J. ROTHCHILD.

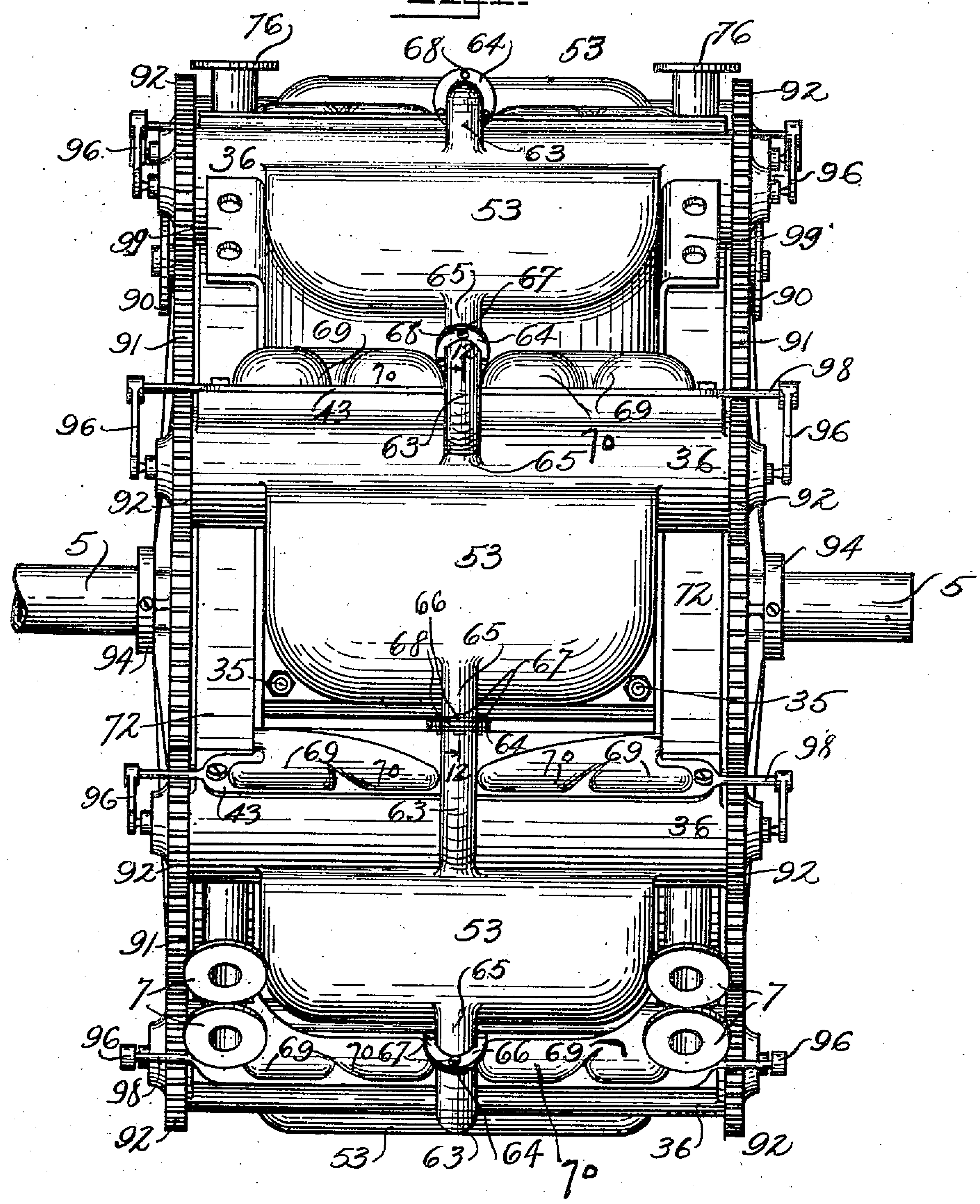
INTERNAL COMBUSTION ENGINE.

APPLICATION FILED NOV. 28, 1917.

1,298,098. Patented Mar. 25, 1919.

8 SHEETS—SHEET 1.

Fig. 1.



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By his Attorney Edward S. Beach

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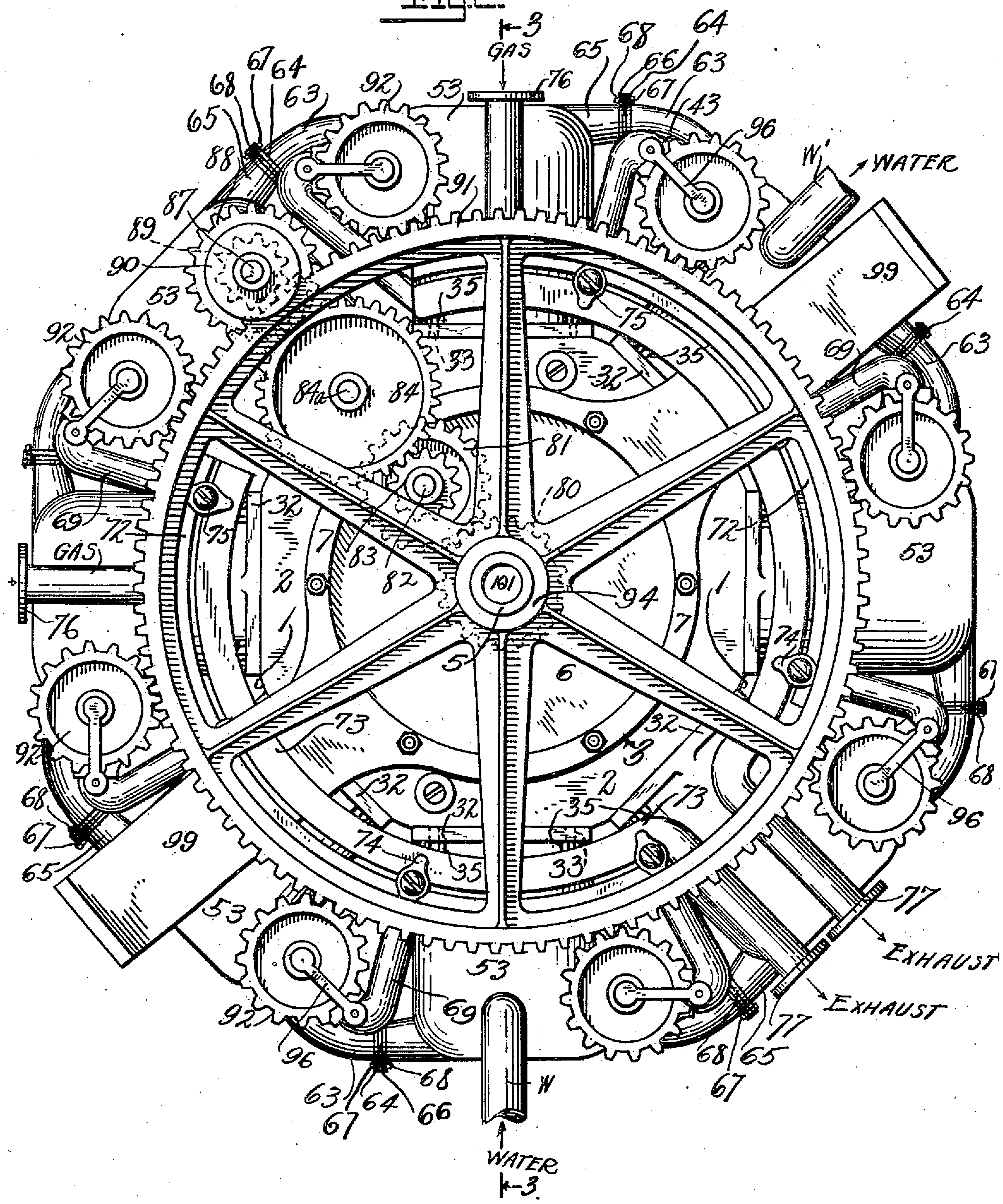
8 SHEETS—SHEET 2.

Fig. 2.



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8 SHEETS—SHEET 3.

Fig. 3.

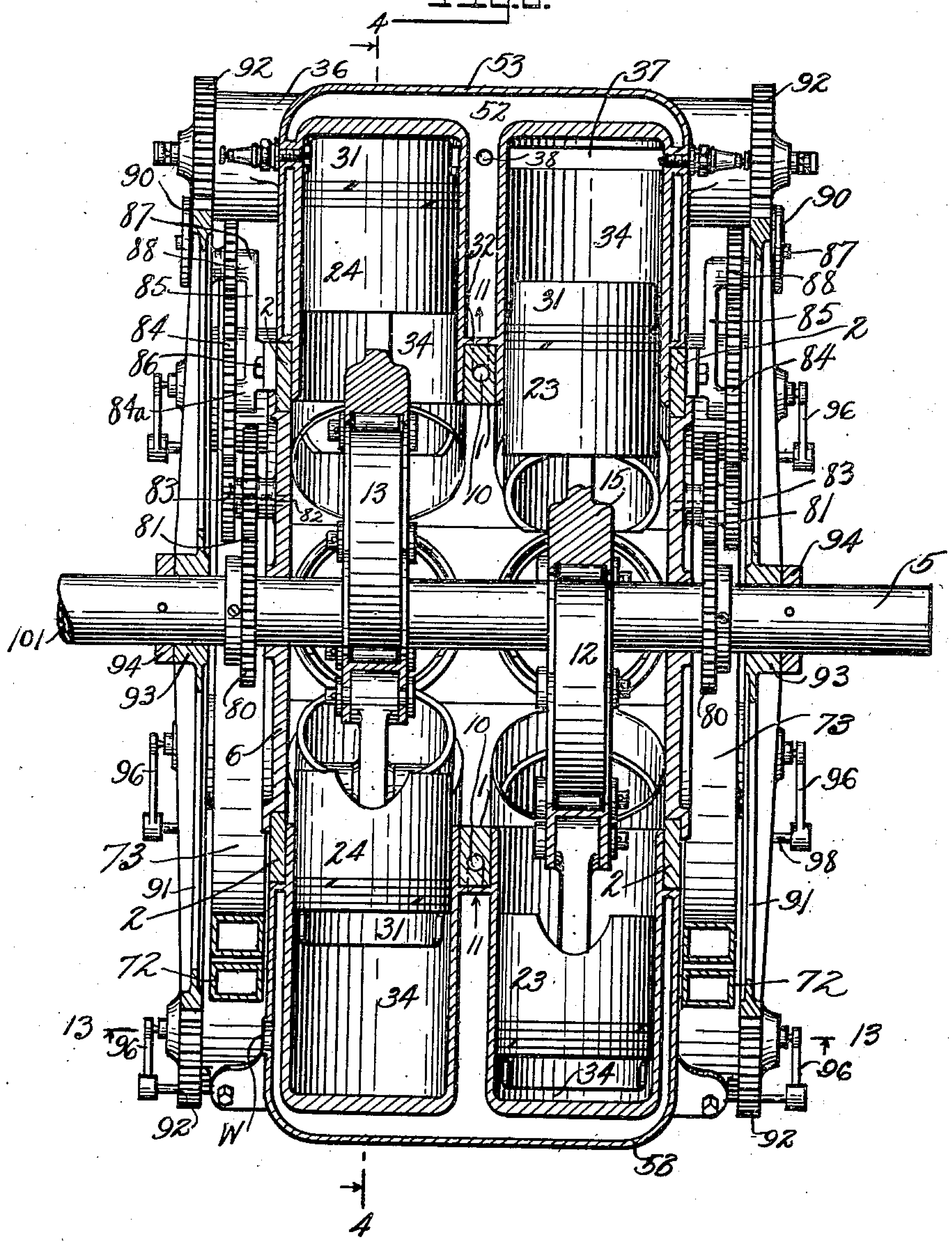

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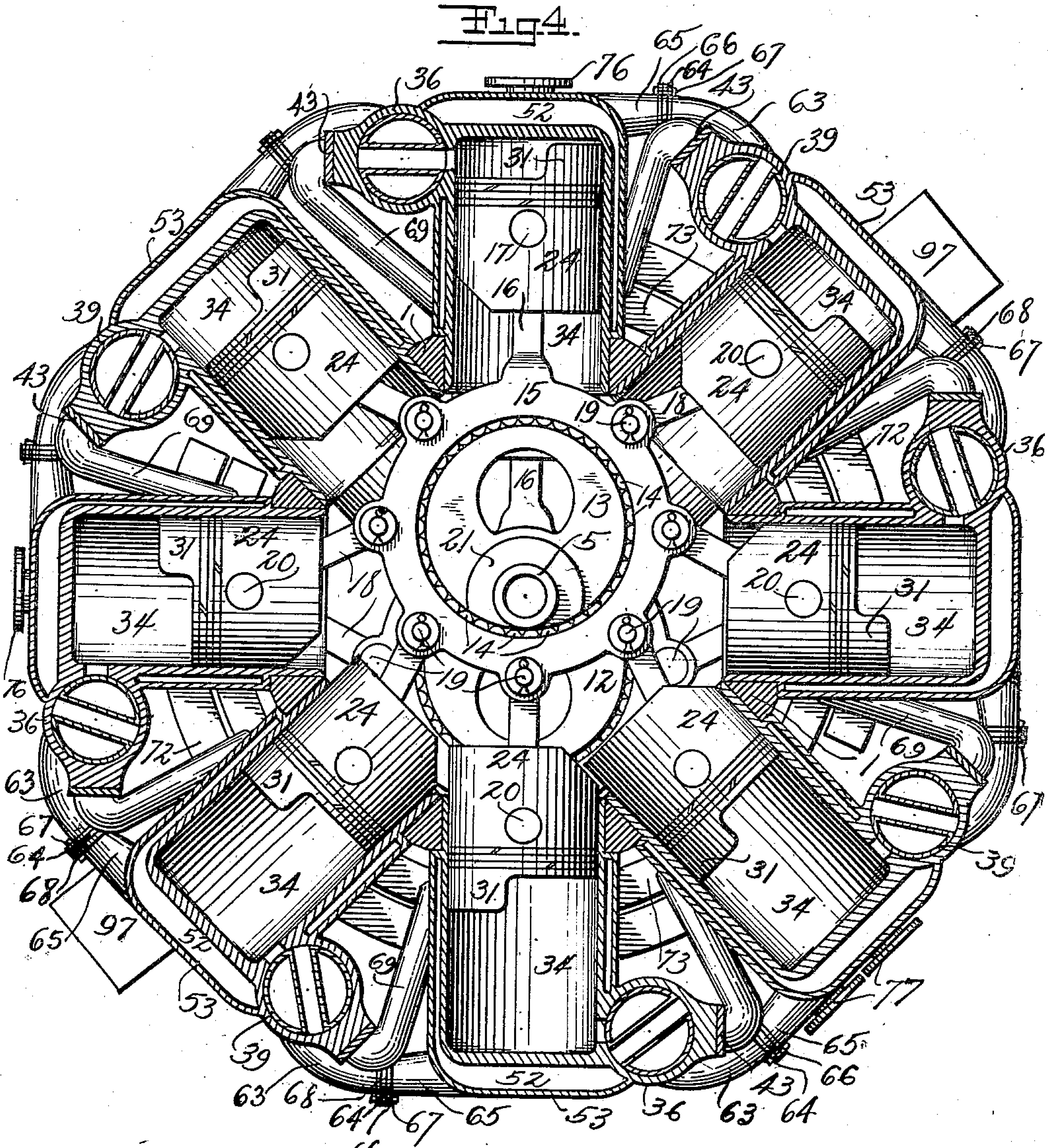
Fig 4.



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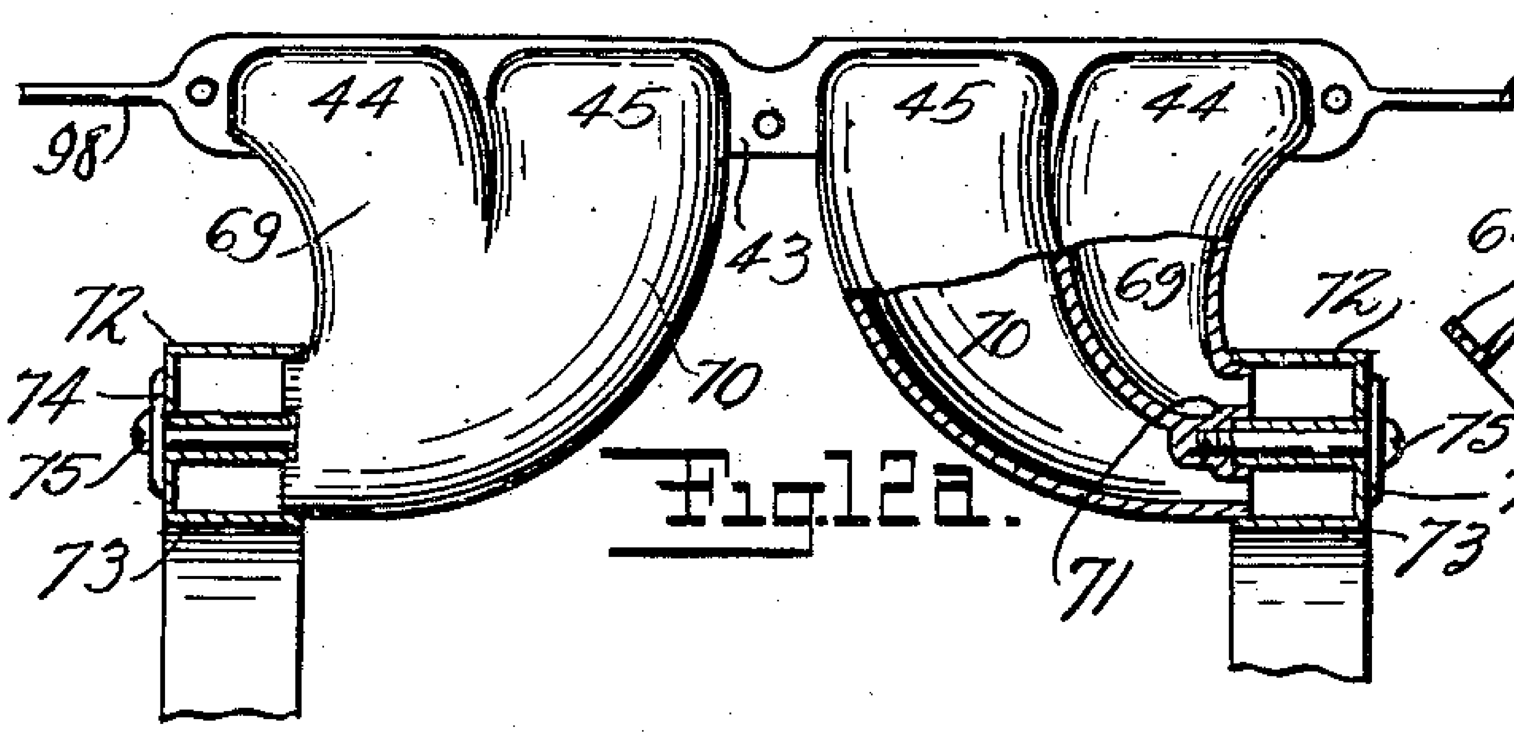

Fig. 12a.

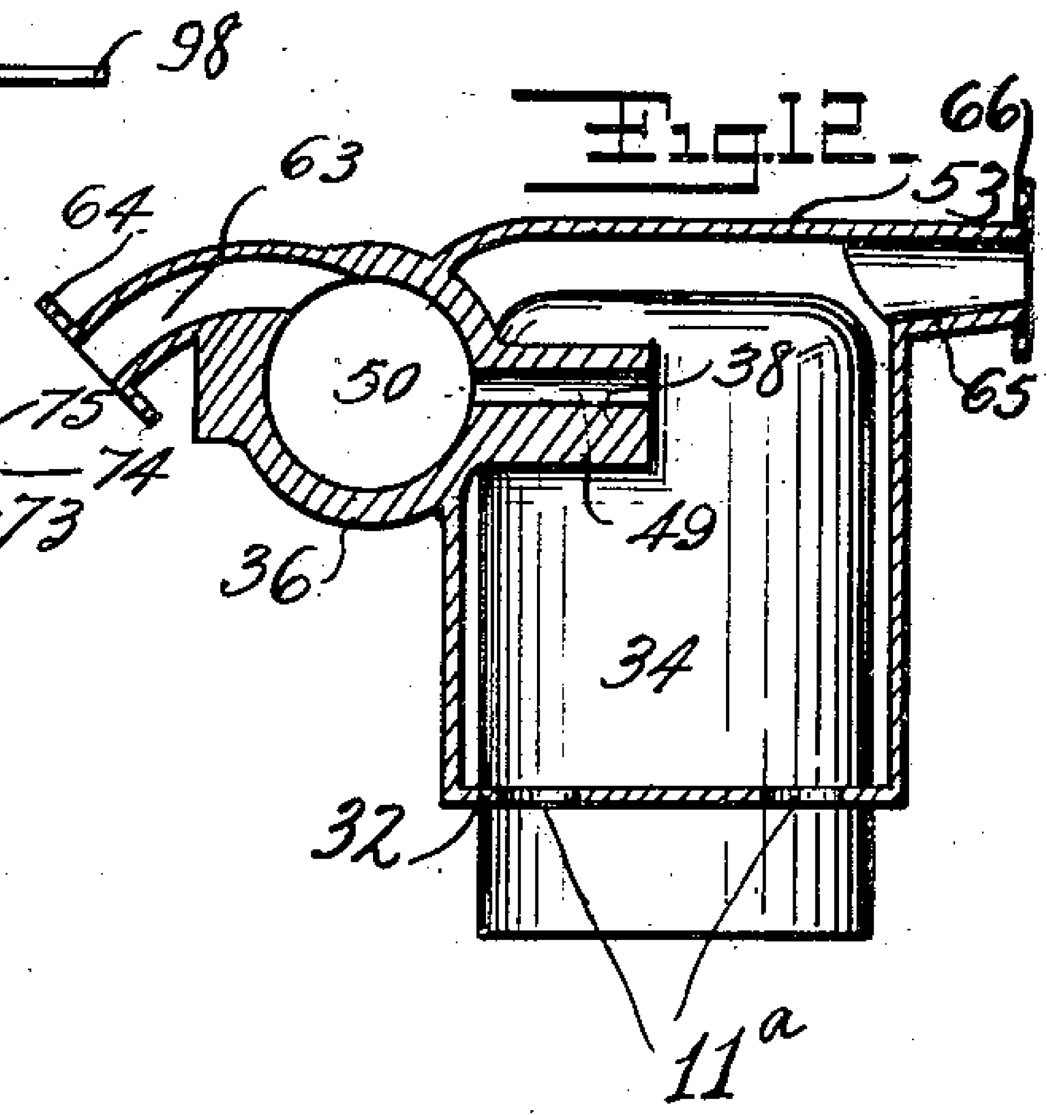

Fig. 12.

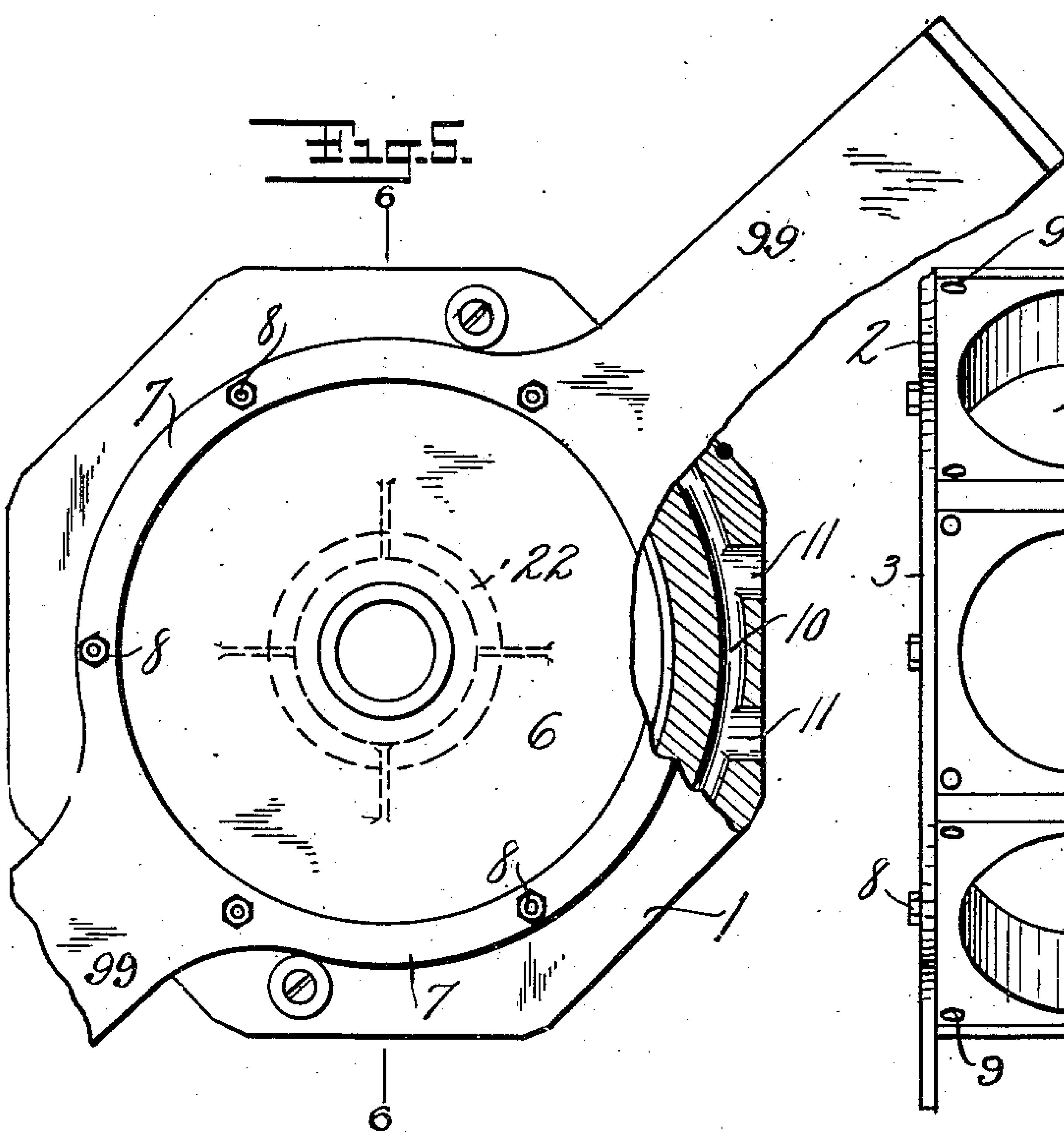

Fig. 5.

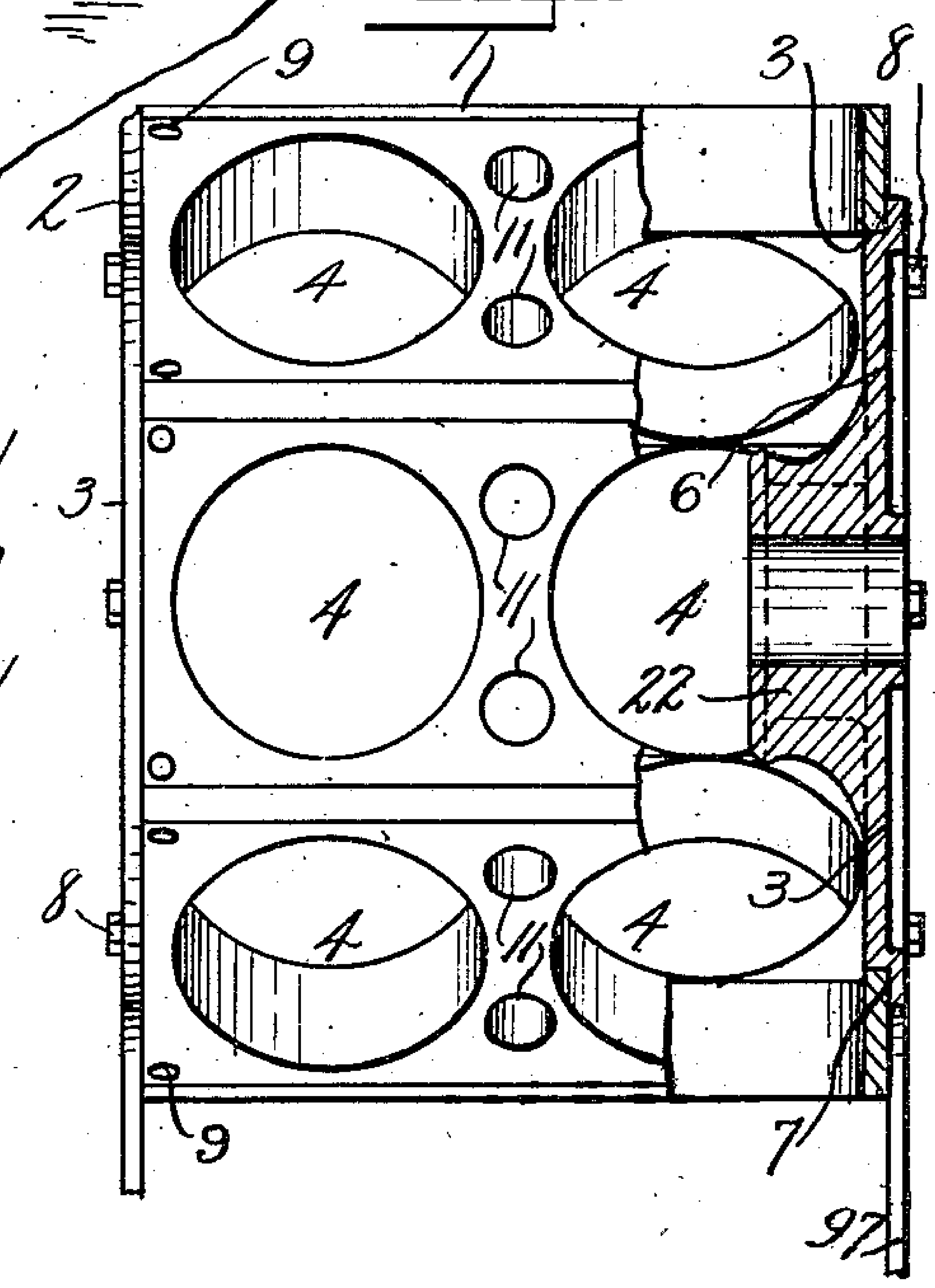

Fig. 6.

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Fig. 10.

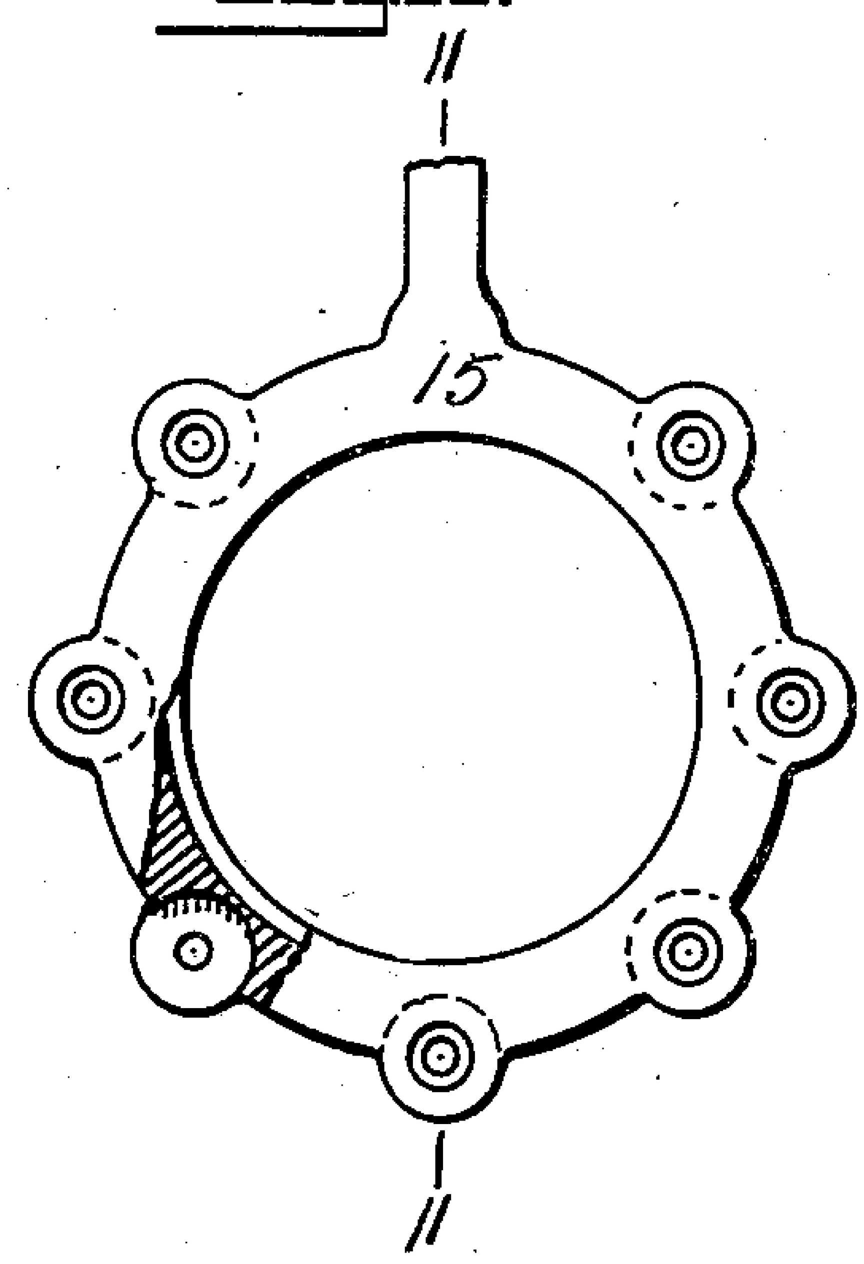

Fig. 9.

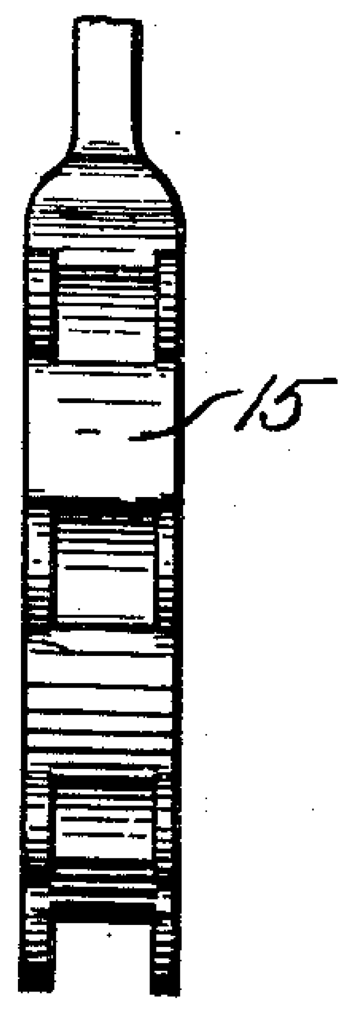

Fig. 11.

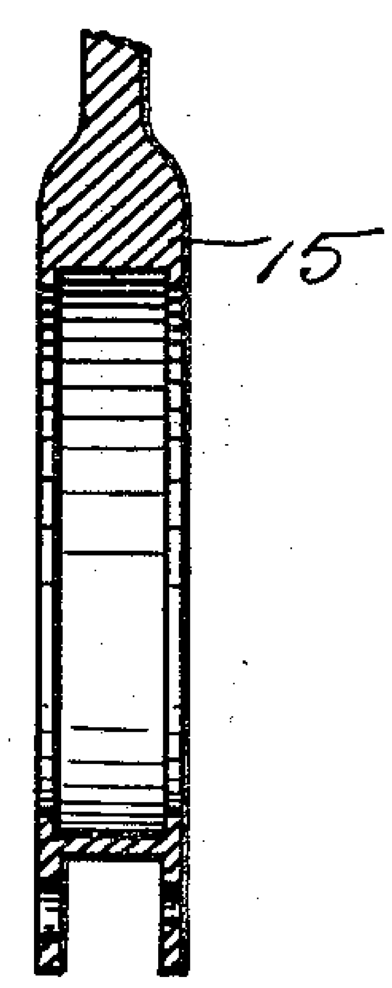

Fig. 7.

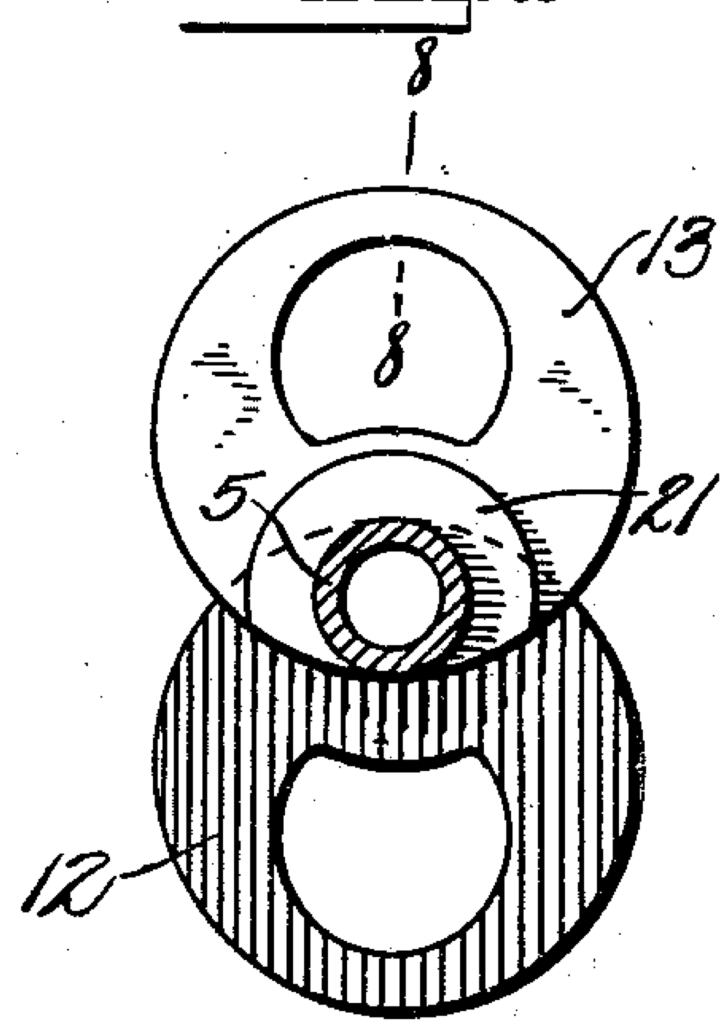

Fig. 8.

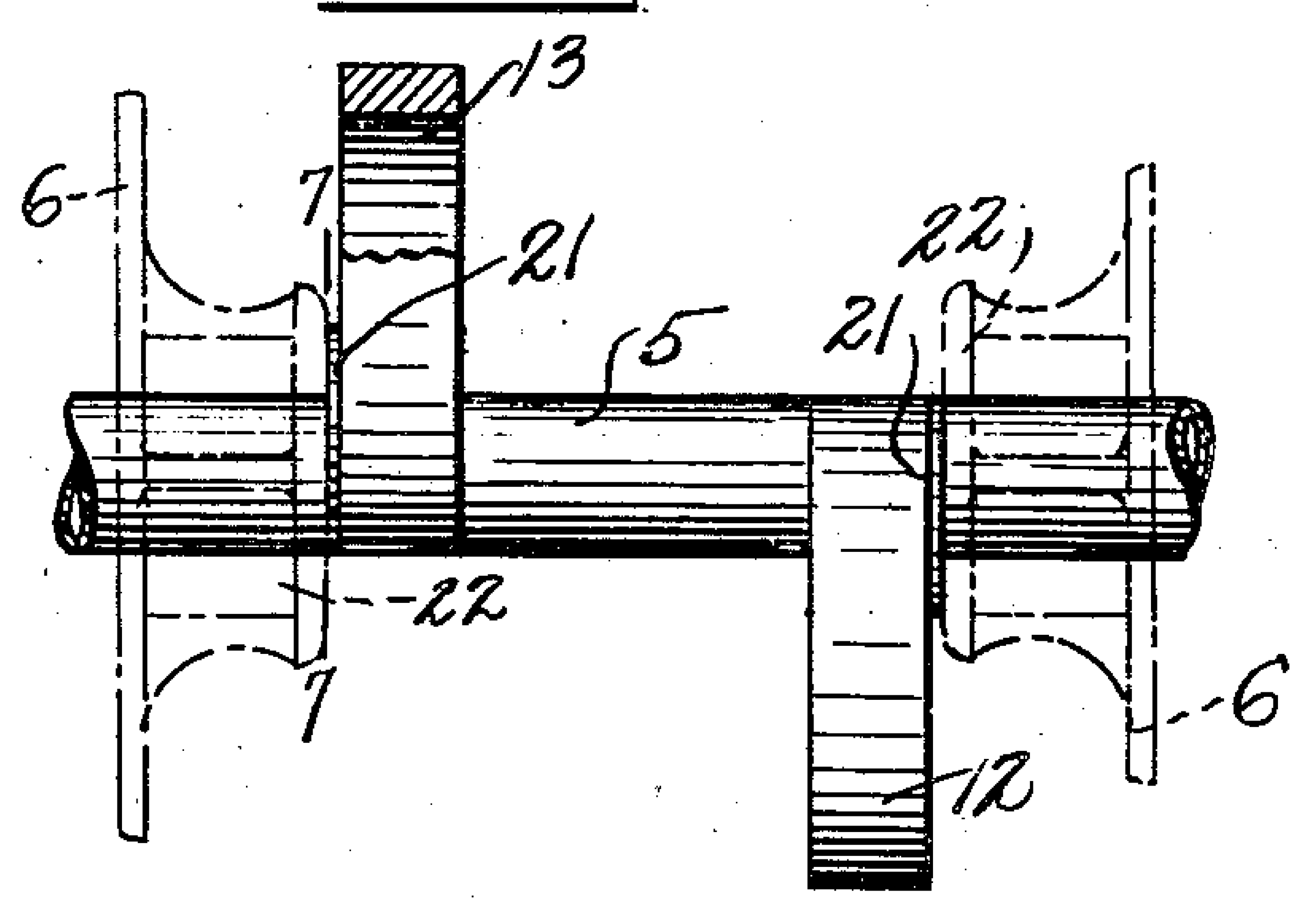

Fig. 25.

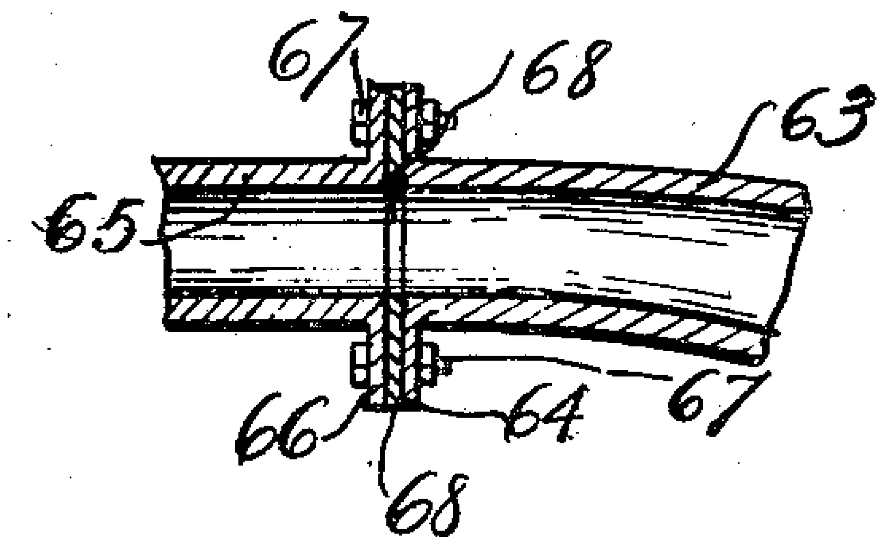

Fig. 23.

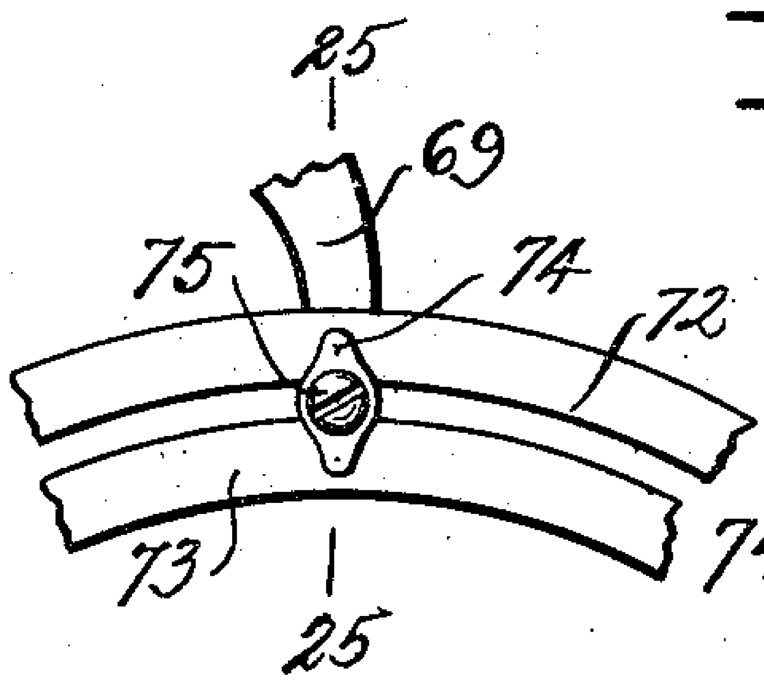

Fig. 24.

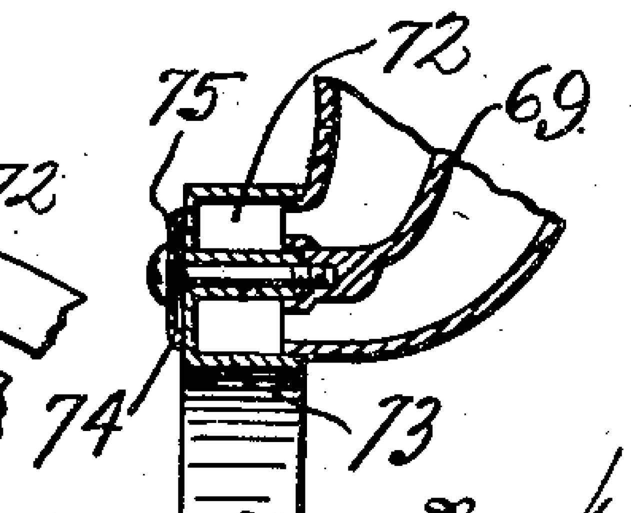

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Fig. 13.

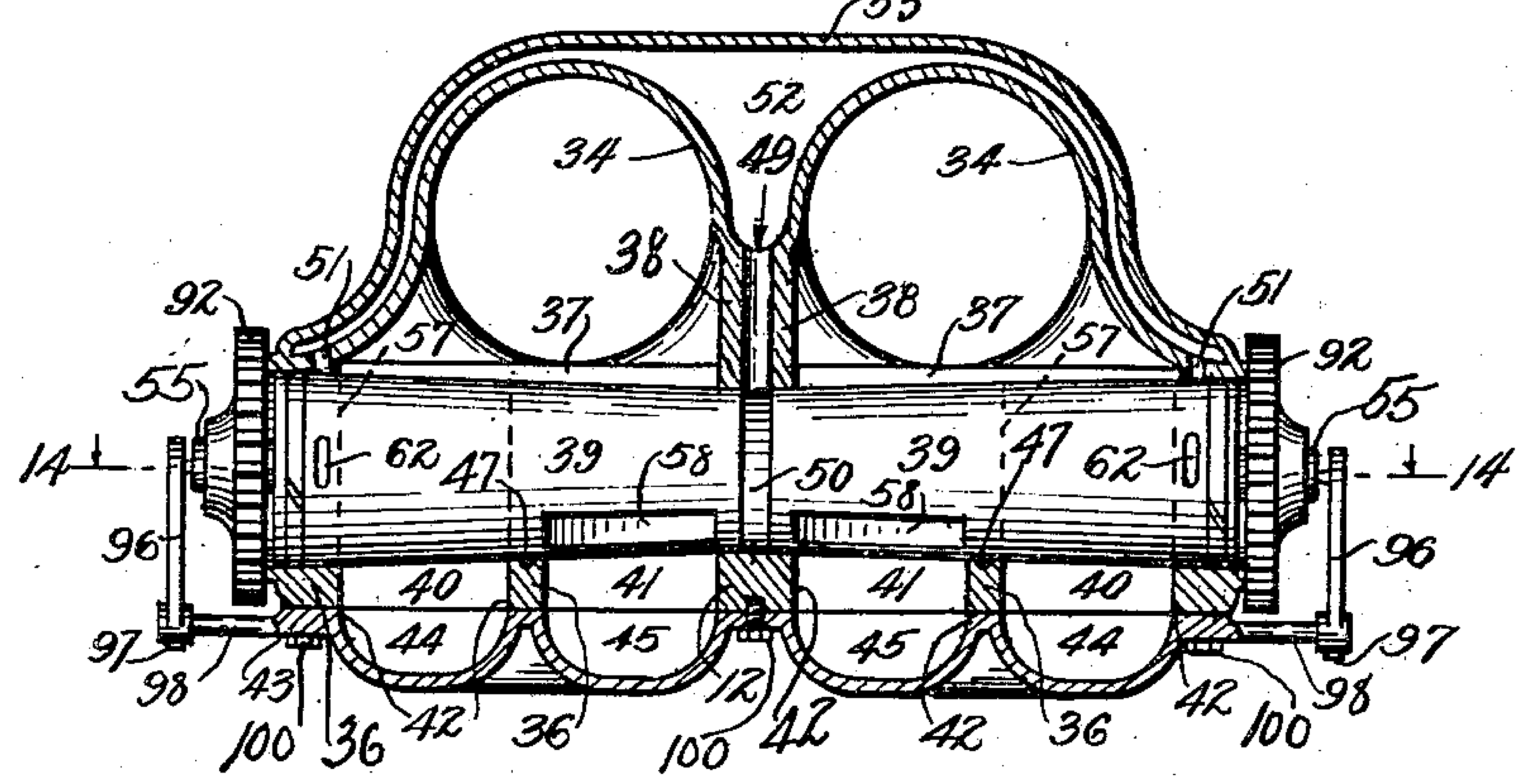


Fig. 14.

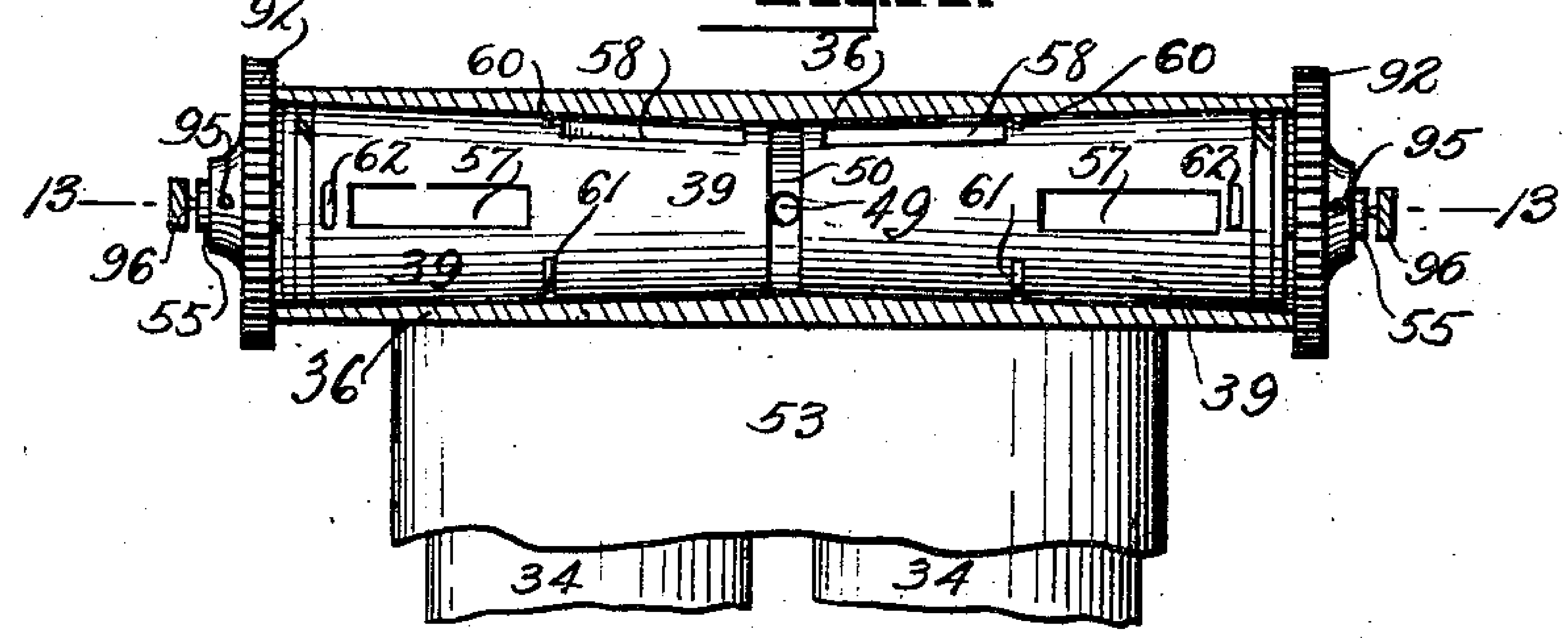


Fig. 15.

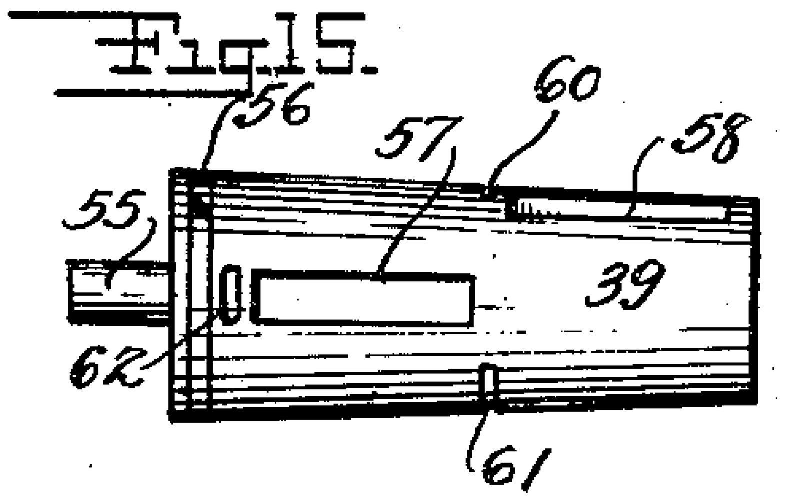


Fig. 16.

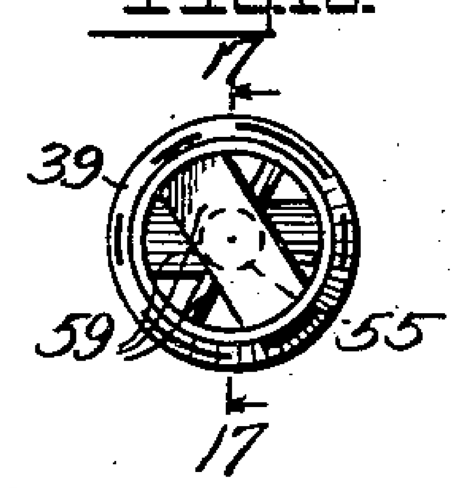


Fig. 17.

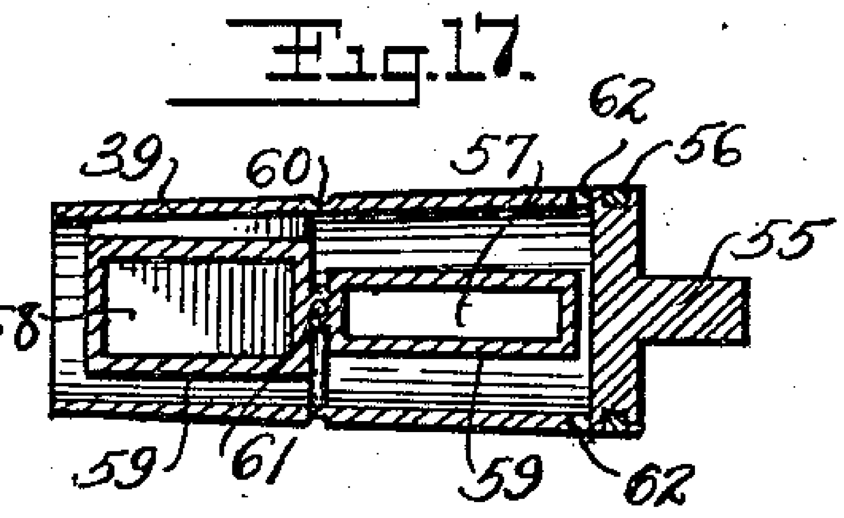


Fig. 19.

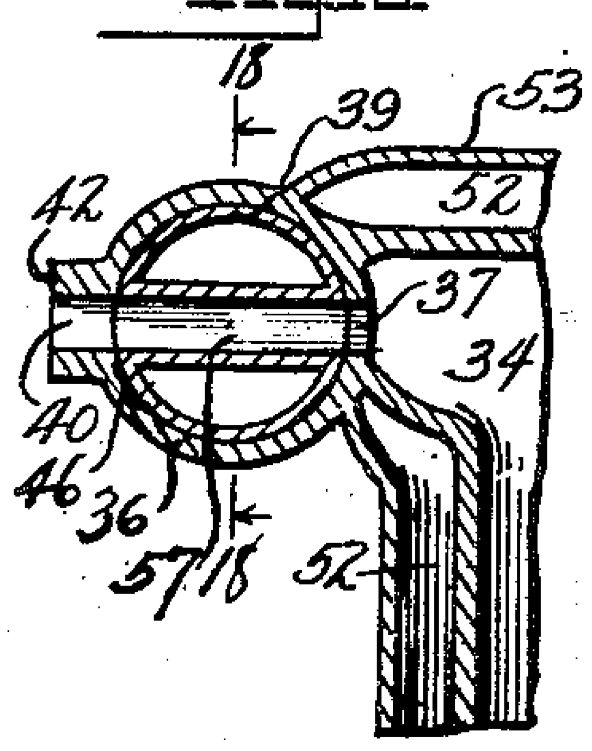


Fig. 18.

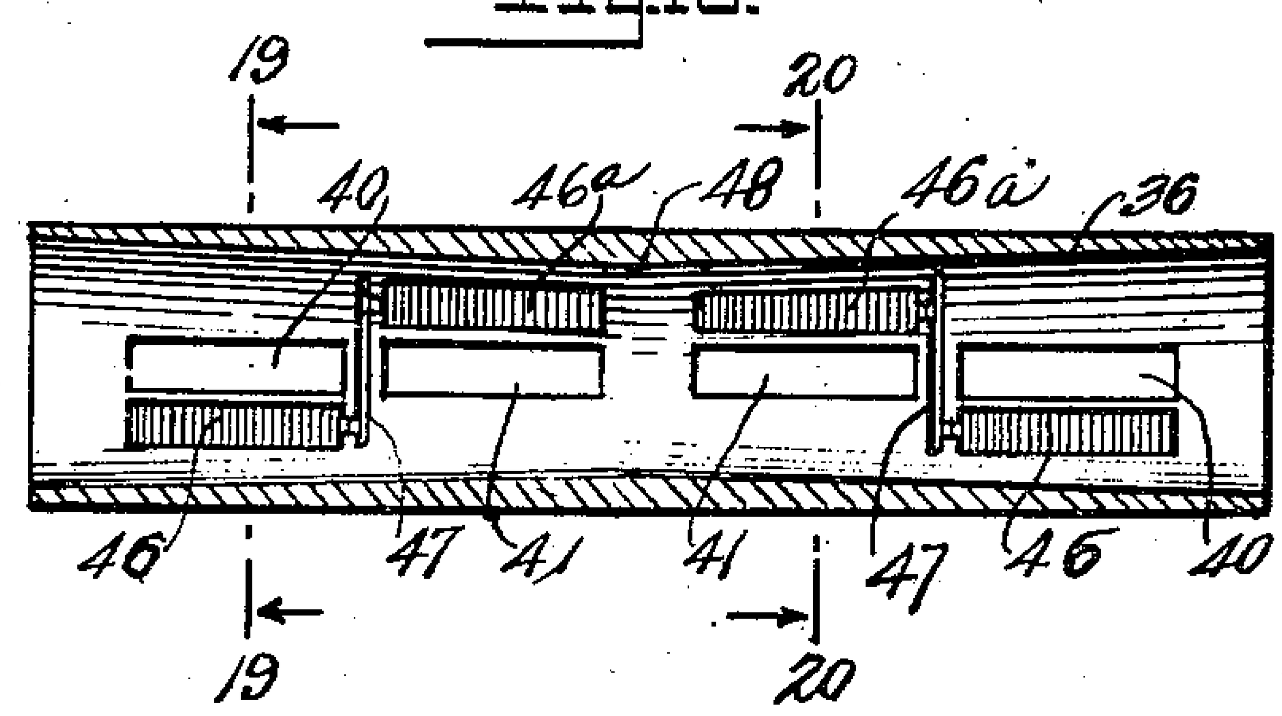
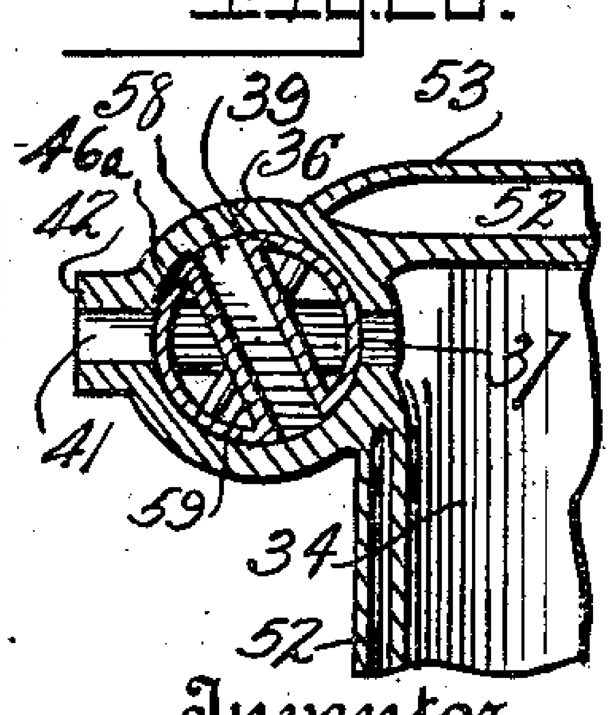


Fig. 20.



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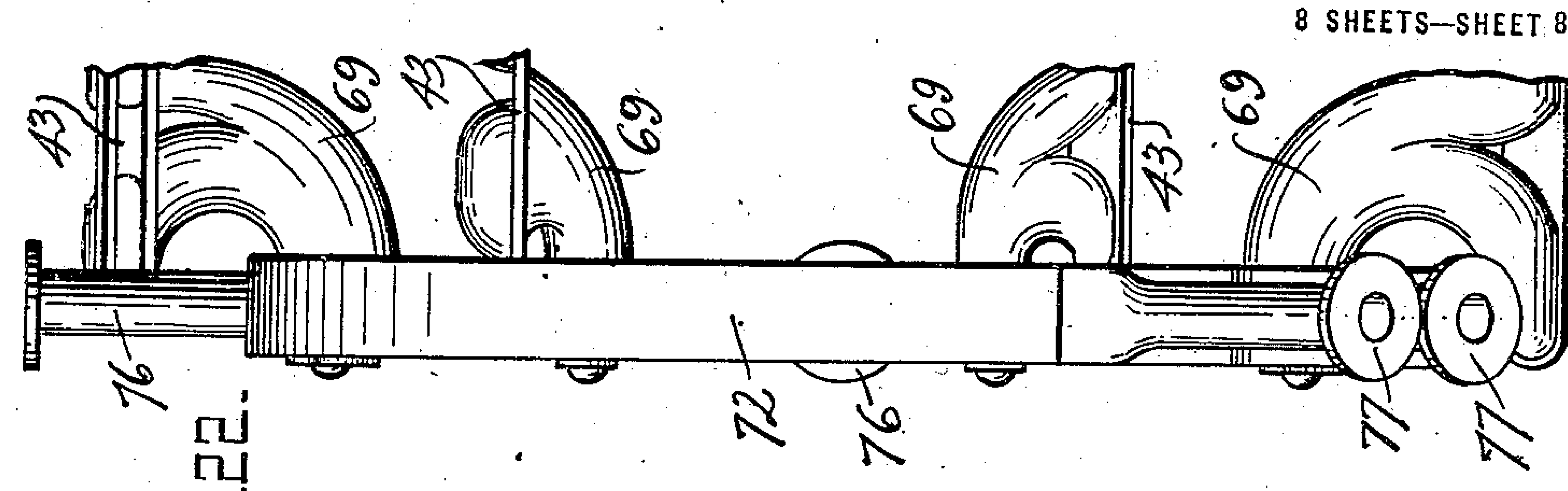

Fig. 22.

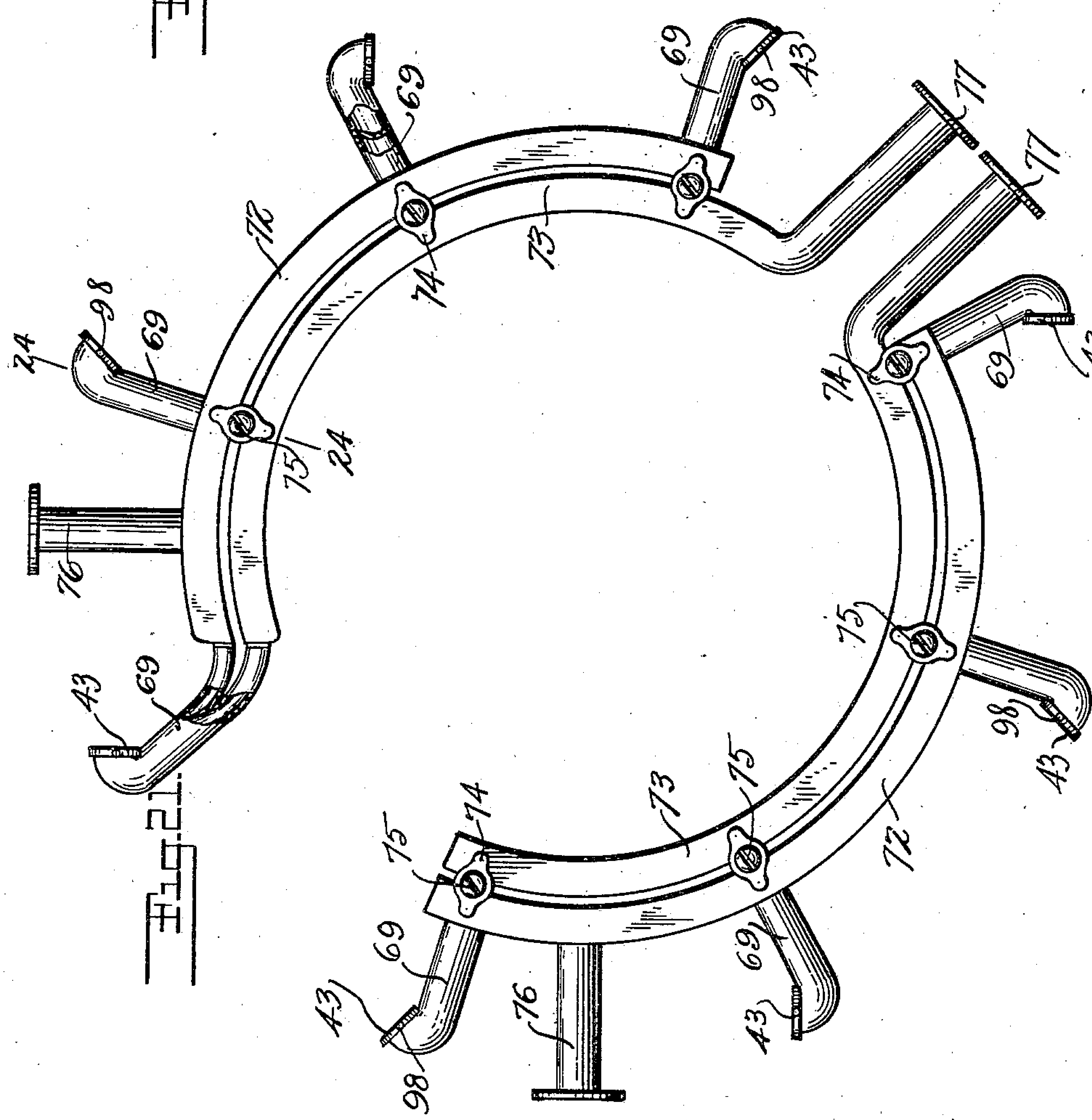

Fig. 21.

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UNITED STATES PATENT OFFICE.

JOSEPH ROTHCHILD, OF NEW YORK, N. Y., ASSIGNOR TO JOHN SIMMONS COMPANY, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK.

INTERNAL-COMBUSTION ENGINE.

1,298,098. Specification of Letters Patent. Patented Mar. 25, 1919.

Application filed November 28, 1917. Serial No. 204,327.

To all whom it may concern:

Be it known that I, JOSEPH ROTHCHILD, a citizen of the United States, residing in the city, county, and State of New York, have invented certain new and useful Improvements in Internal-Combustion Engines, of which the following is a specification.

The object and advantages of this invention are set forth hereinafter, but relate particularly to the gas admission and exhaust valve construction.

Each power cylinder has a rotary gas inlet and exhaust valve provided with an exterior gear by which it is rotated. Such valve is balanced by the compression and explosion; is tapered, endwise adjustable, and practically floating; is water-cooled and at each end is both water and mechanically sealed against escape of supply and exhaust gases; and is workable with exceedingly slight friction. By the use of such rotary valves the noise resulting from puppet valves is eliminated, and the power expended in lifting and exhaust puppet valve against cylinder pressure and the resistance of the spring for the puppet valve, is conserved.

The reduction gear drive for the rotary valves is positive and of practical importance in at least two other particulars: first, its large valve-turning gear loose on the main shaft, rotates at a peripheral speed of but one-fourth the speed of the shaft and then has a short peripheral travel in compelling the individual movements of the valves during the four-cycle operations of the pistons; secondly, if a unit is disassembled for repairs, the reassemblage can be effected with mathematical accuracy in respect to the proper relative positions of each rotary valve gear to the large valve-turning gear, by means of indication marks cut in the large gear and on each of the valve gears.

The outer water jackets over the heads of the radial cylinders are mechanically connected by water conduits, one to the other, peripherally of each multiple-cylinder unit, giving great stability to the outer ends of twin-cylinder blocks which are severally held, between their ends, by a drum-like frame to which the cylinder blocks are bolted.

Such outer end conduit connections of the cylinder blocks provide a free circulation of water around the cylinder sides and heads, in cooling relation to the valve casings and through the valves.

The construction is such that there are no interior bolts, nuts or parts to work loose.

The rotary valves are lubricated by water and the power-transmitting mechanism together with the cylinders and pistons and the piston-rod joints are lubricated by the splashing action of the power-transmitting devices within the oil-tight chamber of the drum-like frame. The stub-shafts which support the gears in the series of speed-reducing gears between a gear fixed on the shaft and the gears fixed on the rotary valve-bodies are chambered from the inside of the frame chamber toward their outward closed ends, and are provided with oil ducts through their side walls for lubricating the gear hubs on such stub-shafts. The large valve-gear driving gear is conveniently oiled from an oil cup.

In the accompanying drawings forming a part hereof and illustrating the principle of my invention in the best mode now known to me of applying that principle,

Figure 1 is a peripheral elevation, and

Fig. 2 is a side elevation of my new engine comprising two multiple-cylinder units of eight power cylinders each.

Fig. 3 is an elevational view partly in central section in the direction of the length of the shaft at line 3—3 of Fig. 2.

Fig. 4 is a transverse elevational view partly in section at line 4—4 of Fig. 3.

Fig. 5 is an end view of the power-cylinder-supporting frame with one of its end plates bolted in place. In this view parts are broken away for greater clearness.

Fig. 6 is a plan view of the power-cylinder-supporting frame, partially in section, at line 6—6 of Fig. 5.

Fig. 7 is an end view partially in section at line 7—7 of Fig. 8, of the hollow main shaft provided with two eccentric circular fixed disks which are spaced apart in the direction of the length of the shaft and project therefrom in diametrically opposite directions. This view shows in side elevation, a boss fixed at the outward side of each eccentric disk.

Fig. 8 is a side view of what is shown in Fig. 7, and is partially in section at line 8—8 of Fig. 7. It also indicates a shaft-supporting and bearing boss, one of which projects inwardly from each end-plate of the frame.

Fig. 9 is an edge view, and

Fig. 10 a side view of the power-transmission ring, Fig. 10 being partially broken away for greater clearness.

Fig. 11 is a sectional view of the power-transmission ring at line 11—11 of Fig. 10.

Fig. 12 is a central, transverse, vertical-sectional view of the twin-cylinder block at line 12—12 of Fig. 1.

Fig. 12ª is an outward side elevation of a gas manifold casing detached from the rotary valve casing and showing its integral curved conduit projections for intaken and exhaust gases.

Fig. 13 is a view partially in plan and partially in horizontal section at line 13—13 of Fig. 14, or line 13—13 of Fig. 3 looking up, and shows a water-jacketed, twin-power-cylinder block having an integral, laterally projecting rotary-valve casing and water-jacket coupling construction together with a pair of rotary valves in place and with an exterior gear on each valve and a valve-keeper for each valve.

Fig. 14 is a view partially in elevation, showing a portion of a twin cylinder casting, the valve casing and rotary valves with other parts shown in Fig. 13; the view being partially in section at a line corresponding to line 14—14 of Fig. 13.

Fig. 15 is a side elevation of one of the rotary valves detached.

Fig. 16 is a view of the smaller end of the rotary valve; and

Fig. 17 is a lengthwise vertical section of the valve at line 17—17 of Fig. 15.

Fig. 18 is a lengthwise central section of the rotary valve casing for the twin cylinder construction, detached, the section being taken at a line corresponding to line 18—18 of Fig. 19.

Fig. 19 is a sectional detail at line 19—19 of Fig. 18, showing a portion of a power cylinder with the rotary valve having its gas supply passage in line with opposed gas intake ports of the valve casing.

Fig. 20 is a sectional detail at line 20—20 of Fig. 18, and shows the rotary valve closing the gas-intake ports of the valve-casing, and having its exhaust port in the position of its alinement with opposed exhaust ports of the valve casing.

Fig. 21 is an elevational view showing the gas supply and exhaust manifolds removed from the engine but located relatively to one another as they are located in the engine.

Fig. 22 may be called an edge elevation of what is shown in Fig. 21.

Fig. 23 is a detail elevational view of a means of securing the free ends of a gas conduit structure to two gas manifolds, one for intake and the other for exhaust gas.

Fig. 24 is a sectional view at line 25—25 of Fig. 23, and illustrates the conduit structure shown in Fig. 23 as comprising two gas conduits, each in communication with a manifold.

Fig. 25 is a lengthwise sectional detail showing the opposed ends of two water conduits clamped together, each of such conduits being an extension of a water jacket over the heads of two adjacent power cylinders.

In the drawings, the various members and mechanisms illustrated and to be described are as follows:

Engine frame, main-shaft, and power-transmitting mechanism.—The engine frame 1 is a drum, exteriorly octagonal and interiorly circular, and having integral end walls 2 which are oppositely provided with relatively large central openings 3. Each exterior flat surface is provided with two power-cylinder-receiving openings 4 that are spaced apart and alined in the direction of the length of the main shaft 5 which is continuously straight through the drum and is journaled in opposed central interiorly-projecting bearings of the circular drum-end-plates 6 each of which is fitted in a drum end opening 3 and has a marginal flange 7 that is bolted to a drum end wall 2 by bolts and exterior nuts 8. The flat exterior walls of the drum are provided with appropriate bolt-holes 9 adjacent the cylinder-receiving openings. Midway between its ends, the wall of the frame is cored out circularly, forming a water-conduit 10. This conduit is intersected by ports 11 which extend outwardly to the surface of each flat face of the frame and the purpose of which is stated below. The main shaft 5, within the drum chamber, is provided with two oppositely-projecting eccentrically-fixed circular disks, one of which for one multiple-cylinder unit is marked 12, and the other of which for another multiple-cylinder unit is marked 13. Each eccentric disk in each multiple-cylinder unit is peripherally inclosed by a series of anti-friction rolls 14 which are partially inclosed by the walls of an interior groove in a power-transmission ring 15 having a rigid piston-rod-forming arm 16 which is pivoted at 17 to one of the pistons in its multiple-cylinder unit, and the purpose of which is to keep the power-transmission ring in a uniform path under all conditions. The other piston rods 18 of each unit have their inner ends respectively pivoted at 19 and at equal distances apart to the power-transmission ring of their unit, their outer ends being pivoted at 20 to their respective pistons. In each multiple-cylinder unit, the eight pistons, the piston-rods, power-transmission ring and eccentrically-mounted disk, and the anti-friction rolls, constitute one form of power-transmission mechanism whereby the power strokes of the pistons impart rotational movement to the shaft. Preferably each eccentric disk 12 and 13 is provided with a lateral boss 21 on its outward side to form a working surface directly against the inward end of the bearing-forming boss 22 cast on the inner side of each end-plate 6.

Piston construction involving diametric compactness.—The pistons in the unit provided with the eccentric disk 12 are each indicated by 23, and the pistons in the multiple-cylinder unit comprising eccentric disk 13 are each indicated by 24; but it is now pointed out that, because good practice requires the pivotal connection of piston rods and pistons to be about midway between the piston ends in order to equalize the strains brought on the far sides of the cylinders by the angular thrusts of the pistons during their power strokes, and because in the present construction the shortest permissible diametric dimension of my engine is desirable, and in order to minimize such diametric dimension it is necessary to have as little angular movement of each piston rod from the vertical as is feasible, I lengthen each piston by adding to its face a half-round outward extension 31 the outer surface of which is flush with the outer surface of the piston; and I make each pivotal connection 20 at a point midway between the ends of this piston. This however is not an essential feature.

Power-cylinder and integral rotary-valve-casing construction.—The power cylinders are cast *en bloc* in identical pairs. As the twin cylinder blocks are identical, description of one will suffice for all. Each block has between its ends a flange 32 flat on its under side and provided with bolt-holes 33. The inward ends 34 of the two cylinders in the twin-cylinder block are spaced apart in the direction of the length of the flange, correspondingly to the length of the main shaft, and are socketed in the power-cylinder-receiving openings 4 of the frame, the flange-holes 33 registering with the frame holes 9. The twin-cylinder blocks are severally bolted to the frame at 35.

The outward ends of the cylinders are solidly closed and each pair of cylinders in a block has at its upper end portion an integral, laterally-projecting, lengthwise-chambered, rotary valve casing 36, each end of the rotary valve casing projecting beyond the twin-cylinder block and having its axis parallel to the main shaft. Near its upper end, the side wall of each power cylinder in a block is formed for each rotary valve with a single elongated gas port 37 whereby each power-cylinder is as regards both supply and exhaust gas, in constant communication with the valve chamber, these two ports 37 in a cylinder block being alined and separated between their opposed ends by solid annular intermediate portions 38 of the cylinder walls and valve casing, the lengthwise-extending chamber through which forms an annular bearing for two lengthwise-alined frusto conoidal rotary valves 39 each contained in an inwardly tapered or frusto conoidal outward end portion of the lengthwise-chambered valve casing which is formed on its outward side with an elongated gas intake port 40 and with an alined and adjacent but independent exhaust gas port 41 for each of the two rotary valves, each of the two sets of ports 40 and 41 being opposite one of the two lengthwise-alined elongated ports 37 the opposed ends of which are spaced apart at the portions 38 of the casing 36, each portion 38 forming a bearing for the inward end of a rotary valve.

The two ports 40 and the two ports 41 are through the same side wall of the valve casing, and this casing is made flat along its outer side 42 for abutment thereon of the flat inner wall of a detachable gas manifold casing 43 which is formed on its inward face along its length with two outward depressions forming pockets at 44, 44, and two outward depressions forming pockets at 45, 45. These pockets 44 and 45 are respectively opposed to the inlet and exhaust ports 40 and 41, and the casing 43 has four integral conduit extensions, hereinafter described, one for leading intake gas into each pocket 44 and one for carrying off exhaust gas from each pocket 45.

The inner surface of the outward wall of the valve casing, opposite each elongated port 37 connecting each cylinder with the chamber of the valve casing, is formed below each intake gas port 40 with an elongated recess 46 extending in the direction of the length of the valve chamber; and such inner surface is also provided parallel to and above each exhaust gas port 41 with an elongated recess 46^a. The recesses 46 and 46^a are connected and in communication one with another by a transverse groove 47 which passes between the opposed end portions of each pair of adjacent ports 40 and 41. These recesses 46 and 46^a are opposed to the valve body for the greater part of its length and receive compressed gas at the compression stroke of each piston, and form explosion chambers during explosion whereby the rotary valve body itself is put under opposing pressures or in balanced pressure at each explosion, for the greater part of its length. The chamber of the valve casing is frusto conoidal inwardly from each end, the casing chamber being smallest at 48 midway between its ends. The frusto conoidal valve bodies 39 are severally mounted in an end portion of the casing chamber, each projecting part way to the mid-length section 48 of the casing.

The cylinder wall extensions where opposed at 38, 38, are spaced apart at 49 in their connection with the valve casing wall to permit the water chamber for the cylinders to communicate with the water space 50 between the inner opposed ends of the rotary valves. The wall of each cylinder has lateral extensions which are each ported at 51 in metal which forms a part of an outward end of the valve casing, and these ports 51 lead into the valve-casing chamber from the water space 52 which is formed between the cylinders and an exterior water jacket 53. The water jacket 53 extends from the flange 32 upwardly, encircling the cylinder walls and passes over the tops of the cylinders to an upper portion of the rotary valve casing. The port by which the water chamber 52 and the chamber 50 communicate is indicated by 49 and is between the portions 38 of the cylinder wall extensions and valve casing.

The larger outward end of each rotary valve is provided with a central stud 55 and the larger end of the valve body is provided with a split joint-forming ring 56. The valve body is interiorly chambered from its outer solid end from which the stud 55 projects, through its inward smaller end which is open, but the chamber is spanned by metal integral with the valve. Transversely through the solid metal portion of the valve there is formed a diametric gas intake port 57 which is elongated in the direction of the length of the valve body from its larger end part way to its mid-section; and there is also formed through the solid metal of the valve body a diametric gas exhaust port 58 which is elongated in the direction of the length of the valve from near the smaller end of the valve toward its mid-section. The interior solid portions of the valve are indicated by 59. The mid-section of the valve body is partially encircled by an exterior bleeder groove 60 with which a diametric bleeder port 61 through the solid metal 59 of the valve body communicates. The valve body is also provided with two diametrically opposite water intake ports 62 at the outward end of the valve chamber.

When two valves 39 are mounted in the valve casing chamber with their inner ends spaced apart to form the water space 50, the bleeder port 61 permits gas compressed by the piston power stroke to flow into the bleeder groove 60 and thence into the groove 47 of each valve, which groove puts the two grooves 46 and 46^a into communication and permits them to become charged with gas under compression, wherein the gas is exploded simultaneously with the explosion gas following the compression stroke, for holding the valve as stated.

The valves are cooled by admission of water through the ports 51 and the valve ports 62 into and through the chamber of the valves, and they are also lubricated by the water which in the space 50 forms a water seal for the bearing at the smaller end of each of the valves adjacent a casing wall portion 38. The joint-forming rings 56 bear on surfaces of the valve casing chamber, and water also is maintained at and adjacent to these rings to form a water seal at the outer end of each valve.

While in the small scale of the present drawings it would seem that there could not be much endwise adjustment of either valve without displacing the bleeder groove 60 from communication with a transverse groove 47, yet in full-size construction the transverse dimensions of a bleeder groove 60 and of a therewith-communicating transverse groove 47 are such as to permit the endwise adjustment of a valve without throwing the two grooves out of communication; and the endwise adjustments of the valves are also always possible within practical working limits without interfering with the communication of the ports 57 and 58 with the ports 40 and 41 respectively.

In operation, each gas intake port 57 of the valve body registers with a port 37 and 40 during the suction stroke of the piston; during rotation of the valve an imperforate adjacent portion of the valve body cuts off the communication between said ports during compression and explosion and during the exhaust stroke; and in the rotation of the valve, its exhaust port 58 registers with a port 37 and 41 during the exhaust stroke of the piston, an imperforate adjacent portion of the valve body closing the exhaust port 41 during suction, compression and explosion. The ports 57 and 58 are at an appropriate angle one to another for their described functions during their four-cycle movement; and the bleeder port and bleeder groove are properly positioned for performing their office during the compression and explosion, their function being to equalize pressure along the valve body.

Water chamber and conduit construction.—The water jacket 53 over each cylinder head and midway of the cylinders in a block, has oppositely-extending conduit extensions. One is indicated by 63. It communicates at its junction with the jacket wall 53 with the water space 49 between the cylinder wall portions 38, 38. The free end of this water conduit 63 extension which curves circumferentially relatively to the unit and projects part way across the space between its cylinder and an adjacent cylinder, is provided with a flange 64. The other is indicated bv 65. It extends in a direction opposite to the direction of the projection of conduit 63, is alined with the conduit 63, and curves in the circumferential direction of the unit, and has its free end provided with a flange 66 provided with bolt-holes.

In the assemblage of the radially-disposed identical twin cylinder blocks, the conduit flanges 64 and 66 of each block are respectively joined to the corresponding flanges 66 and 64 of adjacent blocks, one at each side of it. The opposed flanges are bolted together at 67, gaskets 68 being interposed between the flanges.

By this construction the cylinder heads are all circumferentially connected together wholly around the engine by conduit connections, which as mechanical connections reduce vibration in the outward ends of the cylinder blocks and give stability to the whole structure.

Assuming now that water be admitted through the water intake nozzle W (Fig 2) at the under side of the engine, it will in its filling of the water chambers and conduits find its way from the water space about the head and between the two cylinders in the under block (Fig. 3) provided with the nozzle W, through the frame ports 11, 11, into the circular conduit 10 in the frame, from which conduit it will flow outwardly through the remaining frame ports 11 to the water chambers of the remaining cylinder blocks, and through the ports 11^a in the flange 32 of the cylinder block between the cylinders and through all the conduits 63 and 65 until all the water chambers and conduits are properly supplied with water. It will also find its way through the ports 51 (Fig. 13) and valve ports 62 into the valve body chambers, and about the end portions of the valves and between them and into the water space 49 and space 50. When the water becomes hot it will rise and the circulation will be out through the water escape nozzle W′ (Fig. 2). It is assumed that the induction nozzle W and the eduction nozzle W′ are in communication respectively with the induction and eduction sides of a pump. The water pump may be connected with the ports 11, 11 if desired. It will be observed that the water jackets and interconnected nozzles are exposed to the air not only above the heads but also between the radial cylinders, and in this sense the engine is its own radiator.

The gas intake and exhaust gas manifolds.—Each gas manifold casing 43 above referred to as having dependent curved gas intake and exhaust conduit extensions, is provided in communication with each gas intake pocket 44 with a gas intake conduit extension 69 and in communication with each exhaust gas pocket 45 with an exhaust gas conduit extension 70. At each end portion of casing 43 one of the gas intake conduits 69 and one of the exhaust gas conduits 70 curves not only inwardly in the general direction of the shaft, but also outwardly. The conduits 69 and 70 are shown integral with the casing. The inward free end portions of each conduit 69 and 70 are cast integral together and are spaced apart by integral metal at 71 which is tapped for reception of a screw.

On each outward side of each multiple cylinder unit, some of the inward ends of the gas intake conduits 69 make a tight joint with one arced intake gas manifold 72, and other conduits 69 make gas-tight joints with another arced intake gas manifold 72.

At each side of the engine the ends of some of the exhaust gas projections 70 make gas-tight joints with one, and some with another arced exhaust manifold 73. That is, at each side of each multiple-cylinder unit there is an upper and also an under intake gas manifold, and also an upper and an under exhaust gas manifold, and these upper and under arced manifolds are in concentric pairs one above the other in each of the two pairs. They are discontinuous for convenience of construction and assemblage; the members of each pair are spaced slightly apart, and each upper and under pair of these manifolds is supported in place conveniently by means of yokes 74 which span the outer sides of the adjacent projections and are clamped in place by the heads of screws 75 the shanks of which pass through the yokes, between the two manifolds in a pair, and are tapped into the solid metal 71 which unites the free ends of the conduits 69 and 70.

Each intake gas manifold 72 is provided with an intake nozzle 76 and each exhaust gas manifold is provided with an exhaust gas nozzle 77.

The valve-actuating mechanism.—At each outward side of each multiple-cylinder unit there is a valve-actuating mechanism. As these mechanisms are identical, description of one will suffice for both. The main shaft (Fig. 3) is provided with a fixed spur gear 80 which meshes with a loose spur gear 81 on a stub shaft at 82 that is shown projecting from a frame end-plate 6. The hub of the gear 81 is provided with an outward and smaller loose gear 83 which meshes with a loose spur gear 84 on a stub shaft 84^a at the inward end of a bracket 85 which at 86 is fixed to an end wall 2 of the frame. This bracket at its outward end supports a stub shaft 87 on which there is a loose spur gear 88 which is in mesh with the gear 84. The hub of the spur gear 88 is provided with a smaller spur gear 89 between its outward face and a disk 90 at the outer end of its hub. This gear 89 meshes with a large valve-driving gear 91 which is in constant mesh with the series of gears 92 one of which is fixed on each of the rotary valve studs 55. The hub 93 of the valve-gear driving-gear 91 is loose on main shaft 5 and is shown held in place by a collar 94. The periphery of the gear 91 works laterally between the opposed walls of the gear 81 and of the disk 90 whereby the periphery and outer portion of the gear 91 are steadied and held in line during their work. The valve gears are fixed to the studs 55 as indicated by 95, and each rotary valve is held inwardly by a suitable valve-keeper 96 the free end of which impinges on the outer end of a valve stud 55, the other end of the keeper 96 having its hub adjustably connected at 97 to an end projecting arm 98 of the detachable manifold casing 43.

The gears intermediate the gear fixed on the shaft and the gears fixed on the valve studs are all loose gears and comprise reduction speed gears whereby every two rotations of the main shaft cause each valve gear to give its valve one complete rotation to suit the four-cycle operations of the power cylinders and pistons.

I show on one of the end plates, Fig. 5, oppositely-extending projections 99 the free ends of which may be fixed, for example, to the sides of a fuselage to keep the engine frame from turning.

The gas manifold casing 43 is shown bolted to the rotary valve casing at 100, and the lengthwise-extending chamber or bore of the main shaft is indicated by 101.

Various constructional changes may be made without departure from the invention.

What I claim is:

1. In an internal-combustion engine, the combination of a pair of power cylinders cast in a block having a flange between its ends and a rotary valve casing common to the pair of cylinders in the block; each cylinder in the block having an elongated gas port opening into the chamber of the valve casing at each end portion thereof; the casing being chambered from end to end and being frusto conoidal from each outer end toward its mid-section; a frusto conoidal rotary lengthwise-chambered gas supply and exhaust valve located in each end portion of the valve chamber and having an outwardly-projecting fixed valve-rotating member; the valves extending only part way to the mid-section of the valve casing chamber, the latter and each valve being ported for admission of water to and through each valve; water jackets for the cylinder walls in each block, the jacket water-chamber being in communication with the mid-section of the valve casing; and water-conduit connections between all the water jackets.

2. In the structure of claim 1, as means intermediate the main shaft and said valves for actuating them, for each series thereof, a gear fixed on the main shaft; a valve-gear actuating gear loose on the main shaft; a gear fixed on each valve; and a train of loosely mounted intermediate speed-reduction gears between said fixed gear on the shaft and said valve-gear actuating gear, the latter being in mesh with all the valve gears.

3. In the structure of claim 1 the inner surface of the valve chamber wall having lengthwise-extending gas-receiving recesses and a groove connecting them to put the recesses into communication one with the other; the valve being provided with a gas intake port, with an exhaust port, and with a bleeder port and bleeder groove for putting the cylinder chamber and said groove and recesses into communication during the compression stroke of the piston and explosion; and means intermediate the shaft and valve to rotate the latter synchronously with the piston movements and to permit gas in said recesses to be exploded simultaneously with the explosion in the cylinder chamber, all constructed and operating for balancing the valve when explosions occur.

4. In an internal-combustion engine, the combination of an open-ended chambered power-cylinder supporting-frame having end walls provided with openings; clampable end plates to cover said openings; a main shaft journaled in the end plates; within the chamber of the frame a pair of power-transmitting mechanisms spaced apart along the shaft in the direction thereof, and each comprising a series of power pistons; fixed to the frame a series of twin-cylinder blocks radially disposed to the shaft and severally positioned with their longer dimensions extending in the direction of the length of the shaft; the series of pistons in each power-transmitting mechanism working in a circular series of the power cylinders; each twin-cylinder block having a rotary valve chamber the axis of which is parallel to the main shaft; a pair of rotary gas supply and exhaust valves in each valve chamber, the latter being in ported communication with its cylinder chamber; intercommunicating water-jacket chambers for all the power cylinders, such chambers being in communication with water chambers formed between opposed ends of each two valves in one casing and also within the valves; for each rotary valve casing, an intake gas conduit and an exhaust gas conduit each communicating with one end portion of the casing chamber; and connected

with the other end portion of the casing chamber, another gas-supply conduit and another exhaust conduit; the two conduits at each end portion of the casing extending inwardly in the general direction of the shaft, and each of the conduits at each end portion of the casing communicating with an arced manifold supported in a side portion of the engine; and for all the rotary valves on each side of the engine, a valve-gear driving mechanism operatively connected with the main shaft.

In testimony whereof I have hereunto set my hand this 27th day of November, 1917.

JOSEPH ROTHCHILD.