or waste. A channel or passage K is formed in any convenient manner, either by piping or, preferably, by casting or cutting in the end wall or in both end walls of the cylinder A.

Near the point of intersection of the inner circles or walls of cylinder A and supplemental chamber B is located an exhaust-port *f*, through which steam escapes from behind the piston. Under the present construction this port is located wholly within the limits of the cylinder A instead of partially therein and partially within the limits of supplemental chamber B. This enables me to maintain the wall of chamber B to the point of intersection of said circles, and consequently to carry recess or cavity G′ higher or farther before releasing the steam contained in it, and thus to expand said steam more nearly to the limit of its usefulness. It of course also permits the channel or passage K to be carried farther toward the exhaust-port than heretofore, and thus enables the steam to pass from the cavity to the cylinder A and to expand therein to a later point in the revolution of the piston than under the former construction.

Exhaust-port *f* opens into a valve shell or casing formed in the cylinder-casting and containing a tubular valve L, a port *g* in which registers with port *f* when the engine is running to the right, as in Fig. 1. By partially rotating the valve L port *f* may be closed, and this is done when the engine is reversed, the low-pressure cylinder alone then receiving steam or fluid. Tubular valve L extends through the high-pressure-cylinder casting, through the steam-chest casting, and through the low-pressure-cylinder casting and has one or more ports or passages communicating at proper times with each, as will be explained.

When the valve L is set, as in Fig. 1, with the exhaust-port *f* communicating with its interior, its port *h*, Figs. 5, 10, and 11, by which at another time it communicates with the live-steam space of steam-chest J, is closed. Steam or other pressure fluid exhausting from cylinder A will then pass by ports *f* and *g* into tubular valve or sleeve L and longitudinally through the same to a port in the low-pressure-cylinder casting and thence to a passage through which it is led into the low-pressure cylinder at a point corresponding with port *c* of the high-pressure cylinder A.

Passing now to Fig. 2, it will be observed that a construction of cylinder, piston, abutment, and valves is shown essentially like that of Fig. 1. Fig. 2, however, illustrates the low-pressure cylinder and its parts, and there are certain peculiarities of construction which distinguish it from the high-pressure cylinder, as will now be pointed out. M indicates the low-pressure cylinder, advisably

of the same diameter as the high-pressure cylinder A and having a supplemental chamber or enlargement N at one side corresponding to chamber B of the high-pressure cylinder. Shafts C and D extend through cylinder M and chamber N and are respectively provided with toothed gears O and P, precisely like the gears E and F of the high-pressure side, except that gears O and P are of greater measurement in the direction of the axes of their shafts. Gear O carries a piston Q, and gear P is formed with a recess or cavity Q′ to receive or to permit the passage of said piston. Valve L extends, as before mentioned, through steam-chest J and through the low-pressure-cylinder casting below the cylinder proper, and the same is true of valve I, except that it is located at a higher point. In line with exhaust-port *f* of the high-pressure cylinder A are two ports *i* and *j*, Figs. 5, 6, 7, 10, and 11, the first or innermost of which lying nearest the steam-chest serves as an induction-port when the engine is reversed or turning in a left-hand direction and the other of which serves as an exhaust-port normally or when the engine is turning in a right-hand direction. The low-pressure-cylinder casting is provided with a vertical wall or partition S, Figs. 9, 10, and 11, set somewhat nearer to the steam-chest than to the opposite wall or head of the cylinder. Cast or otherwise formed within the low-pressure-cylinder casting is a valve shell or casing R, through the top of which are formed the ports *i* and *j*, already mentioned, and which also contains a port *k*, ports *i* and *k* being on the steam-chest side of partition S and port *j* on the opposite side thereof. Lastly, the valve shell or casing R is formed with an opening or port *m*, Fig. 4, at the rear side of the shell R, whereas ports *i* and *j* are shown at the upper side and port *k* at the forward or left side as the parts are seen in Fig. 2. Valve L is furnished within the axial measurement of cylinder M with three ports *o*, *p*, and *q*, of which *o* is on the steam-chest side of wall S and *p* and *q* are on the opposite side of said wall, a transverse partition *r* being also formed within valve L to separate port *o* from ports *p* and *q*.

Assuming that the parts are set as in Fig. 2, exhaust-steam or other fluid having entered valve L from high-pressure cylinder A through ports *f* and *g* will pass longitudinally within said valve L, and consequently through steam chest or chamber J, until it reaches the port *o*, which at such time registers with the port *k* on the steam-chest side of wall or partition S, being prevented by the cross wall or partition *r* of valve L from passing farther in the direction of the length of said valve. The steam or other fluid thus passing through ports *o k* enters a chamber *n*, partially surrounding the chamber N of low-pressure-cylinder casting M, and passing upward through said channel or passage *n* enters by ports *s t* into the interior of valve I, which latter contains a partition *u*, separating the high and low pressure sections of valve I from each other. Valve I contains, in addition to the port *t*, a port *v* in the same vertical plane, but at a different angular position therein. The port *v* is so located as to register with an inlet-port *w* in line with and corresponding to the inlet-port *c* of the high-pressure cylinder. Hence steam passing through channel or passage *n* will go by way of ports *s t v w* into the low-pressure cylinder at the same point relatively thereto as does the live steam in entering the high-pressure cylinder. Acting upon the piston Q, this steam expanding within the low-pressure cylinder will carry said piston around to the right until its outer extremity passes the wall of port *j*, whereupon the steam will exhaust through said port *j* and the then-registering port *p* of valve L into the interior of said valve and by ports *q* and *m* into the open base of the low-pressure-cylinder casting M, whence it will escape by the exhaust-pipe opening therefrom.

It will thus be seen that with the valves set as in Figs. 1 and 2 steam will enter the high-pressure cylinder through the port *c*, move the piston G around to the right, escape through ports *f g*, and travel by passage *n*, ports *s*, *t*, *v*, and *w* into the low-pressure cylinder, move the piston Q therein, and finally escape by ports *j p*, valve L, and ports *q m* to the exhaust pipe or outlet, both pistons moving in the same direction and of course at the same speed, since they are upon the same common shaft. Steam will thus act with or without expansion in the high-pressure cylinder, according to the setting of the valve H, preferably expanding from about a quarter or a third stroke, and will thereafter pass to and operate expansively within the low-pressure cylinder until it finally escapes therefrom.

Figs. 10 and 11 illustrate the setting of the valve L for forward and backward rotation, respectively.

If now it be desired to reverse the engine, the valve L is set to the position indicated in Figs. 4, 5, 7, and 11. In these figures valve I is set to take the ports *t* and *v* of valve I out of register with the ports *s* and *w*, so that there shall be no communication between the interior of cylinder M and the chamber or passage *n* on the steam-chest side of partition or wall S, this adjustment, however, opening communication by ports *s′*, *t′*, *v′*, and *w′* on the opposite side of partition S and separated from the ports *s t u v* by a partition *x*, Figs. 4, 12, and 13, in the valve I, so that steam may escape from cylinder M by the ports *s′ t′ v′ w′* into the open space *n*, partially encircling the chamber N outside of partition or wall S or on the side farthest from the steam-chest J. Valve L is at such time set so as to bring port *o* into register with port *i* and to close port *k*, as shown in Fig. 5. It also at such time brings the port *h* of valve L within

the steam-chest J into register with a port *y*, formed in the shell or casing surrounding said valve within the steam-chest, as shown in Figs. 5 and 11. Port *y* is controlled by an oscillating or throttling valve T, similar to the valve H and operable by the same cam or eccentric which controls said valve H or by separate cams or eccentrics, as shown in Fig. 14. When the ports *o i* and the ports *h y* are made to register, ports *p q* are thrown out of register with ports *j m*, as in Fig. 7, so that there can be no escape of steam from the low-pressure cylinder by port *j*. Steam therefore enters cylinder M by way of ports *y h*, valve L, ports *o i* and moving the piston Q around to the left escapes by ports *w' v'*, valve I, ports *t' s'* and passes to the open base of the casting of low-pressure cylinder M, whence it escapes by the usual outlet, port, or pipe.

In Fig. 14 I have shown in side elevation the fly-wheel governor and connections whereby the valves I and L are actuated merely for the sake of illustrating a complete engine. It is to be understood, however, that the form and arrangement of the governor, the type of valves, and like matters are variable at will and that the invention is in no sense restricted thereto. The cylinders, steam-chest, and heads will be bolted together or united in any convenient manner. The space in the high-pressure-cylinder casting surrounding or partially surrounding the chamber B will be filled in with asbestos or other non-conductor, and in practice a packing of asbestos, magnesia, or other non-conductor will be placed in and fill the spaces between the flanges or heads on the outside of the castings, a sheet of asbestos fiber and a casing of sheet metal being employed to retain all in place. The purpose of this arrangement is to prevent radiation of heat or cooling of the engine and condensation of the steam therein.

In practice the pistons G and Q will be so set that the low-pressure cylinder will begin to take steam at the time that the high-pressure cylinder begins to exhaust and that each piston at the moment of beginning to receive the steam-pressure shall be immediately above the inlet-port when turning to the right or in the normal direction. It is obvious also that the steam or other fluid may be led progressively to and through a series of cylinders and expanded to any extent desired and of which it is capable. This being a mere duplication or multiplication of parts already shown and involving no additional mechanism, it need not be described in further detail.

It will be observed upon reference to Figs. 9 and 11 that the wall or partition S is placed nearer the steam-chest side of cylinder M than the opposite side, this being done for the purpose of giving a larger passage and a free exhaust for the steam, which by reason of its expansion requires more space for its free escape from than for its passage to the low-pressure cylinder.

In order to afford a free exhaust or to give proper clearance for the steam of the high-pressure cylinder, I make a channel or depression *z* in the inner wall of said cylinder at the lower side thereof and from a point somewhat to one side of the exhaust-port *f* to said port. This depression permits the steam to escape past the outer extremity of the piston G before said piston reaches the exhaust-port and to escape through said port during the travel of the piston through the length of said cavity or depression and across the port *f*. As all of the steam escaping through the port *f* passes to the low-pressure cylinder and is expanded and utilized therein, it will be seen that the slightly earlier exhaust thus effected does not lessen the utilization of the steam or other pressure fluid, whereas the freer exhaust incident to this clearance prevents the cushioning and back pressure which otherwise would obtain in greater or less degree.

Having thus described my invention, what I claim is—

1. In a rotary steam-engine, the combination of a high-pressure cylinder adapted to receive live steam; a low-pressure cylinder adapted to receive the exhaust-steam from the high-pressure cylinder; an intermediate steam chest or chamber; and a conduit connecting the high and low pressure cylinders and passing through the steam chest or chamber, whereby the exhaust-steam is subjected to the heat of the live steam on its passage from one to the other cylinder.

2. A compound rotary engine comprising a plurality of cylinders in axial alinement; a plurality of chambers likewise in axial alinement, each of circular form and having the circle of its inner wall arranged to cut that of the cylinder with which it is formed; a shaft passing axially through the cylinders; a second shaft parallel with the first passing axially through the supplemental chambers; gears carried by said shafts, one in each cylinder and one in each chamber and arranged to mesh in pairs; pistons carried one by each gear within the cylinders; a port for the admission of fluid to the first of said cylinders; an eduction-port for the exit of said fluid from said cylinder; a conduit or passage connecting the exhaust-port with an inlet-port of a succeeding cylinder; an exhaust-port for such succeeding cylinder; and a valve adapted alternately to admit and to cut off steam from the inlet-port of the first cylinder of the series.

3. In a compound rotary engine, the combination of a high-pressure cylinder; a low-pressure cylinder; and an intermediate steam-chest having walls in common and coextensive with the adjacent cylinders, whereby the live steam within the chest is caused to maintain a relatively high temperature in the high and low pressure cylinders.

4. In combination with high-pressure cylinder A and chamber B in communication therewith, shafts C, D, provided with gears E, F, the former carrying a piston G; steam chest or chamber J; a cut-off valve H serving to open and close an induction-port between the steam-chest and the cylinder A; a reversing-valve I interposed between the cut-off valve H and the cylinder A, said valve I being provided with ports *d* and *e* within the casting of cylinder A adapted to register with ports *b* and *c* thereof and further provided with ports *t* and *v* and *t'* and *v'*; a low-pressure-cylinder casting M provided with ports *s*, *s'*, *w*, *w'* with which under different adjustments the ports *t* and *v* and the ports *t'*, *v'* may be made to register alternately; shafts C and D extending axially through the cylinders and the supplemental chambers A and M and B and N; gears E, F within the chamber A, gear E being provided with a piston G and gear F with a recess G'; gears O and P carried by the shafts C and D within the cylinder M and chamber N, gear O being provided with piston Q and gear P with recess or cavity Q'; valve L provided with ports *o*, *p*, *q* adapted to register under different adjustments with ports *i*, *j*, *k* and *m* in a casing surrounding the valve; a partition S separating the low-pressure-cylinder casting into two spaces or chambers outside of the cylinder and its supplemental chamber; inlet-ports *h* and *y* affording communication from the interior of the steam-chest to the interior of the valve L under a certain adjustment of the valve; and a valve T controlling the port *y*, all substantially as set forth.

5. In combination with cylinder A, provided with an inlet-port *c* and an outlet-port *f*; a rotary member E contained within the cylinder A and provided with a revolving piston G; a rotary abutment adapted to coöperate with the rotary member E and piston G; a second cylinder M provided with a rotary member O, having piston Q and coacting rotary abutment P; a tubular valve controlling the exhaust-port *f* of the first cylinder and extending thence to a steam-passage of the second cylinder; and an inlet-port for said second cylinder communicating with said valve through the intermediate steam-passage, all substantially as shown and described.

6. In a rotary engine, the combination of a cylinder A and supplemental chamber B, the former provided with a channel or depression *z*; an inlet-port *c*; an exhaust-port *f*; rotary gears E, F arranged within the cylinder A and chamber B and concentric with said chambers, the gear E being provided with a piston G and the gear F formed with a recess G'; and means for admitting steam to and cutting off the steam-supply of cylinder A.

7. In a compound rotary engine, the combination of cylinders A and M and intermediate steam-chest J; gears E, F and O, P arranged within the respective cylinders and their supplemental chambers, and provided respectively with pistons G and Q and cavities G' and Q'; reversing-valves I and L; and cut-off valves H and T adapted to control the several induction and eduction ports, substantially as described and shown.

8. In a rotary compound engine, a low-pressure cylinder provided with induction and eduction ports; and a valve controlling said ports and adapted when set in one position to admit steam into the cylinder from the high-pressure cylinder and when adjusted to another position to cut off communication with the high-pressure cylinder and to open communication with the steam chest or supply, and thereby to admit live steam to the low-pressure cylinder to reverse its action.

In testimony whereof I have signed my name to this specification in the presence of two subscribing witnesses.

JOHN L. McMILLAN.

Witnesses:
JOHN W. EDDY,
E. I. MORAN.