No. 709,682. Patented Sept. 23, 1902.

L. ROEDEL.

ROTARY SLIDE VALVE FOR PUMPS, COMPRESSORS, OR MOTORS.

(Application filed Mar. 24, 1900. Renewed June 10, 1902.)

(No Model.) 9 Sheets—Sheet 1.

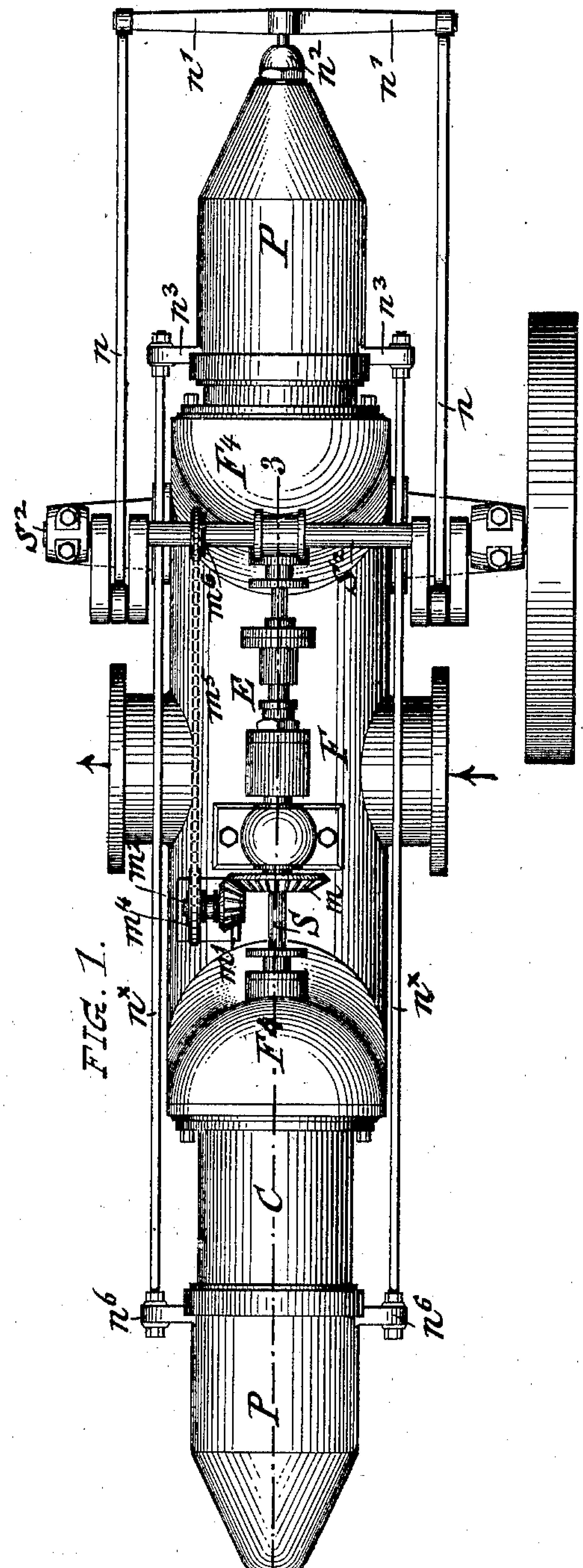

FIG. 1.

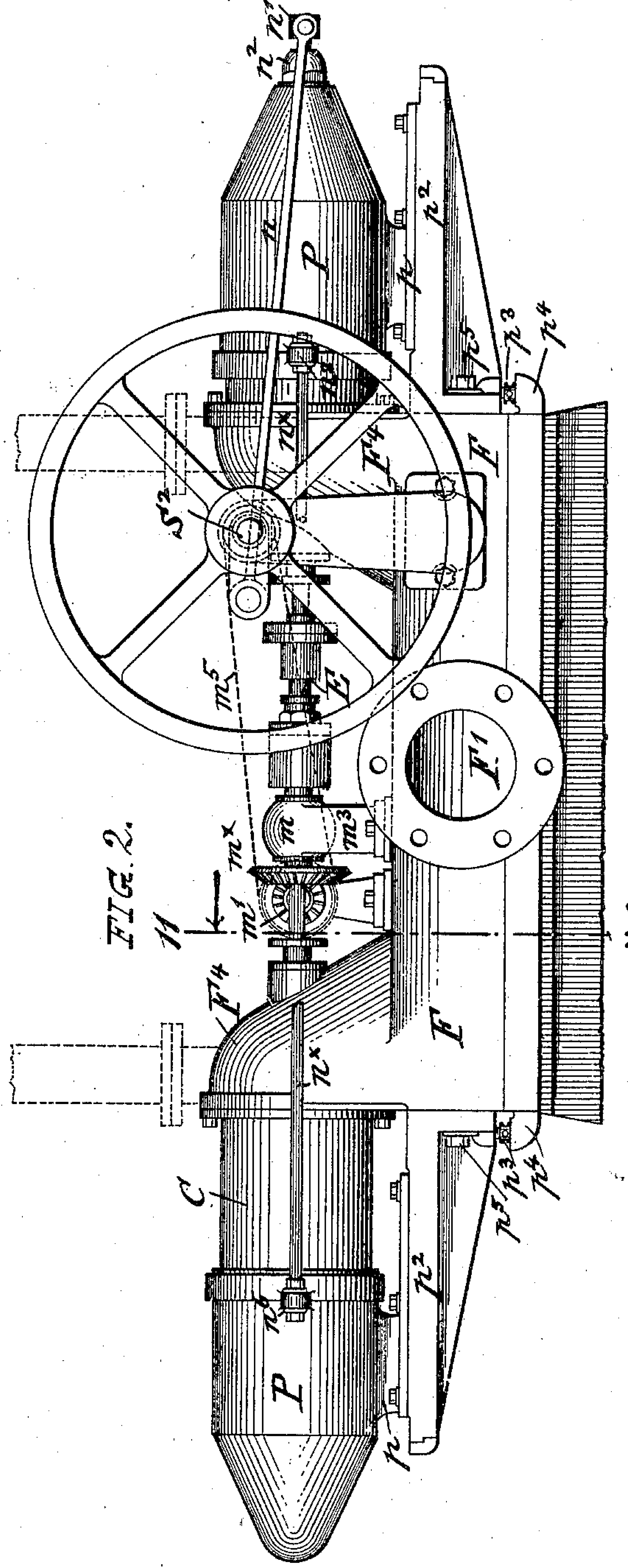

FIG. 2.

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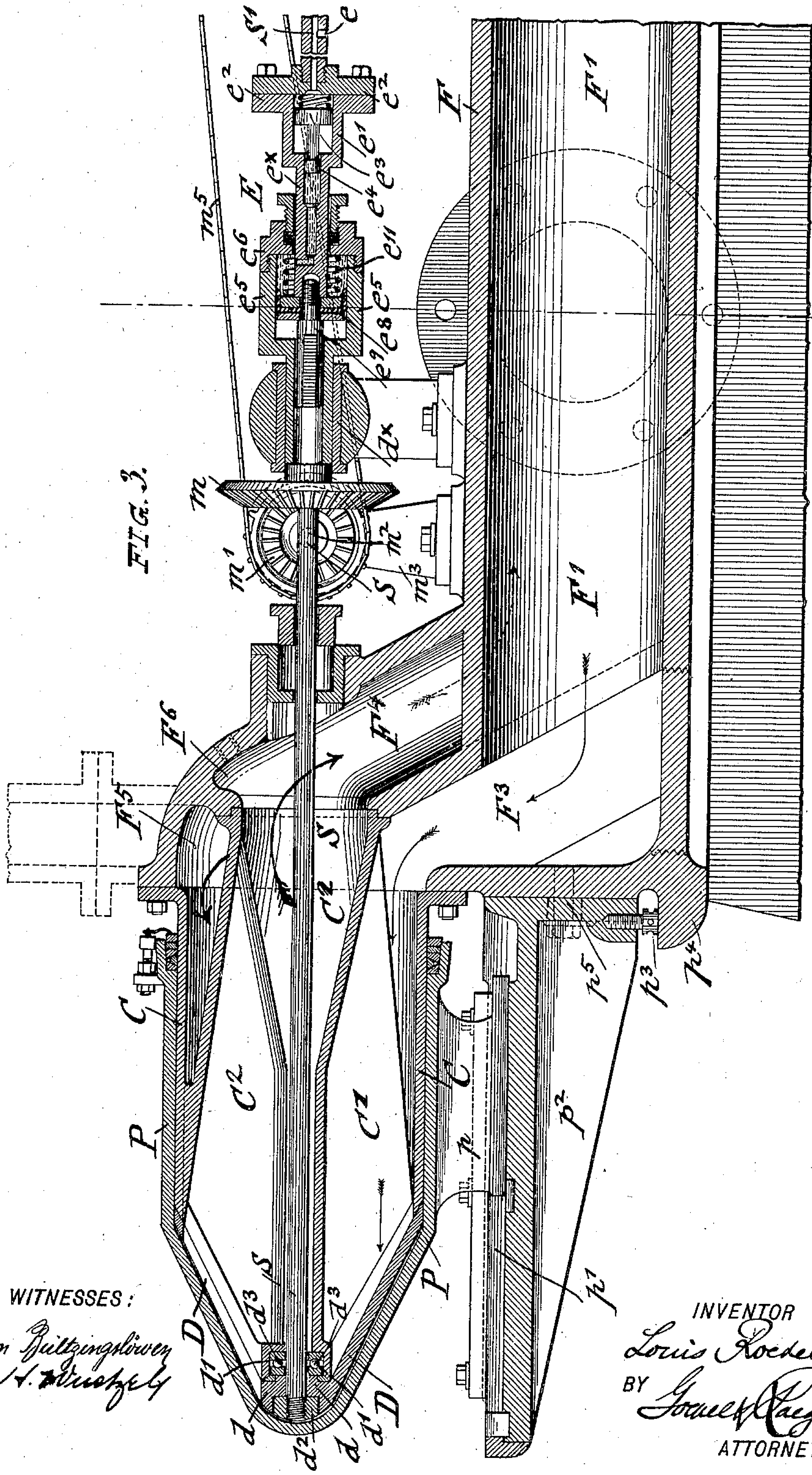

WITNESSES:

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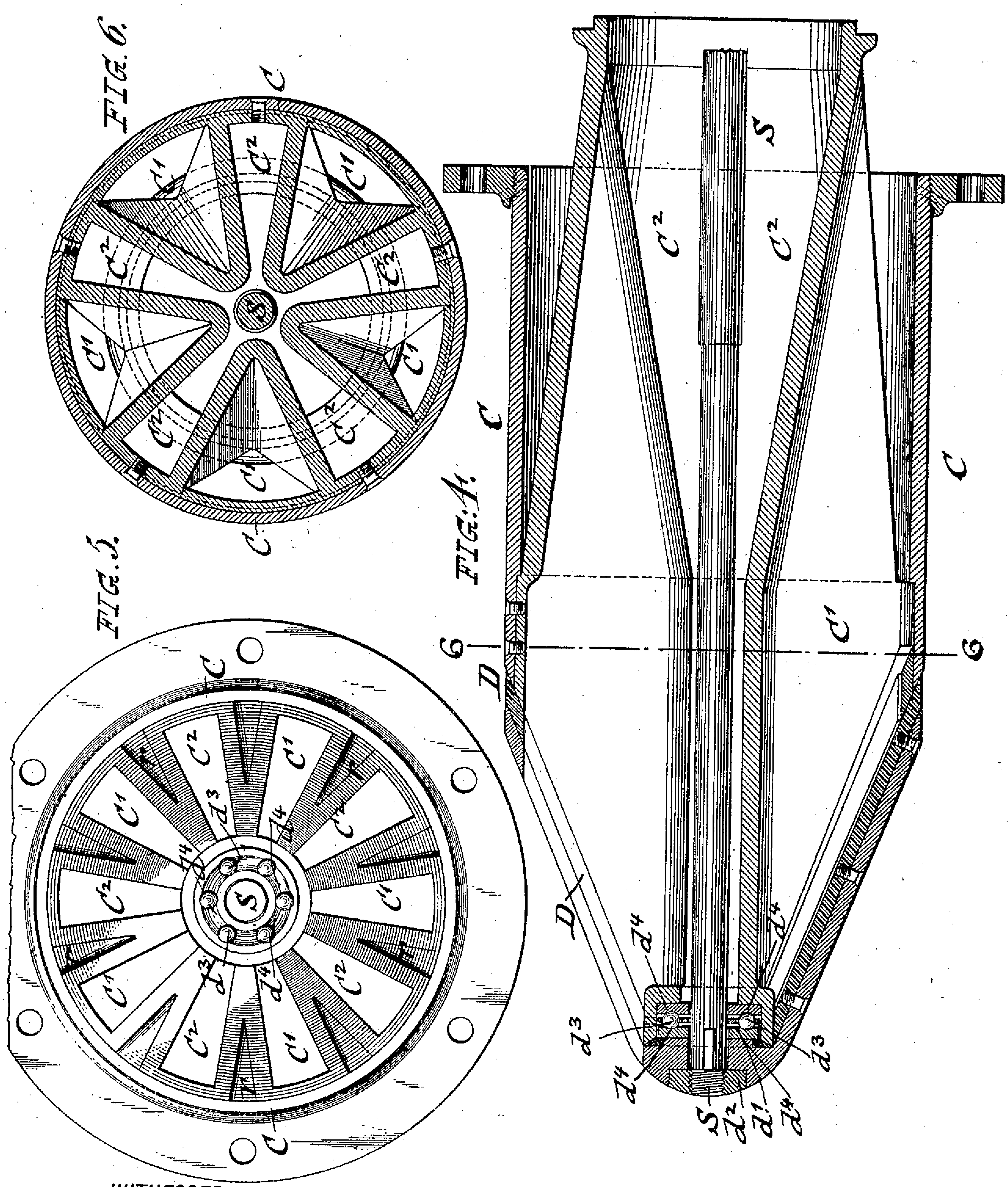

FIG. 6.

FIG. 5.

FIG. 4.

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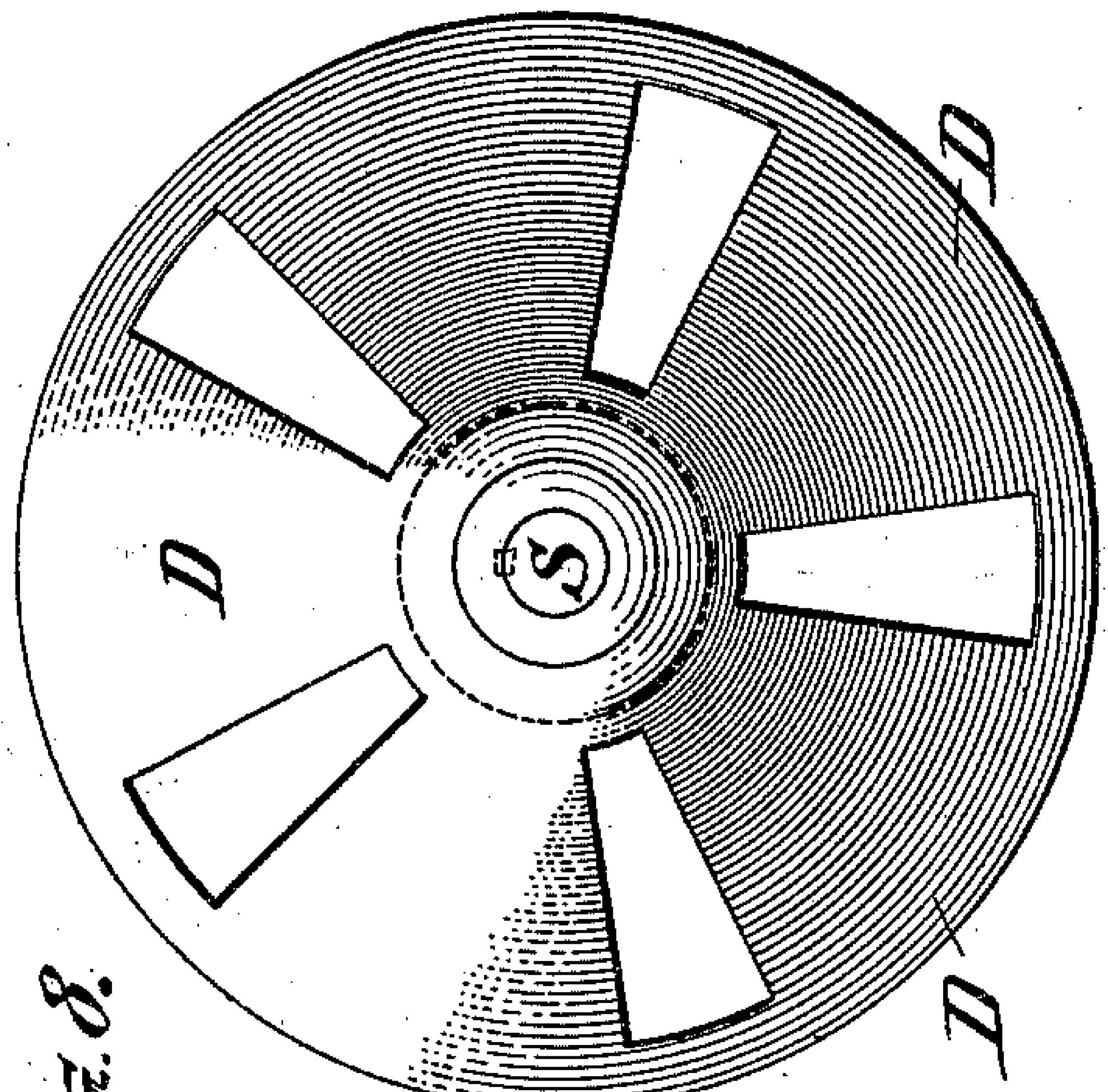

FIG. 8.

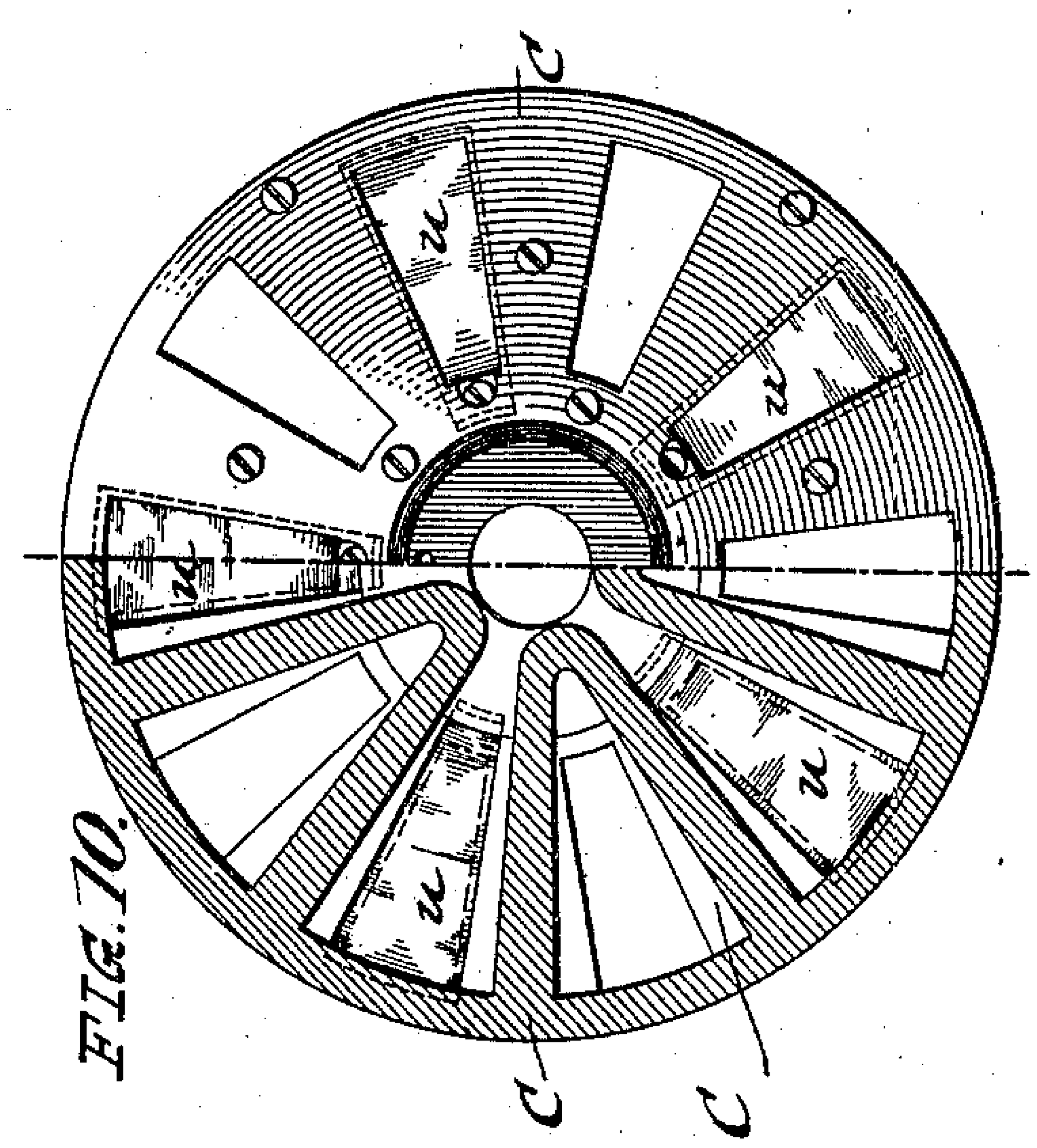

FIG. 10.

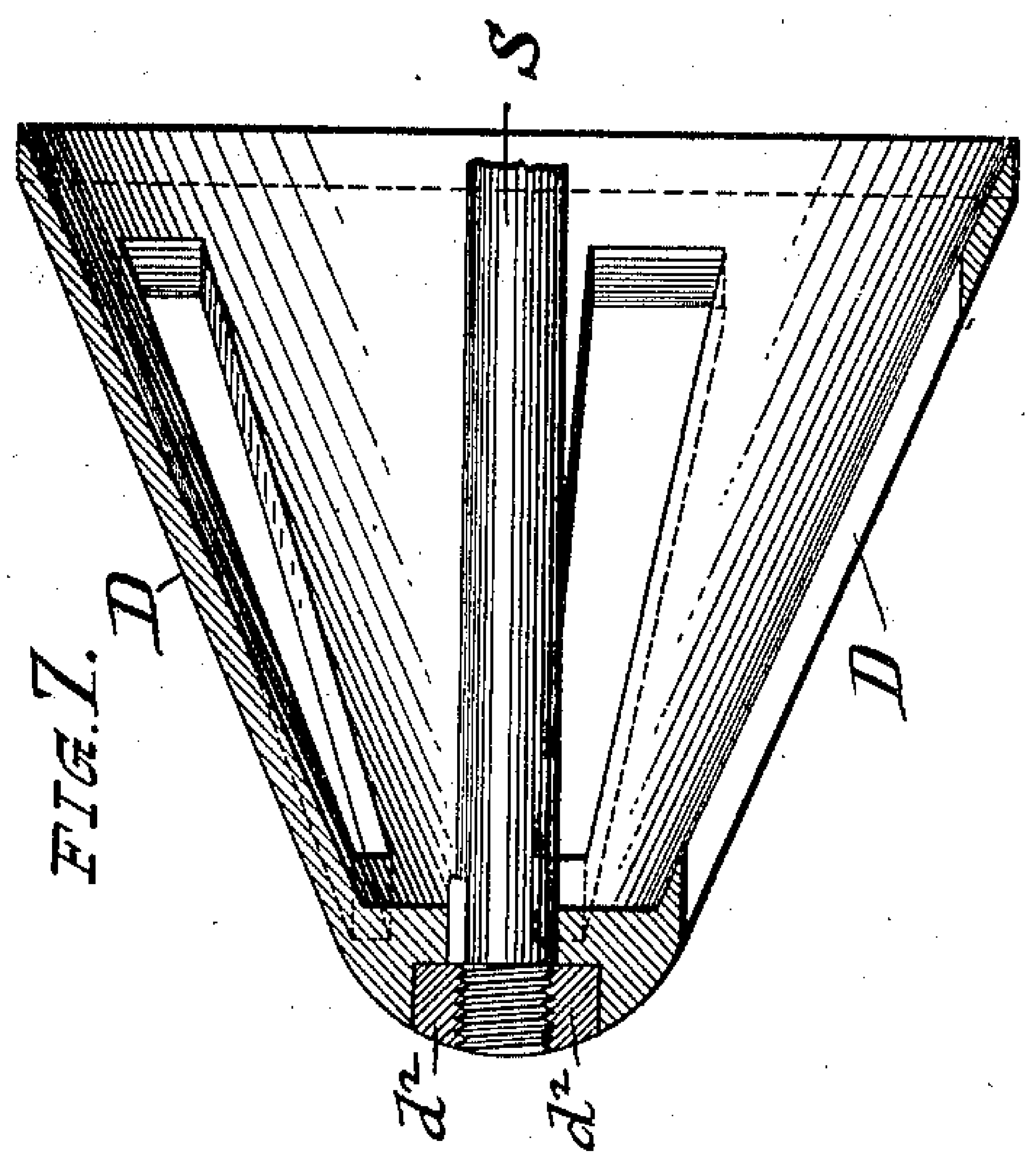

FIG. 7.

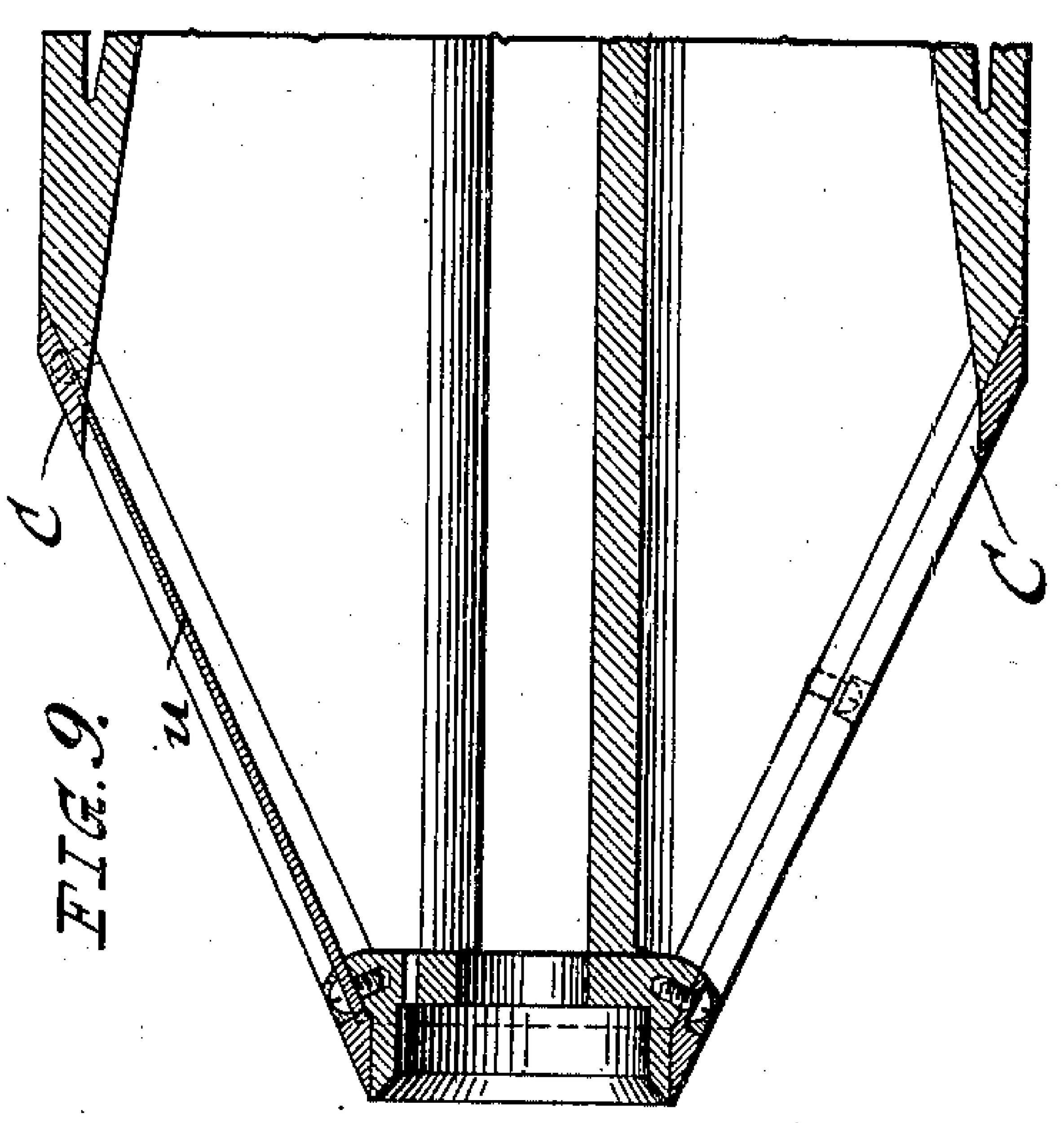

FIG. 9.

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9 Sheets—Sheet 5.

FIG. 13.

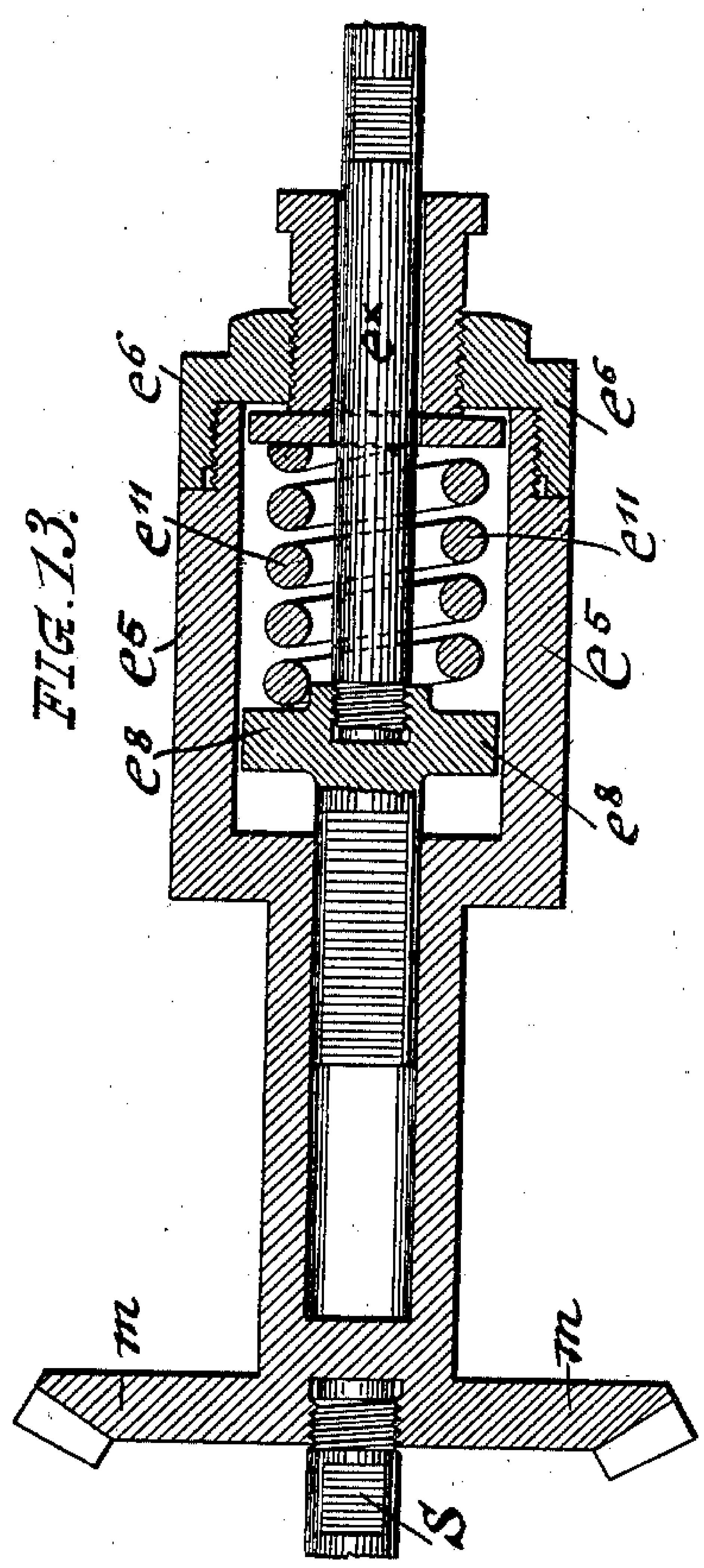

FIG. 12.

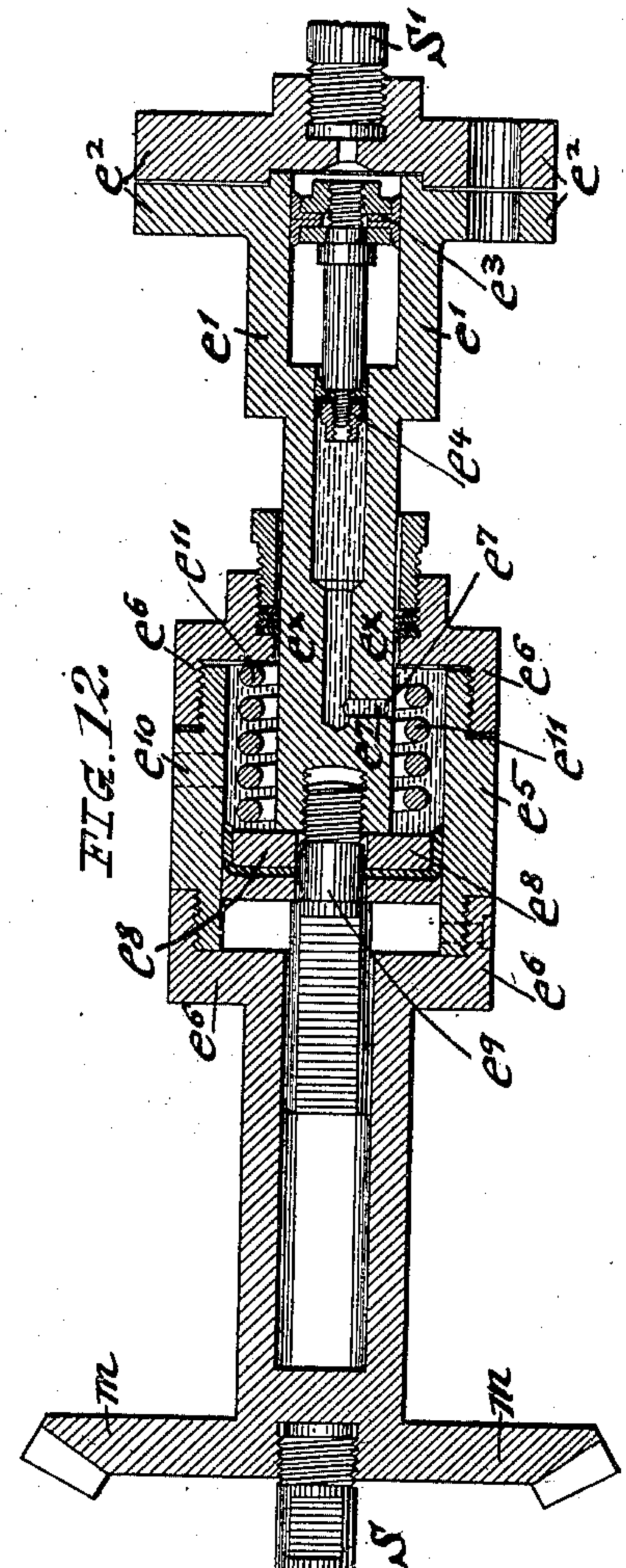

FIG. 11.

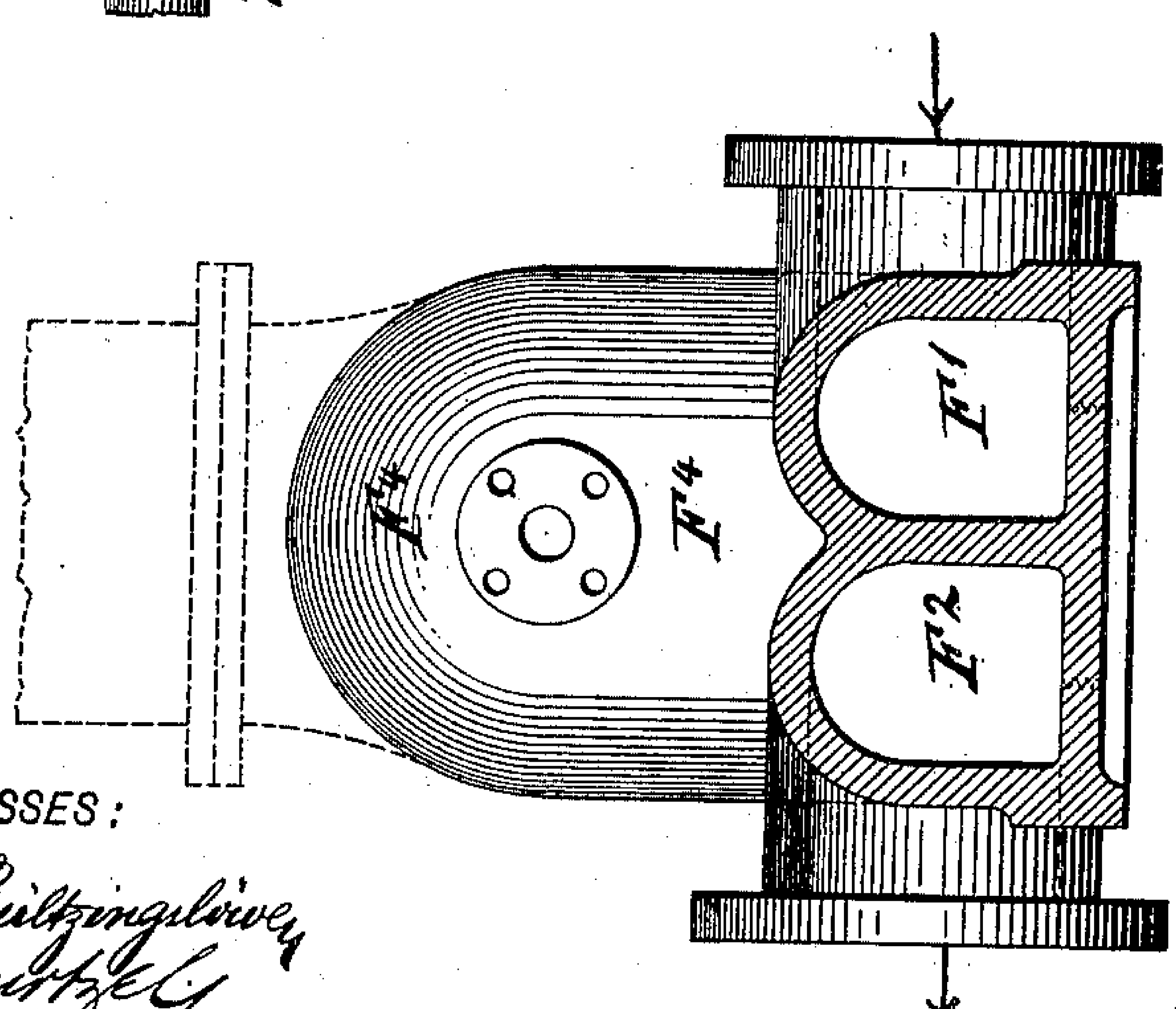

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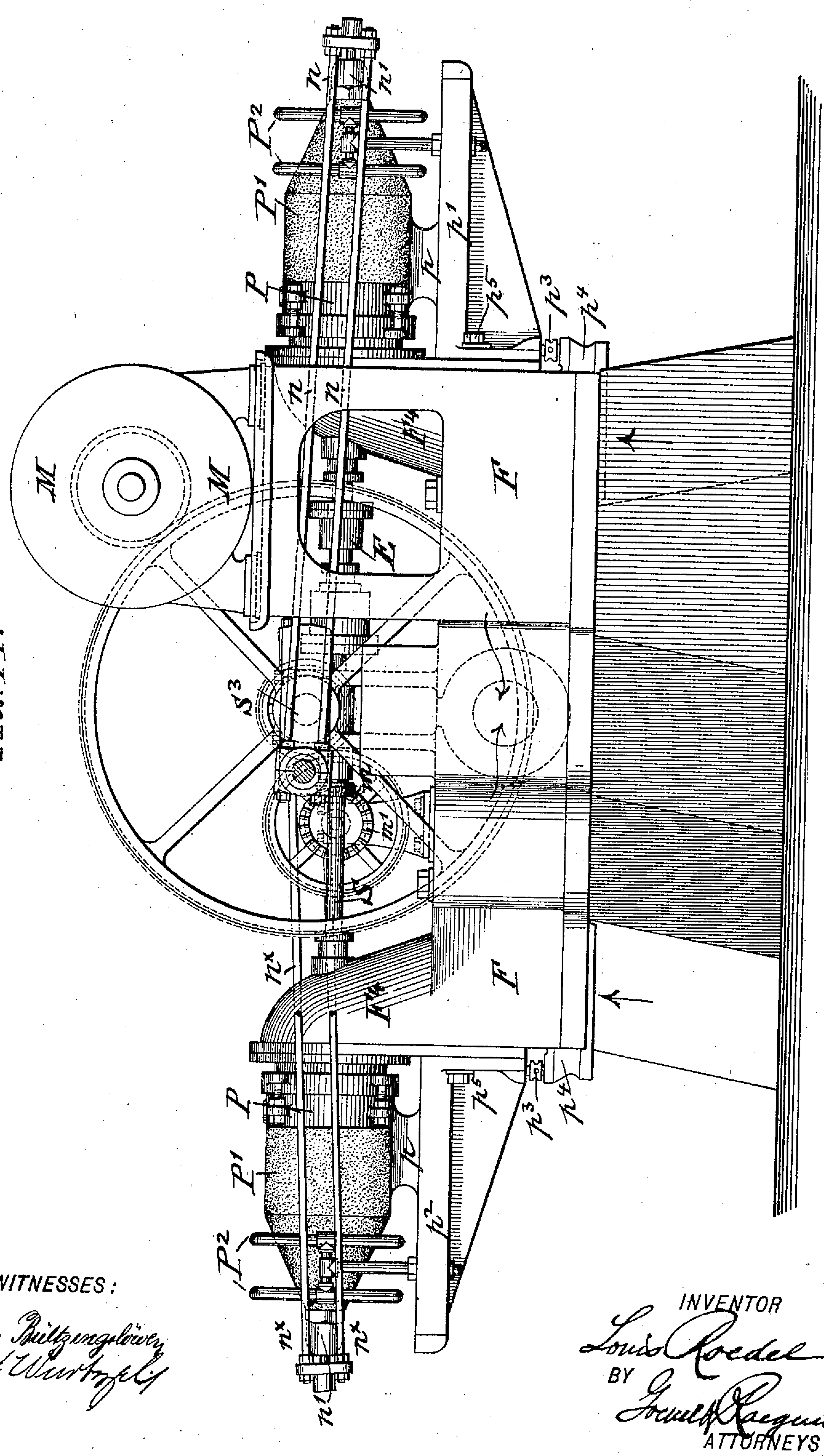
FIG. 14.



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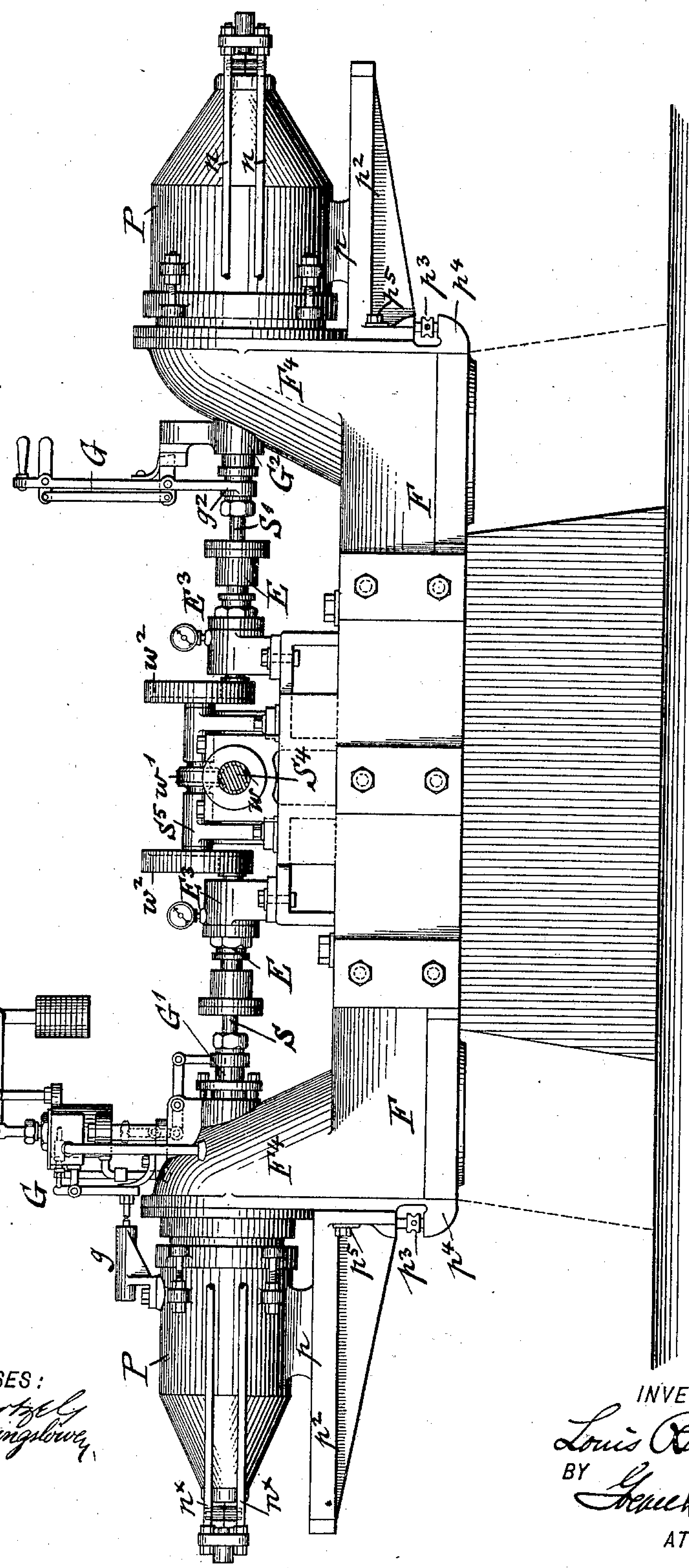
9 Sheets—Sheet 7.

FIG. 15.



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(No Model.)

9 Sheets—Sheet 8.

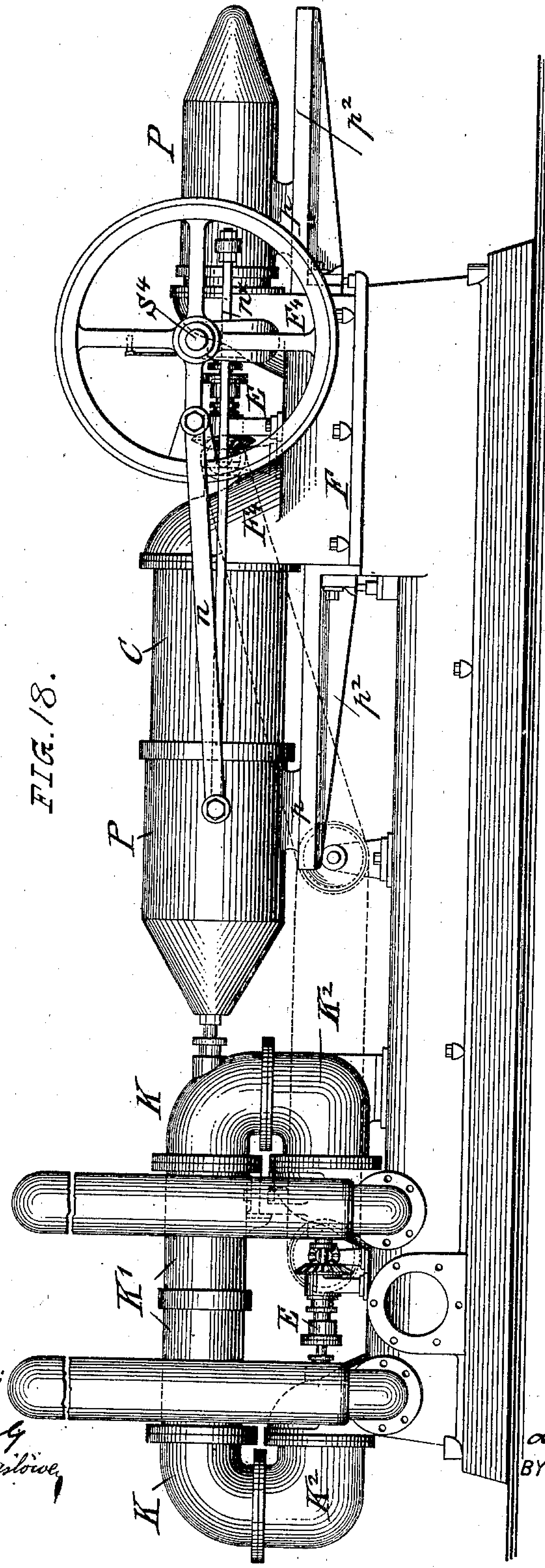

FIG. 18.

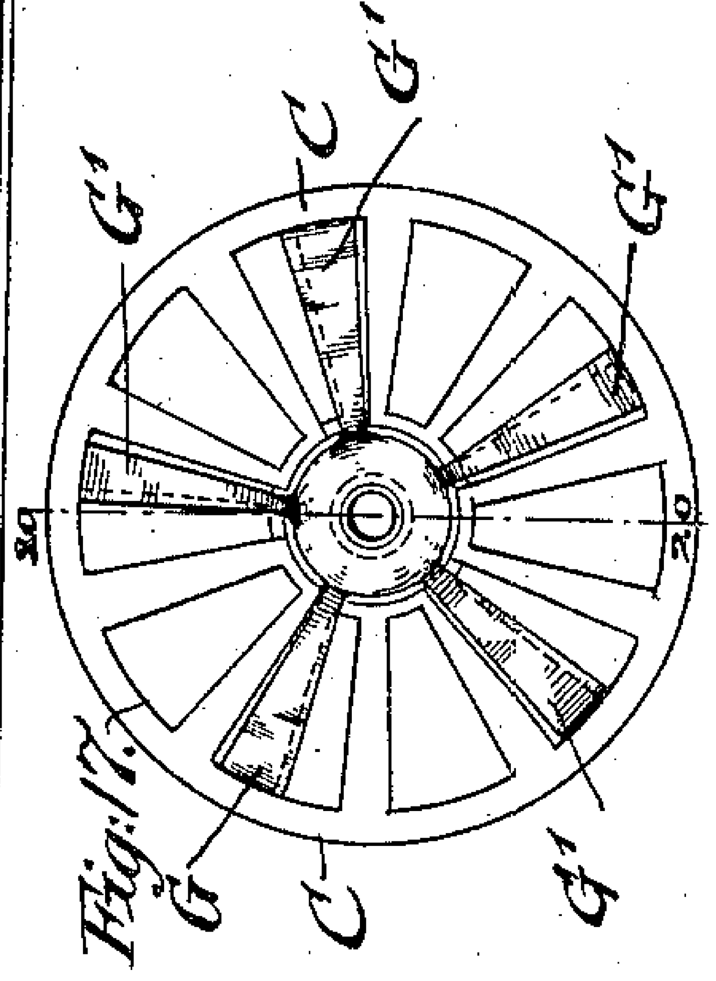

Fig. 17.

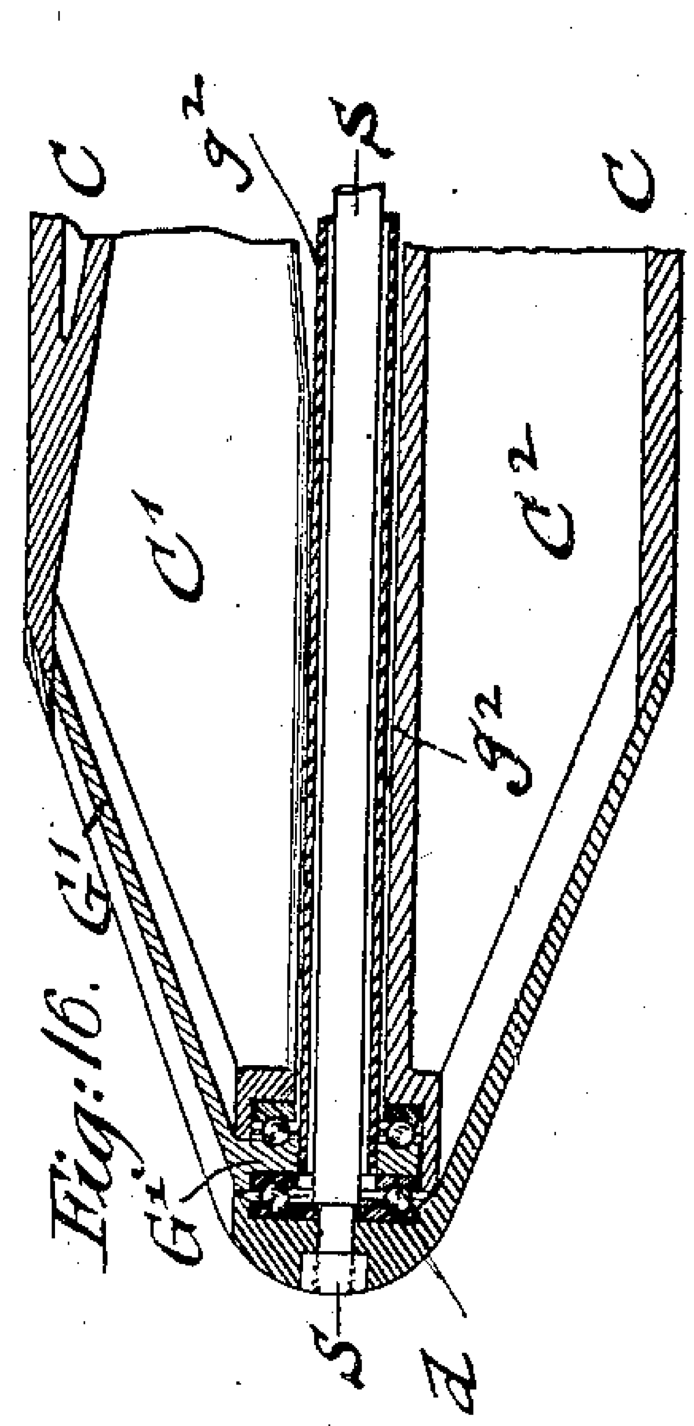

Fig. 16.

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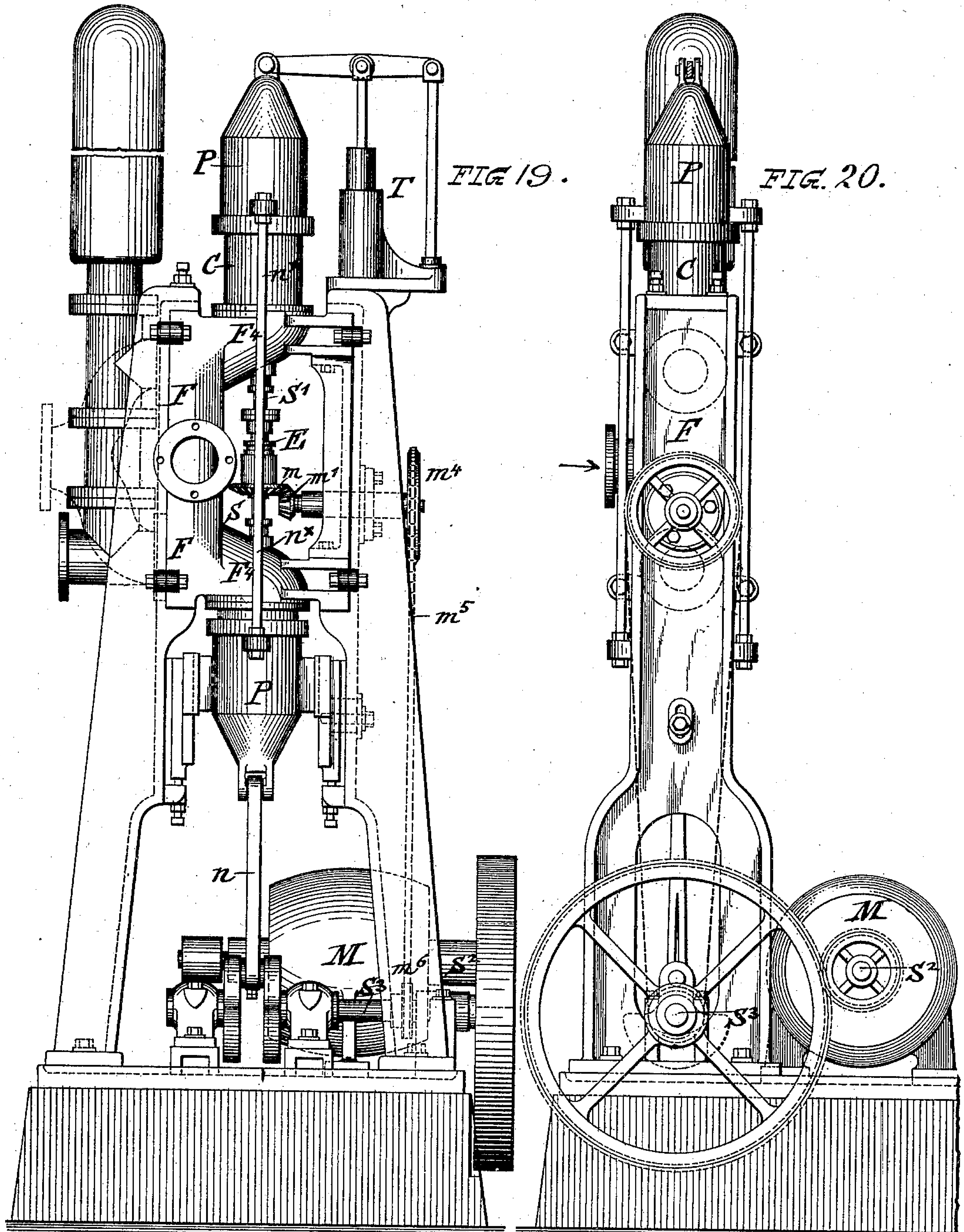

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UNITED STATES PATENT OFFICE.

LOUIS ROEDEL, OF PASSAIC, NEW JERSEY.

ROTARY SLIDE-VALVE FOR PUMPS, COMPRESSORS, OR MOTORS.

SPECIFICATION forming part of Letters Patent No. 709,682, dated September 23, 1902.

Application filed March 24, 1900. Renewed June 10, 1902. Serial No. 111,006. (No model.)

To all whom it may concern:

Be it known that I, LOUIS ROEDEL, a citizen of the United States, residing in Passaic, in the county of Passaic and State of New Jersey, have invented certain new and useful Improvements in Rotary Slide-Valves for Pumps, Compressors, or Motors, of which the following is a specification.

This invention has reference to an improved rotary slide-valve for pumps, compressors, steam-engines, air and water motors, &c., which are to be operated at a high speed and in which in place of a rectilinear or rotary reciprocating motion of the slide-valve a continuous rotary motion is imparted to the same for opening or closing the inlet and outlet ports and in which the number of the inlet and outlet ports is increased and their area enlarged, so that the velocity of the valve can be reduced to a minimum, while the velocity of the plunger may be increased to a maximum; and the invention consists in the combination, with a stationary cylinder having interior inlet and outlet channels, of a rotary slide-valve at the head of said cylinder, a shaft connected at one end with said valve, means for imparting rotary motion to said shaft, and a balancing device arranged at the opposite end of said shaft.

The invention consists, secondly, in the combination, with a stationary cylinder having inlet and outlet channels and inlet and outlet ports, of a rotary slide-valve having ports registering with the inlet and outlet ports of the cylinder, and a reciprocating plunger guided on the cylinder.

The invention consists, further, in certain other combinations of operative parts, which will be more fully described hereinafter and finally claimed.

In the accompanying drawings, Figures 1 and 2 represent, respectively, a plan view and side elevation of a double-cylindrical high-speed pump for liquid or gaseous fluids provided with my improved rotary slide-valves. Fig. 3 is a vertical longitudinal section through one cylinder, slide-valve, plunger, and pressure-balance device of the high-speed pump, drawn on a larger scale. Fig. 4 is a vertical longitudinal section, drawn on a still larger scale, of my improved rotary slide-valve, shown in position on the cylinder. Fig. 5 is an end elevation of the cylinder-heads with the rotary slide-valve removed. Fig. 6 is a vertical transverse section through the cylinder on line 6 6, Fig. 4, showing the alternating inlet and outlet channels of the same. Figs. 7 and 8 are respectively a vertical longitudinal section and an end elevation of my improved rotary slide-valve, shown as detached from the cylinder. Figs. 9 and 10 are respectively a vertical longitudinal section and an end elevation, partly in vertical transverse section, of a modified construction of the cylinder as used for compressors. Fig. 11 is a detail vertical transverse section through the supporting-frame, showing the supply and discharge channels for the pump-cylinder on line 11 11, Fig. 2. Fig. 12 is a vertical longitudinal section of the pressure-balancing device for the rotary slide-valves of a double-cylindrical-pump compressor-motor. Fig. 13 is a vertical longitudinal section of a simplified construction of the pressure-balancing device. Fig. 14 is a side elevation of a double-cylindrical compressor with my improved slide-valves, showing the plungers provided with evaporating cooling-jackets. Fig. 15 is a side elevation of a double-cylindrical steam-engine the high-pressure and low-pressure cylinders of which are provided with my improved rotary slide-valves. Fig. 16 is a vertical longitudinal section on line 16 16, Fig. 17, of a cylinder rotary slide-valve and cut-off valve employed for the cylinders of steam-engines. Fig. 17 is an end elevation of the cylinder and cut-off valve with the rotary slide-valve removed. Fig. 18 is a side elevation of a double-cylindrical steam-engine with my improved rotary slide-valves shown as operating a pump the cylinder of which is also provided with rotary slide-valves; and Figs. 19 and 20 are respectively a front elevation and a side elevation of a pump or compressor arranged with vertical cylinders, slide-valves, and plungers.

Similar letters of reference indicate corresponding parts.

Referring to the drawings, C represents a stationary cylinder which may be arranged either horizontally or vertically, said cylinder being made with a conically-tapering head at the outer end and bolted at its inner end to a hollow supporting-frame F, in which are located alongside of each other the main supply and discharge channels F′ F^2 for the liquid or gaseous fluid. The channels F′ F^2 are connected by inclined channels F^3 F^4 with rim-spaces F^5 F^6, which communicate, respectively, with the rear ends of the inlet and outlet channels of the stationary cylinder C, as shown in Fig. 3. At the interior of the cylinder C are arranged a number of alternating inlet and outlet channels C′ C^2, the inlet-channels being V-shaped in cross-section and diminishing in size toward their inner ends, while the outlet-channels are made tapering toward the center of the cylinder and communicating with a cylindrical space at the center of the cylinder, said space being gradually enlarged toward the inner end of the cylinder and connected with the discharge-channel F^2 in the supporting-frame F, as indicated by arrows in Fig. 3. The inlet and outlet channels of the cylinder C are preferably made in one integral casting, as shown in Fig. 4, and connected at the outer circumference by fastening-screws with the cylinder, or they may be cast integral with the shell of the cylinder C, as shown in Fig. 16. The inlet and outlet ports in the cylinder-head are equal in size and equidistantly from each other, there being suitable faces or bridges between said ports. The bridges of the cylinder C are provided at their outer portions with recesses r, into which the liquid enters, so as to balance part of the pressure exerted on the opposite side of the slide-valve D, which is fitted on the head of the cylinder C. The slide-valve D is lined with lignum-vitæ and provided at its apex with a recessed hub d and keyed to the end of a rotary shaft S, which turns in suitable thrust-bearings d' in the apex of the cylinder C. The shaft S is connected with the recessed hub of the slide-valve D by means of a screw-nut d^2, that is screwed onto the threaded end of the shaft S, as shown clearly in Figs. 3 and 4. The shaft S passes through the central space of the cylinder and through the inclined portion F^4 of the supporting-frame F to the outside of the same, the inclined portion of the frame being provided with a suitable stuffing-box for the shaft S. The outer end of the shaft S is supported in a bearing $d^{\times}$ in line with the axis of the stationary cylinder C. The thrust-bearing d', between the hub of the slide-valve D and the apex of the head of the cylinder C, is provided with antifriction-balls d^3, that are held by a suitable retainer between thrust-rings d^4, as shown in Fig. 4, said thrust-bearing holding the rotary slide-valve firmly in position and taking up the friction of the slide-valve with the cylinder-head. The inner end of the shell of the cylinder C is attached by means of a circumferential flange and screw-bolts to the inclined portion of the supporting-frame F, while the rimmed inner end of the casting by which the inlet and outlet channels are formed is tightly fitted to a seat at the interior of the inclined portion of the frame F, as shown in Fig. 3.

On the outside of the stationary cylinder C is guided a hollow reciprocating plunger P, having a conical head corresponding in shape with the slide-valve and cylinder-head and which is provided at its inner end with a recessed circumferential rim in which are arranged suitable packing-rings, so as to produce the tight connection between the cylinder and plunger and prevent the leakage of liquid or gaseous fluid at the end of the plunger. The apex of the conical end of the plunger is preferably rounded off so as to correspond in curvature to the rounded-off head of the slide-valve. The plunger P is provided at its lower part with a sliding support p, which is preferably guided in the ways p' of a horizontal bracket p^2, that is attached to the end of the supporting-frame F, said bracket being capable of vertical adjustment along the upright face of the frame by means of set-screws p^3, the heads of which abut against a shoulder p^4 of the supporting-frame F, as shown clearly in Fig. 3. The end wall of the bracket p^2 adjacent to the face of the frame F is preferably provided with slots for the fastening-screws p^5 of the bracket, so as to permit the accurate adjustment of the bracket and the plunger guided thereon toward the cylinder C.

The slide-valve D is provided with half the number of ports as the total number of ports in the head of the cylinder. If there are ten outlet and inlet ports in the cylinder-head, the slide-valve is provided with five equidistant ports, which register alternately with the inlet and outlet ports. For cylinders of larger size a larger number of inlet and outlet channels are arranged in the same, in which case the number of ports in the rotary slide-valve is proportionately increased, provided that there are always half the number of ports as those in the cylinder.

Continuous rotary motion in the same direction is imparted to the shaft S of the slide-valve D from the driving-shaft of an electric or other motor M by means of a bevel-gear transmission, of which the bevel gear-wheel m is keyed to the shouldered end of the shaft S, while the intermeshing bevel gear-wheel m' is keyed to a short shaft m^2, supported at right angles to the shaft S in bearings of an upright standard m^3 on the supporting-frame F. The short shaft m^2 is provided with a sprocket-wheel m^4, to which rotary motion is imparted by a sprocket-chain m^5, which is in gear with a sprocket-wheel m^6 on the motor-shaft S^3, as shown in Figs. 1 and 2. It is preferable for the advantageous use of my improved rotary slide-valve that the pump, compressor, or motor be arranged in the nature of a double-cylindrical structure in which two stationary cylinders are arranged on the supporting-frame axially in line with each other at opposite ends of the frame F, as shown in Figs. 1 and 2. The cranks of the motor-shaft are then connected by connecting-rods n n with a transverse rod n', that is connected by a universal joint n^2 with the head of the plunger, while the opposite end of the plunger is provided with lugs n^3 at diametrically opposite points, said lugs being connected by a second pair of connecting-rods $n^\times$ with corresponding lugs n^6 on the plunger of the second cylinder at the opposite end of the supporting-frame F, as shown in Figs. 1 and 2. The supply-channel F' is provided with an inlet-opening for the supply-pipe and the discharge-channel F^2 with an opening for the discharge-pipe. The supply-channel F' of each cylinder is in case of a pump preferably provided with air-chambers, as shown in dotted lines in Fig. 2, while the shafts S S' of the slide-valves D D of both cylinders are mounted axially in line with each other and rotated simultaneously by the motion-transmitting gear described. The pressure on both slide-valves from the cylinders is equalized by a balancing device E, which is interposed between the shafts. This balancing device is clearly shown in Figs. 1 and 2 and in vertical longitudinal section in Figs. 3, 12, and 13. In the right-hand shaft S' is arranged a central bore or channel e, that communicates with the discharge-channel F^2 of the right-hand cylinder C by a short radial connection, so as to take up liquid or fluid under pressure and conduct it through the bore of the shaft S' into a cylinder e', in which is arranged a differential piston $e^3 e^4$. The shaft S' is connected by a coupling e^2 with the cylinder e', which is composed of a larger and a smaller portion, the larger piston e^3 being located in the larger portion, the smaller piston e^4 in the smaller portion, of the cylinder e'. The smaller portion of the cylinder e' is extended into a cylindrical casing e^5, having threaded caps e^6 e^6, the extension $e^\times$ of the cylinder e' being tightly connected with the cap e^6 by a suitable stuffing-box, as shown in Fig. 12. The interior of the cylinder extension $e^\times$ is connected with the interior of the casing e^5 by a radial outlet-channel e^7 and the cap e^6 tightly fitted to the casing e^5 by a suitable packing-ring. The opposite cap e^6 is preferably made integral with the hollow socket of the bevel gear-wheel m, which socket turns in bearings of the standard m^3. The casing e^5 and its caps e^6 e^6 inclose a larger piston e^8, which is firmly closed to the end of the extension $e^\times$ of the cylinder e' and retained thereon by a screw-nut e^9, having an enlarged shank with flats fitted into the hollow socket of the bevel gear-wheel m, so as to rotate with the same and produce thereby the turning of the piston e^8 with the shafts S S'. The space between the small end e^4 of the differential piston e^3 e^4 and the large piston e^8 is filled with a suitable liquid, such as glycerin, through a suitable plugged opening e^{10} in the casing e^5. All the pistons are tightly fitted by suitable cup-leathers in their respective cylinders. It is evident that any pressure which is brought to bear on the differential piston e^3 e^4 will act on the larger piston e^8 and cap e^6 of the casing e^5 with a pressure which is in the same ratio as the areas of the differential pistons. When the area of the larger piston e^8 is arranged in the same ratio to the horizontal projection of the area of the outlet-ports of the cylinder C, it will be balanced against the pressure in the discharge-channel, and thereby the proper equilibrium of the rotary slide-valves of both cylinders obtained. Through the bore in the shaft S' the liquid or gas is conducted from the discharge-channel to the differential piston e^3 e^4, so that the slide-valves are always properly balanced. Between the larger piston e^8 and the cap e^6 of the casing e^5 is interposed a helical spring e^{11}, which serves for the purpose of keeping the valves in their proper places when there is no pressure in the discharge-channel. As both rotary slide-valves D are so fitted and ground onto the conical faces of their respective cylinders that they will bear uniformly on all the bridges between the inlet and outlet-ports when the thrust-bearing shown in Figs. 3 and 4 rests against the balls, it is evident that the total pressure exerted on the valve will be taken up by the antifriction-balls, and thereby this sliding friction between the valve-faces and bridges transformed into a rolling friction between the balls and their bearing-rings. The valve-faces will thereby be kept tight against the bridges of the cylinders C and yet rotate without exerting any pressure against them, as this pressure is taken up by the antifriction-balls of the thrust-bearing. The total unbalanced pressure which is exerted on the face of the rotary slide-valve by the return stroke of the pump is confined to the small circumference of the thrust-bearing, and as the angle between the center of the inlet and outlet channels, which is the travel of the rotary slide-valve for one stroke of the plunger, is very small the angular velocity of the balls is also small. Considering the rolling motion of the load on the slide-valve face and the short distance traversed by the same, the work which is expended to move the valve for each discharge-stroke of the plunger is comparatively small. Therefore the number of inlet and outlet channels can be increased with the size of the cylinder and the travel of the rotary slide-valve still more reduced. When, for instance, in a cylinder having a diameter of nine, ten, eleven, or twelve inches six, seven, eight, or nine inlet and six, seven, eight, or nine outlet channels are arranged, one entire rotation of the slide-valve is made for every six, seven, eight, or nine strokes of the machine. This shows clearly that by the continuous rotary motion of the slide-valve a considerably higher speed is admissible than was possible with the pumps, compressors, or motors heretofore in use. In Fig. 13 a simplified form of balancing device is shown, in which the balancing of the slide-valves is accomplished entirely by the tension of the interposed spring e^{11}. This simplified form is specially adapted for blowers and pumps of low pressure.

In Fig. 14 my improved rotary slide-valve is used in connection with a compressor in which the diameters of the stationary cylinders are of equal size and in which the plungers P are connected with a crank-shaft S^3 by independent connecting-rods n $n^{\times}$, each of which is connected by a transverse rod and a ball-and-socket joint with the end of its plunger. The plungers are covered by a jacket P', of fibrous material, such as felt, to which a continuous spray of water is supplied by means of suitable sprinklers P^2, so that the heat of compression is removed by the cooling action of the evaporating water. Rotary motion is transmitted from the shaft of the motor by a gear-wheel transmission to the crank-shaft S^3, which is supported in bearings at the center of the supporting-frame F. The balancing device E for the rotary slide-valve is interposed between the shafts S S' of the same in the same manner as in the pump construction shown in Figs. 1 and 2.

In compressors each cylinder may be provided in its outlet-ports with steel or brass spring-plates, which are attached to the central portion of the cylinder-head and permitted to open inwardly at their free opposite ends, said spring-plates u closing the outlet-ports, so as to prevent the air or other gases from coming back in the cylinder when the discharge-ports begin to open for the discharge-stroke of the piston. The spring-plates u are clearly shown in Figs. 9 and 10.

Fig. 15 shows a side elevation of a steam-engine with my improved slide-valves, but with cylinders of different diameters, so as to act as high and low pressure cylinders, respectively. The high-pressure cylinder is provided with a steam-governor G, which is actuated by the inertia of a loaded piston in a cylinder g. The governor G actuates a cut-off valve G', which is shown in Figs. 16 and 17, and by which the ports of the cylinder can be covered, so as to effect a cut off at from two-thirds of a stroke to zero. The low-pressure cylinder is provided with a hand-operated cut-off valve G^2, said valve being connected with the governing devices by a sleeve g^2. (Shown in Fig. 16.) The rotary slide-valves are separately rotated by a worm-gear w', which gears with a worm w on the main shaft S^4, driven by the reciprocating plungers. The worm-gear w' is located on a shaft S^5, placed across the main shaft S^4 and provided with internal gears w^2, which in turn mesh with pinions on the shafts S S' of the slide-valves, each shaft being provided with a separate balancing device E, which is arranged in a cylinder E^3, supported on standards of the frame F.

A steam-engine provided with my improved rotary slide-valves can on account of the large areas of the inlet and outlet ports attain a plunger speed of from thirty to thirty-five feet per second. The retarding pressures of the movable parts at the dead-points can be balanced by arranging the cranks at one hundred and eighty degrees and giving the high-pressure cylinder a larger stroke than the low-pressure cylinder. With the same object in view two double-cylindrical motors can be placed in tandem and the adjacent cylinders of both motors connected to cranks at an angle of one hundred and eighty degrees, so that a perfectly-balanced high-speed quadruple-expansion engine is obtained. The supporting-frame of the engine may be provided with bolts and facing-strips for attaching the frame of a dynamo, which can be thus driven directly by the crank-shaft of the engine.

In Fig. 18 a steam-engine with my improved rotary slide-valves is shown in connection with a large pump K, of which K' is the pump-cylinder in which the pump-piston moves. This piston is directly connected with the plunger of the low-pressure cylinder. The pump is also provided with rotary slide-valves, which are located in the elbows K^2 of the pump and which are driven by a suitable sprocket wheel and chain transmission from the main shaft to the steam-engine, as shown in dotted lines. A second sprocket wheel and chain are arranged for the pump slide-valves, so as to reduce the length of the sprocket-chain transmission when driving the pump slide-valves directly from the crank-shaft of the engine.

In Figs. 19 and 20 my improved slide-valve is applied to an upright arrangement of pump, blower, or compressor. In case of a compressor water can be injected, as the presence of water will not interfere with and come in contact with the working surfaces. A cushioning device T may be employed for counterbalancing the weight of the moving parts of the pump. In these figures the electromotor for driving the pump or compressor is shown as supported on the bed-plate of the structure.

The advantages of my improved rotary slide-valve are best stated in connection with the different applications of the same. When the valve is used for pumps, the valve area can be made equal or larger than the cross-sectional area of the plunger. When the plunger arrives at either end of its stroke, the opening or closing of the ports is promptly obtained. As the rotary motion of the slide-valve is continuous and in the same direction, the slide-valve is rotated at comparatively small speed, and as the valve is closely fitted to its seat it will always remain tight. The valve is always kept to its seat by the balancing device and firmly held there, the valve-seat acting as a guide at the same time. In pumps the valves can be lined with lignum-vitæ or any other antifriction substance. The flow of the liquid through the inlet and outlet channels and ports takes place without deviating from a straight line, whereby the resistance to the liquid or fluid is diminished. The free inlet and outlet area of the ports exposed by the slide-valve during the stroke of the plunger is directly proportioned to the volume displaced by the plunger at the same time, so that a high speed of the plunger and noiseless operation of the pump are obtained. Pumps and compressors with external plungers are especially adapted for liquids and gases where it is not desirable to have the lubricating agents come in contact with the same. The pump can be converted into a motor simply by reversing the connections of the supply and discharge openings and air-chambers.

The advantages stated in regard to the use of my improved slide-valve for pumps hold good equally or even in greater degree for compressors and blowers. For compressors, however, it is necessary to insert a spring-plate in each outlet-port of the cylinder, so that a certain pressure is necessary before a spring-plate will open the port. The spring-plates are cushioned while closing by the gas interposed between the spring-plates and valve and then closed by means of their own elasticity. The outlet-ports, however, can be also arranged without spring-plates, in which case they have to be made of smaller size, so that they open only when the desired pressure is reached. For cooling either jacket-cooling, evaporation, or injection can be used. The latter will not endanger the compressor, as the valve allows the non-evaporated water to pass out through the outlet-channels. The clearance is not excessive. When the diameter of the plunger is equal to the stroke, it amounts to only about two per cent. of the total volume.

In steam-engines large port area, small clearance, continuous slow rotary motion of the valve, and the balancing of retarding pressures of the moving parts at the dead-points are the main features of advantage in connection with high speed. By interposing a cut-off valve between the rotary slide-valve and its seat a cut off of from two-thirds to zero can be obtained. The steam-inlet channels are preferably so arranged that the incoming steam of higher temperature passing through said channels is protected against the temperature of the atmosphere by the outgoing steam of lower temperature in the outlet-channels. This is of special advantage for quadruple-expansion engines. The pressure on the slide-valve in case of steam-engines and air-motors is considerably less than in pumps, as the expanding steam or air reduces the pressure on the valve. Lastly, a double-cylindrical machine can be so arranged that the cylinder at one end acts as either water, steam, or air motor, while the cylinder at the other end of the machine acts as a pump, compressor, or blower.

The advantages common to all applications of my improved slide-valve are, first, that a slow speed of the slide-valve during its continuous rotary motion in the same direction is obtained; secondly, that a high speed can be imparted to the plunger, and thereby to the driving-shafts, as a number of strokes of the plunger are obtained for one rotation of the slide-valve; thirdly, that by the conical shape of the slide-valve the size of the inlet and outlet ports is considerably increased, that by the straight flow imparted to the liquids or fluids their velocity in entering or leaving the inlet or outlet channels is diminished, and, fourthly, that by the continuously-rotating slide-valve pumps, compressors, or motors are obtained which occupy a much smaller space than the corresponding reciprocating machines heretofore in use and which can be manufactured at a considerably smaller cost.

Having thus described my invention, I claim as new and desire to secure by Letters Patent—

1. The combination, with a stationary cylinder having interior inlet and outlet channels, of a rotary slide-valve at the head of said cylinder, a shaft connected at one end with said valve, means for imparting rotary motion to said shaft, and a balancing device arranged at the opposite end of said shaft, substantially as set forth.

2. The combination, with a stationary cylinder having interior inlet and outlet channels and inlet and outlet ports, of a rotary slide-valve having ports registering with the inlet or outlet ports of the cylinder, and a reciprocating plunger guided on the cylinder, substantially as set forth.

3. The combination, with a stationary cylinder having interior inlet and outlet channels and inlet and outlet ports, and a supporting-frame having supply and discharge channels communicating with one end of said channels, of a rotary slide-valve having ports registering successively with the inlet and outlet ports, a plunger on the cylinder, and means for imparting reciprocating motion to said plunger, substantially as set forth.

4. The combination of two stationary cylinders having interior inlet and outlet channels and inlet and outlet ports and provided each with a conical outer end, conical slide-valves, one for each cylinder, rotating in contact with the same, thrust-bearings, one for each slide-valve, arranged at the apex of its cylinder, and a shaft connecting the slide-valves of both cylinders, substantially as set forth.

5. The combination, with two stationary cylinders having interior inlet and outlet channels, of rotary slide-valves at the heads of said cylinders, shafts connected with said valves, means for imparting rotary motion to said shafts, and a balancing device interposed between the inner ends of the shafts, substantially as set forth.

6. The combination, with two stationary cylinders arranged axially in line with each other and provided with interior inlet and outlet channels, of conical slide-valves at the ends of said cylinders, means for imparting

rotary motion to the slide-valves, plungers guided on said cylinders, and means for imparting reciprocating motion to said plungers, substantially as set forth.

7. The combination, with two stationary cylinders having interior inlet and outlet channels, of slide-valves on the heads of said cylinders, shafts connected with the slide-valves, means for imparting rotary motion to said shafts, and a balancing device between the inner ends of said shafts, said balancing device consisting of a differential piston, a larger piston, cylinders for said pistons, and couplings between the shafts and cylinders, substantially as set forth.

8. The combination, with two stationary cylinders having interior inlet and outlet channels, of rotary slide-valves on the heads of said cylinders, plungers guided on said cylinders, means for connecting said plungers, and means for simultaneously reciprocating both plungers, substantially as set forth.

9. The combination, with a stationary cylinder having interior inlet and outlet channels and inlet and outlet ports and provided with a conical outer end, of a slide-valve, a thrust-bearing for the head of the slide-valve at the apex of the cylinder, a cut-off valve interposed between said slide-valve and cylinder, and a thrust-bearing for said cut-off valve at the apex of the cylinder in line with the bearing of the slide-valve, substantially as set forth.

10. The combination of a stationary cylinder having interior inlet and outlet channels and inlet and outlet ports and provided with a conical outer end, of a slide-valve, a thrust-bearing for the head of the slide-valve at the apex of the cylinder, a shaft connected with said slide-valve, means for imparting rotary motion to said shaft, and a balancing device arranged at the opposite end of said shaft, substantially as set forth.

11. The combination, with a stationary cylinder having interior inlet and outlet channels, said cylinder being provided with spring-plates in its outlet-ports, of a rotary slide-valve on the head of said cylinder, and a reciprocating plunger guided on said cylinder, substantially as set forth.

In testimony that I claim the foregoing as my invention I have signed my name in presence of two subscribing witnesses.

LOUIS ROEDEL.

Witnesses:
PAUL GOEPEL,
M. H. WURTZEL.