G. H. HARDY.
ROTARY ENGINE.
APPLICATION FILED MAR. 20, 1909.

959,856.

Patented May 31, 1910.

3 SHEETS—SHEET 1.

Fig. 1.

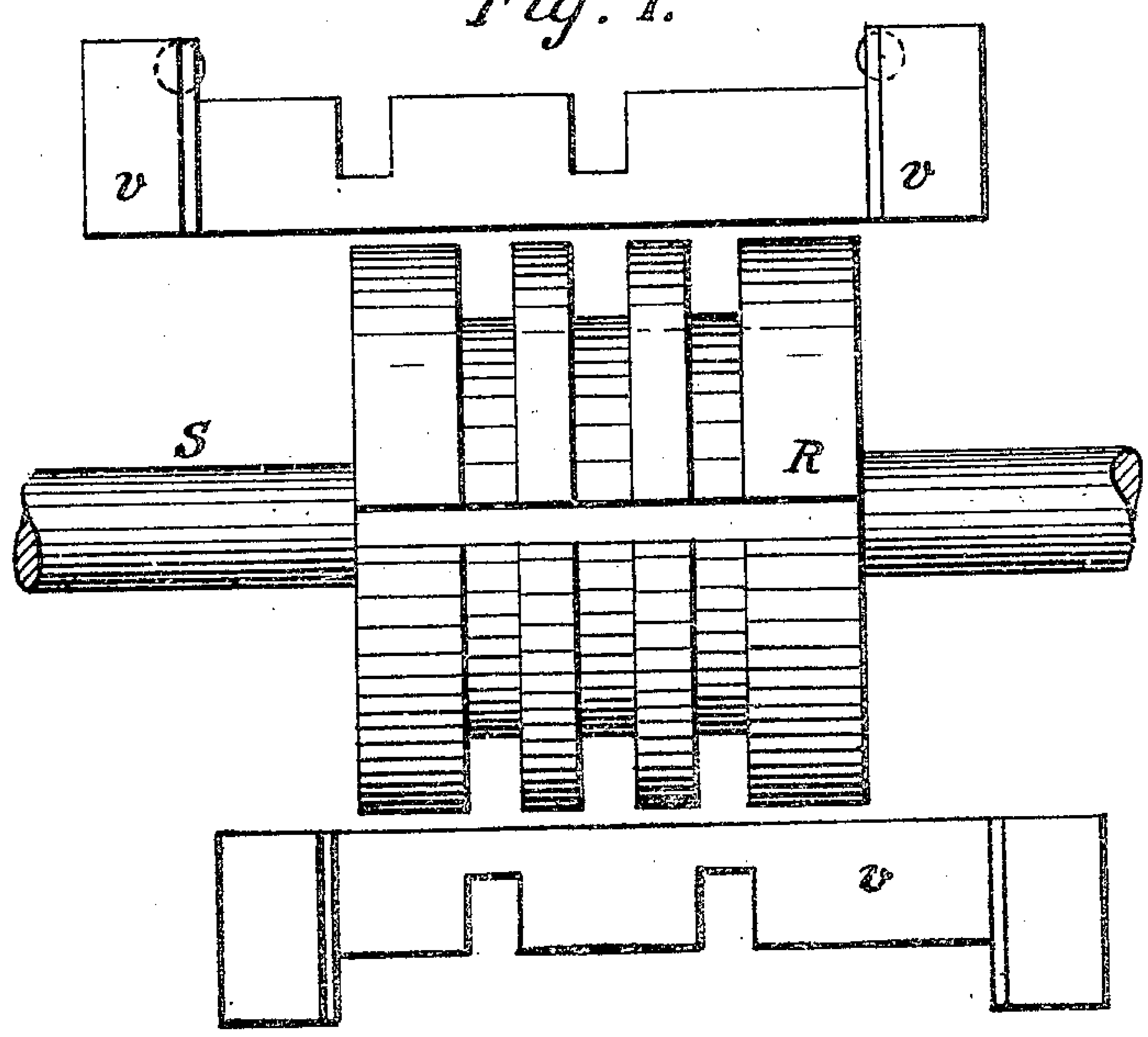
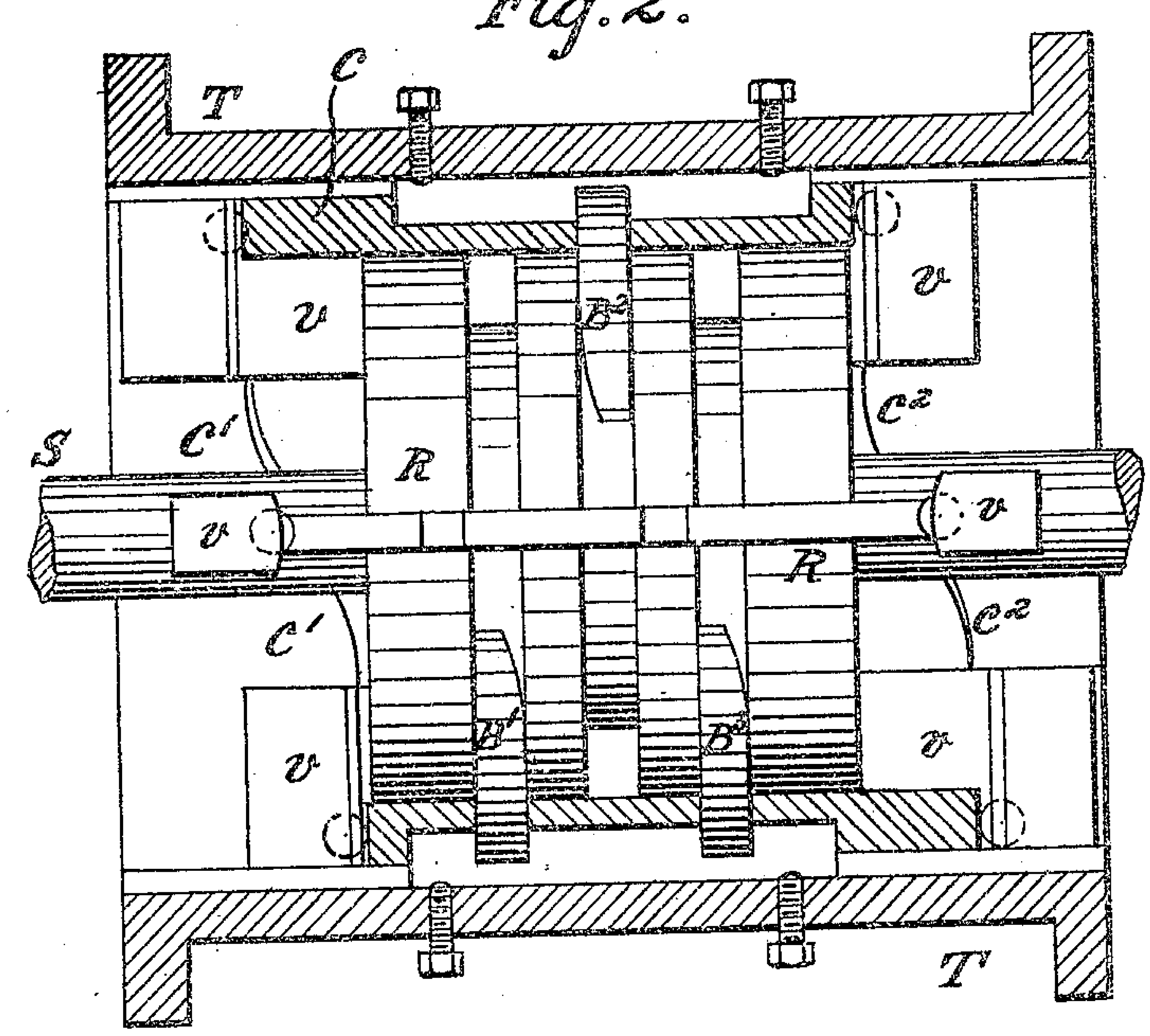


Fig. 2.



Witnesses.
Marie F. Wainwright
J. A. Fischer

Inventor:
G. H. Hardy
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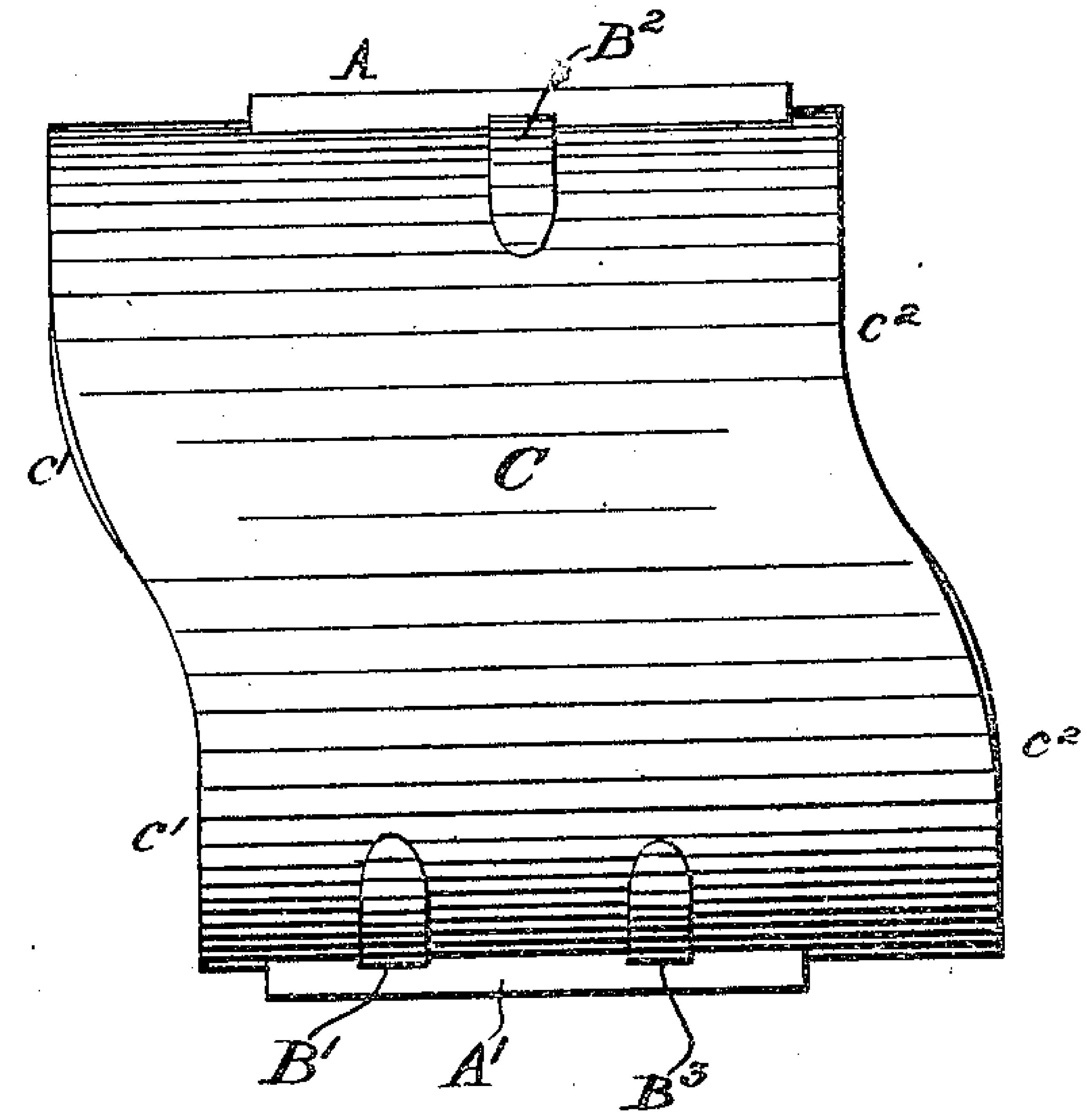
3 SHEETS—SHEET 2.

Fig. 3.



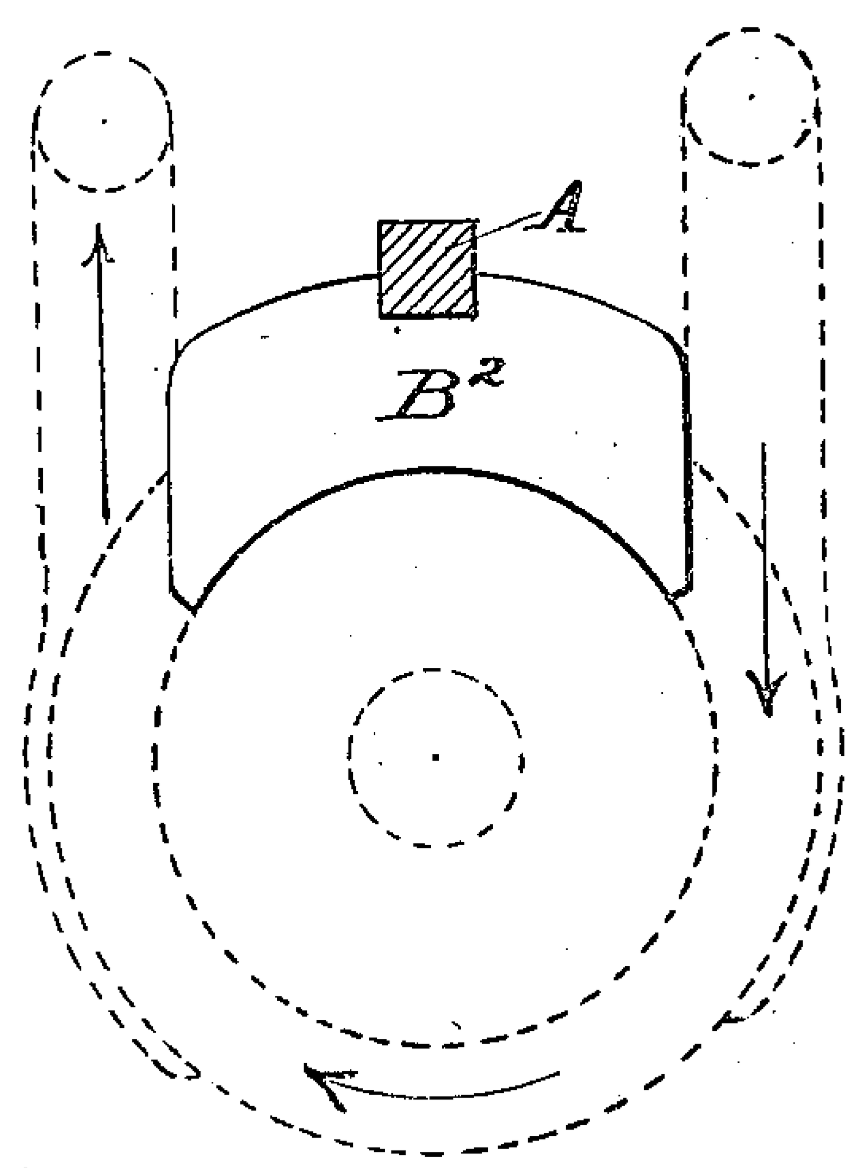


Fig. 4.

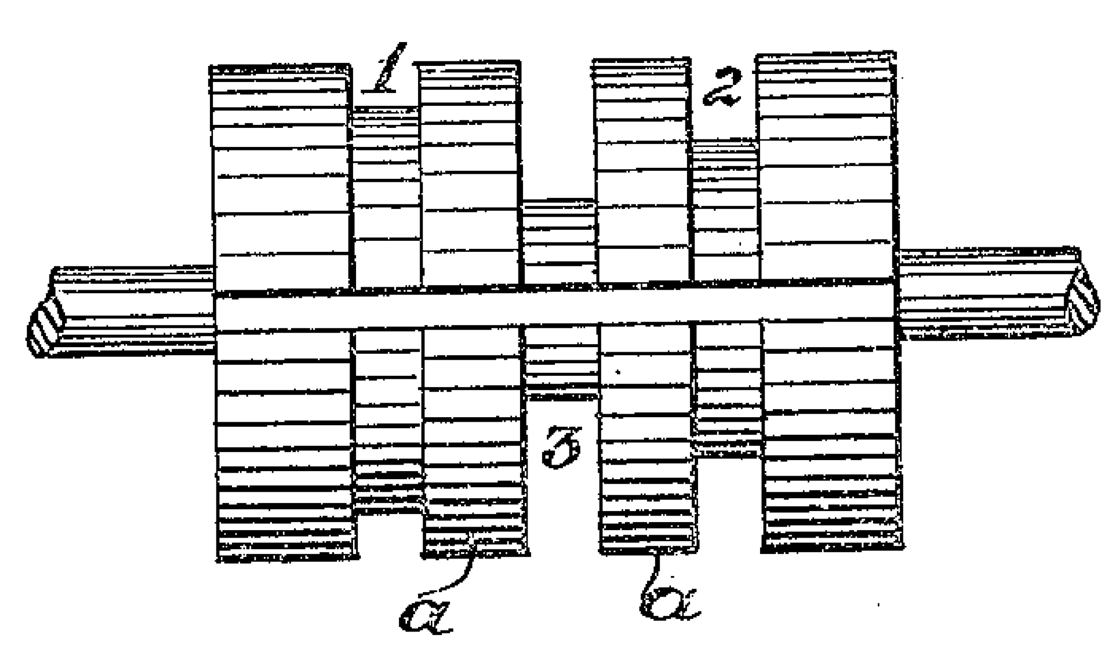


Fig. 5.

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3 SHEETS—SHEET 3.

Fig. 6.

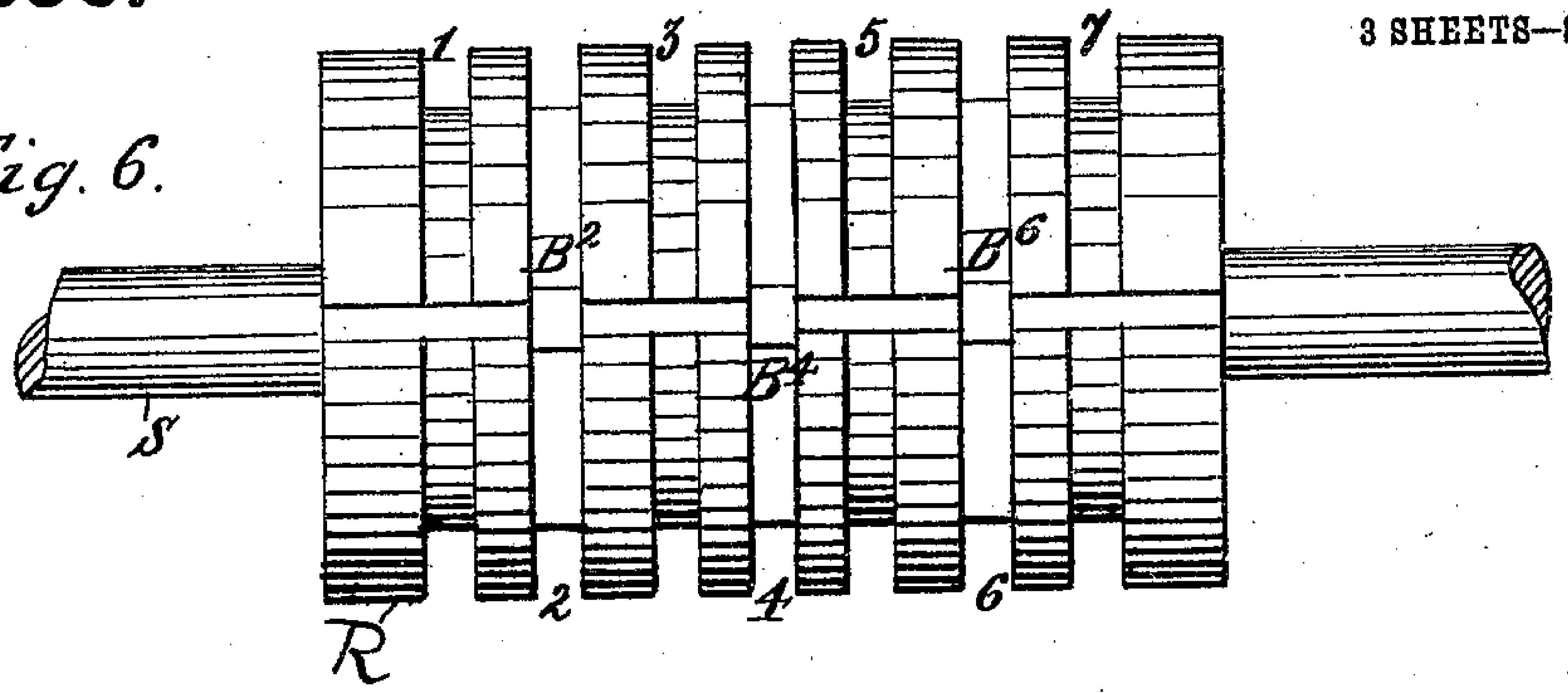


Fig. 7.

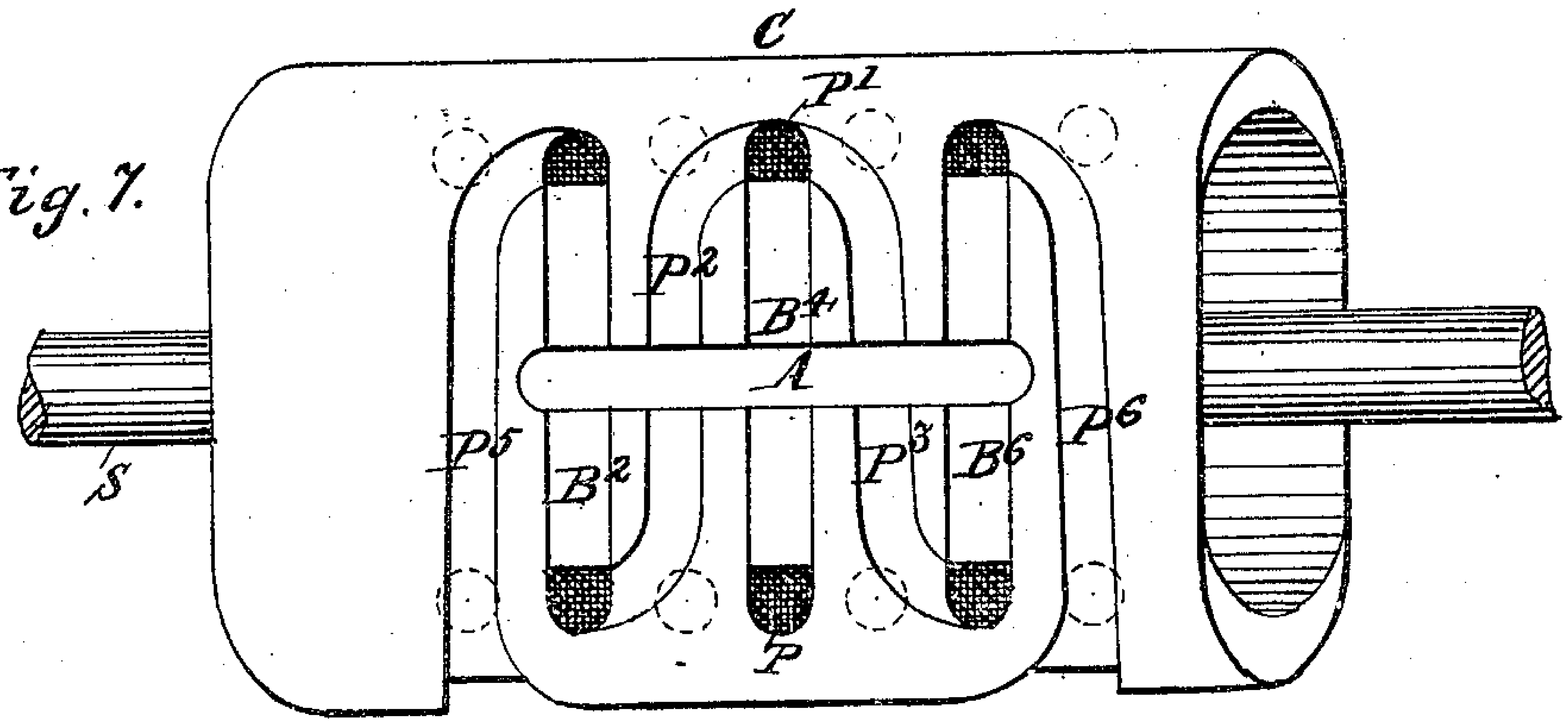
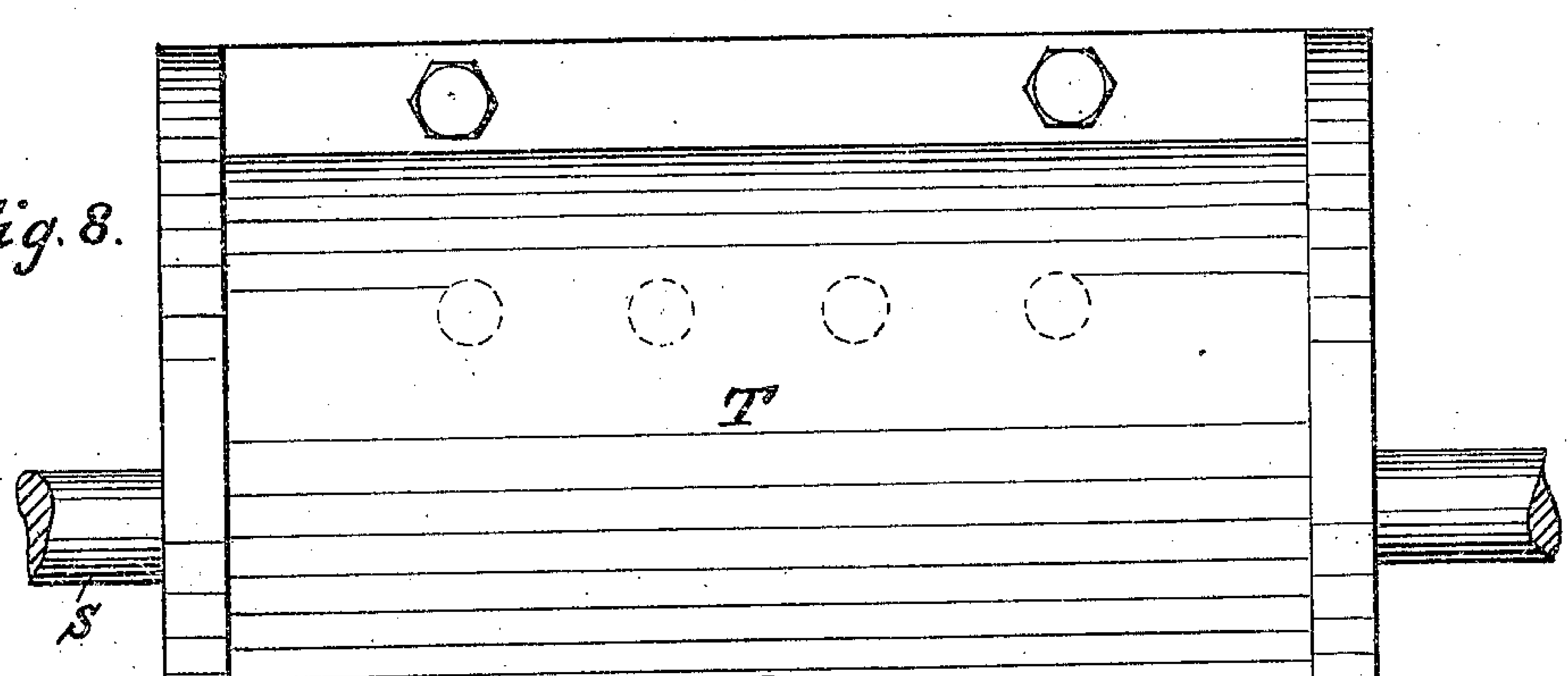


Fig. 8.



Witnesses:
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Inventor. G H Hardy
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UNITED STATES PATENT OFFICE.

GEORGE HURLSTONE HARDY, OF TWICKENHAM, ENGLAND.

ROTARY ENGINE.

959,856. Specification of Letters Patent. **Patented May 31, 1910.**

Application filed March 20, 1909. Serial No. 484,841.

To all whom it may concern:

Be it known that I, George Hurlstone Hardy, engineer, a subject of the King of Great Britain, residing at Twickenham, in the county of Middlesex, England, have invented certain new and useful Improvements in and Relating to Rotary Engines, of which the following is a specification.

This improved form of engine possesses two principal members of which one termed the "rotor" is a drum-like body possessing three (or more) adjacent parallel-sided annular chambers separated from each other by uniform substantial disk-like partitions; thus the rotor has a number of annular channels side by side at regulated intervals along its periphery. This rotor carries four (or more) sets of vanes which slide longitudinally (that is to say, across the disk-like partitions and annular channels) in deep narrow grooves which are radial to the axis of rotation.

Each annular channel has in one quarter a fixed abutment, but these abutments are so disposed that every abutment (obstructing the continuity of a chamber) is diagonally opposite the abutment in an adjacent chamber. The inlet and outlet ports of the chambers are valveless peripheral openings immediately before and behind the abutments.

The second principal member is termed the "stator" which comprises all the fixed parts and includes the cylindrical case which encompasses the rotor and which holds the above mentioned abutments in their fixed stations. It is a special feature of the cylindrical part of the stator that it has external cam inclines upon its extremities adapted to reciprocate the sliding vanes while they are being carried around in the rotor. These inclines are sinusoidal curves acting as face-cams, drawing the sets of vanes to-and-fro with smooth harmonic motions. The sinusoidal curves are spaced on alternate quadrants (a little more or less), and are separated by alternate flat quadrants (a little more or less). It is essential that the curvature of the inclines should be absolutely sinusoidal transmitting to the set of vanes during their reciprocated movements the exact ratio of acceleration and retardation (alternating backward and forward from zero to a maximum and back again to zero) which is inherent in the swing of the pendulum and is mathematically defined as the "sine-curve" ratio expressed in the equation formula:

$$\frac{x^2}{b^2}+\frac{y^2}{c^2}=1$$

wherein b is half the major axis, while c is half the minor axis of an ellipse.

My improved construction is illustrated in the accompanying drawing, in which—

Figure 1 is a side elevation of the rotor and two of the sets of sliding vanes detached; Fig. 2 is a longitudinal section through the case of the engine; Fig. 3 is a side elevation of the internal cylinder; Fig. 4 is an end elevation of one of the abutments; Fig. 5 is a side elevation, on a reduced scale, of a rotor having a modified arrangement of the annular chambers to permit of working expansively or effecting compression. Fig. 6 is a side elevation of a rotor suitable for a rotary motive engine propelled by high pressure elastic fluid working by graduated expansion. Fig. 7 is a side elevation of the inner shell-like case which surrounds the rotor, and Fig. 8 is a side elevation of the external cylindrical case thereof.

The essential members of this apparatus comprise the rotor R, the shaft S, and the stator (partly in section) which is an encompassing cylindrical case T having an internal cylinder C holding three stationary abutments B^1, B^2, B^3. The rotor R is a drum-like body furnished with two, three, or more, adjacent annular channels which are the working chambers of which the continuity is interrupted by the interposed stationary abutments B^1, B^2, B^3. The rotor carries longitudinally sliding vanes v, v, v, v, which receive a reciprocating movement during rotation by the cam-like guiding action of their extended terminal parts, which press against curvature inclines c^1, c^1, c^2, c^2, on the flanks of the internal cylinder C.

It is to be observed that the sinusoidal cam actuation of this arrangement is preferably intermittent, and may with advantage be divided and applied in two diametrically opposite quadrants (or divisions slightly exceeding a quadrant).

The internal cylinder C, shown separately in Fig. 3, is furnished with two longitudinal grooves on its periphery across which are cross-slots in which the abutments B^1, B^2, B^3, are fixed. Abutment holding plates A, A, lie in the two grooves and across retaining notches in the tops of the abutments.

Every annular chamber may be considered to have four quarters, namely, an abutment holding quadrant, a working chamber quadrant, and two intermediate quadrants which are fluid circulating quadrants, one containing the inlet and one the outlet port. Throughout the rotor the disposition of the four quarters are arranged so that every working chamber quadrant and its abutment holding quadrant are diagonally opposite the similar working chamber quadrant and the abutment quadrant of any immediately adjacent chamber. Thus in Fig. 2 the abutments B^1 and B^3 are diagonally opposite the abutment B^2; in every chamber the inlet and outlet ports are diametrically opposite each other and tangential to the direction of the flow of the circulating fluid. The abutments may be for some uses of hard metal, but for other uses they may be of antifriction metal, or even of fusible metal such as may be cast in position.

The internal cylinder C is encompassed by one outer cylinder T which is made in two semi-cylinders bolted together; these semi-cylinders may have attachments holding them fixed to a bed plate, or they may have attached end cover plates connected to a bed plate, or the whole apparatus may be otherwise fixed in any ordinary way to a foundation, while suitable supports and an end thrust bearing may be furnished for the central shaft.

In the side view of abutment B^2 shown in Fig. 4 the engine working chamber, the two ports, and the situation of the inlet and outlet channels are shown in dotted lines, the pressure of the holding plate A upon the abutment B^2 can be effected by set screws.

The plan of having more than two working chambers on one rotor greatly economizes space and weight; the vanes are timed to work alternately in adjacent chambers in quadrants contiguous with adjacent abutments. The outlet of a central chamber may lead to the inlets of two flanking chambers for working as a motor by steam expansively. Conversely the outflow from two chambers may go to one central chamber for working as, say, an air compressor by stages. Otherwise the outflow from one chamber may be joined to the outflow of one or more chambers of the same rotor, or the outflow may be shunted by a suitable two-way cock or cocks and led twice or thrice around the rotor before being finally led away.

Fig. 5 (drawn to a smaller scale) illustrates a rotor furnished with three annular channels which provide three adjacent working chambers 1, 3, and 2, of graduated capacities; the longitudinal width of each chamber and of the intervening partitions *a*, *a*, is uniform throughout, but the depths of the chambers 1, 2, and 3 are to be in a graduated ratio of increase suitable for the circulation of, say, steam working expansively or (in the reverse direction) for air compression.

In the engine illustrated in Figs. 6 to 8 inclusive intended to work by graduated expansion or exhaustion the rotor R (Fig. 6) is provided with seven annular channels numbered consecutively, the abutments of channels 1, 3, 5 and 7, on the opposite side from that on which Fig. 6 is taken, being diagonally opposite the abutments B^2, B^4, B^6, of channels 2, 4, and 6. In Fig. 6 the vanes which slide in the longitudinal grooves as hereinbefore described are omitted.

The case C (Fig. 7), which encompasses the rotor, is provided with external sinusoidal cam-curves on each flank. A longitudinal groove holds the cross-piece A which fixes the abutments B^2, B^4, and B^6, extending into channels 2, 4 and 6. In front of abutment B^4 (as also at B^2 and B^6) is an inlet port P, while behind same is an outlet port P^1.

In working as an elastic fluid motor, say by high pressure steam (expanding by stages) the inflow through P into chamber 4 emerging from the outlet port P^1 is led by the bifurcating passages P^2, P^3, into the inlet ports of the two chambers 6 and 2; whence reëmerging from the latter it is led by passages bifurcating from the channels P^5 and P^6 to the inlet ports of the four chambers 1, 3, 5 and 7; these four inlet ports are indicated in broken lines being on the hidden side of the figure. After the third stage the steam, expanded to a low pressure, issues from the outlet ports of chambers 1, 3, 5 and 7, being led to exhaust or collected into one common channel and conducted to a condenser.

The external cylindrical case T (Fig. 8) is in two halves bolted together and encompasses cylindrical case C. Said case T is provided with inlet pipe O leading direct to inlet port P of chamber 4 (Fig. 7). On the opposite side of external cylindrical case T in line with outlet pipe O are the exhaust outlet pipes, which are shown in dotted lines.

Instead of internal passages connecting outlet to inlet ports of different chambers as above described and illustrated, all (or some) inlets and exits can be by pipe connections of which the pipes are led to the ports directly (or tangentially to the circuit of the rotor) through the inner and outer encompassing cylindrical cases; the separate inlet and outlet pipes will then be joined as required externally by junction pieces of any ordinary description.

What I claim as my invention, and desire to secure by Letters Patent, is—

1. A rotary engine having a rotor provided with a plurality of working chambers in the form of parallel-sided annular channels separated from each other by uniform disk-like partitions and having adjacent working chambers diagonally opposite each other, abutments of adjacent annular channels diagonally opposite each other, peripheral inlet and outlet ports for said chambers, sets of vane-like pistons reciprocative longitudinally in radial grooves across the rotor and having wing-like extremities, and a stator having external sinusoidal inclines against which said wing-like extremities bear.

2. A rotary engine having a rotor provided with a plurality of working chambers in the form of parallel-sided annular channels separated from each other by uniform disk-like partitions and having adjacent working chambers diagonally opposite each other, abutments of adjacent annular channels diagonally opposite each other, peripheral inlet and outlet ports for said chambers, sets of vane-like pistons reciprocative longitudinally in radial grooves across the rotor and having wing-like extremities, and a stator having external peripheral cams on the end faces of its cylindrical part with sinusoidal curved inclines intervening between flats on alternate quadrants.

3. A rotary engine having a rotor provided with a plurality of working chambers in the form of parallel-sided annular channels separated from each other by uniform disk-like partitions and having adjacent working chambers diagonally opposite each other, abutments of adjacent annular channels diagonally opposite each other, peripheral inlet and outlet ports for said chambers, sets of vane-like pistons reciprocative longitudinally in radial grooves across the rotor and having wing-like extremities, and a stator comprising a cylindrical case having cam-curves on its end faces, the wing-like extremities of said pistons bearing against said end faces of the stator.

4. A rotary engine having a rotor comprising a drum-like body provided with a plurality of adjacent annular groove-like chambers, a stator having fixed abutments entering said chambers, the abutment of one chamber being diagonally opposite the abutment of an adjacent chamber, intercommunicating passages to convey the outflow from one chamber to the inlet ports of other chambers.

5. A rotary engine having a rotor provided with a plurality of working chambers in the form of parallel-sided annular channels separated from each other by uniform disk-like partitions and having adjacent working chambers diagonally opposite each other, abutments of adjacent annular channels diagonally opposite each other, peripheral inlet and outlet ports for said chambers, sets of vane-like pistons reciprocative longitudinally in radial grooves across the rotor and having wing-like extremities, and a stator comprising a cylindrical case encompassing the rotor and formed in two parts, one part being an external case and the other an internal case which latter has cam-curves on its end faces, the abutments being securely held in position by the stator, said stator having inlet and outlet passages communicating with peripheral ports that communicate with the chambers in the rotor.

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

G. HURLSTONE HARDY.

Witnesses:

CHAS. A. ALLISON,

WM. MARKHAM.