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La Puente, Calif.

[21] Appl. No. 805,936
[22] Filed Feb. 13, 1969
[45] Patented June 22, 1971
[73] Assignee General Management Company
North Hollywood, Calif.
a part interest
Continuation-in-part of application Ser. No. 553,227, May 26, 1966.

[54] RADIAL CHAMBER POSITIVE DISPLACEMENT, FLUID POWER DEVICE
29 Claims, 55 Drawing Figs.

[52] U.S. Cl. 123/8.45, 418/91
[51] Int. Cl. F02b 53/04, F02b 55/08, F01c 19/02
[50] Field of Search 91/67; 230/140; 123/8, 16

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Primary Examiner—Mark M. Newman

ABSTRACT: The specification discloses a radial chamber, positive displacement, fluid power device including a housing means, a piston means of somewhat smaller cross-sectional configuration positioned within the housing means, and vane means between the housing means and the piston means and sealingly cooperable therewith for defining two or more angularly adjacent inner chamber spaces of a complete chamber defined within the housing means. The housing means and the piston means are both supported by a pair of relatively eccentrically related supporting means having two eccentrically related spaced substantially parallel axes referred to herein as a housing axis and a piston axis and coaxial, respectively, with a corresponding actual axis of said housing means (usually substantially centrally disposed of said housing means although not specifically so limited in all cases) and a corresponding actual axis of said piston means (usually substantially centrally disposed of said piston means, although not specifically so limited in all cases). Said supporting means may also be said to have an axis of operation substantially parallel to said housing axis and said piston axis and positioned in a plane terminating at one end and being coincident with said housing axis and terminating at the other end and being coincident with said piston axis, thus making it possible for said axis of operation in certain forms of the invention to be coincident with said housing axis, in other forms of the invention to be coincident with said piston axis, and in further forms of said invention to lie between said housing and piston axes. The relatively rotatable support of said housing means and said piston means by said supporting means is such as to provide for substantially simultaneous relative rotation thereof around said axis of operation of said supporting means and for simultaneous relative rotation of at least one of said housing and piston axes around said axis of operation and relative to said housing means and said piston means in an opposite direction in a manner such as to effect cyclic contraction and expansion of the chamber spaces without any substantial relative angular movement between said piston means and said housing means occurring.

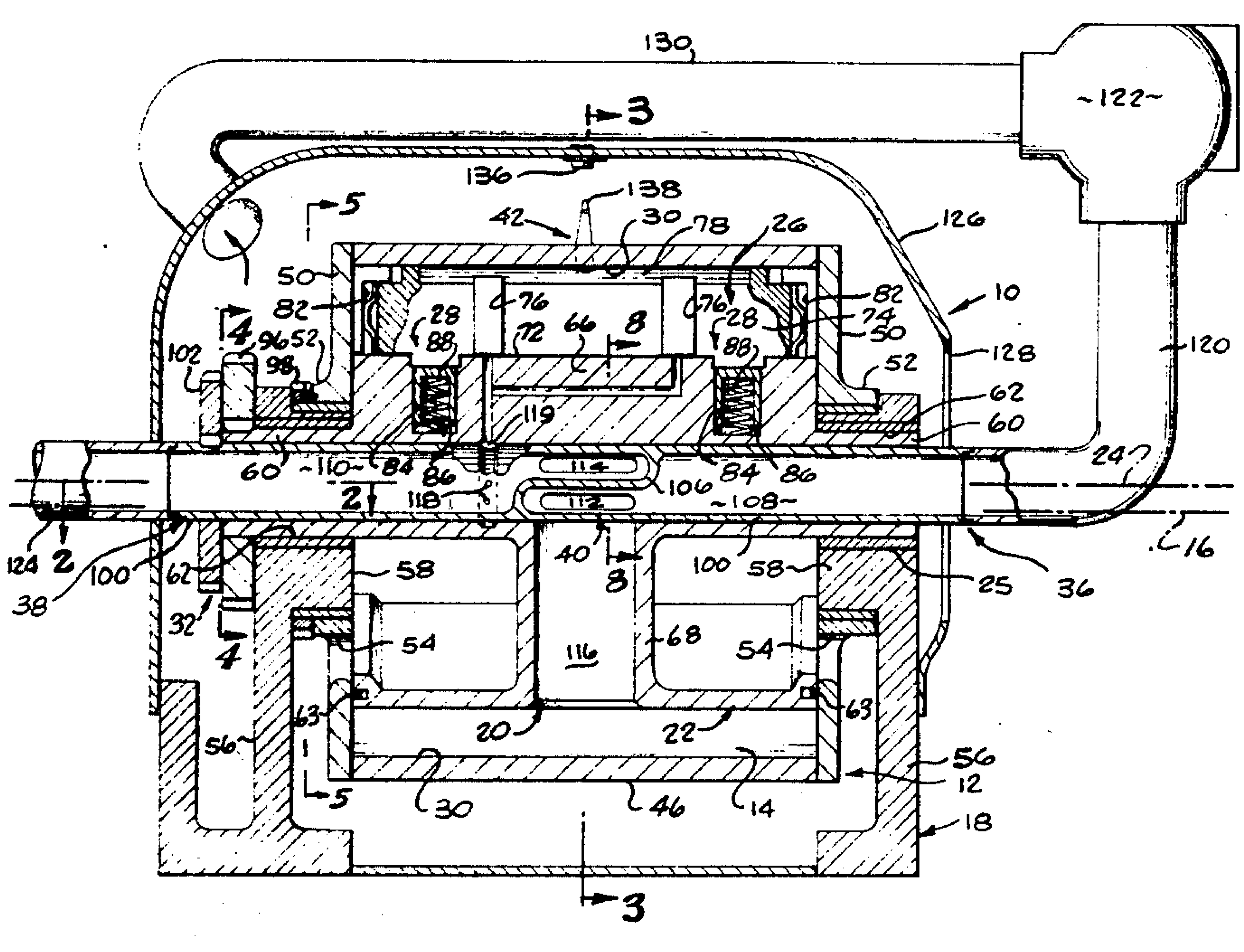

FIG. 1

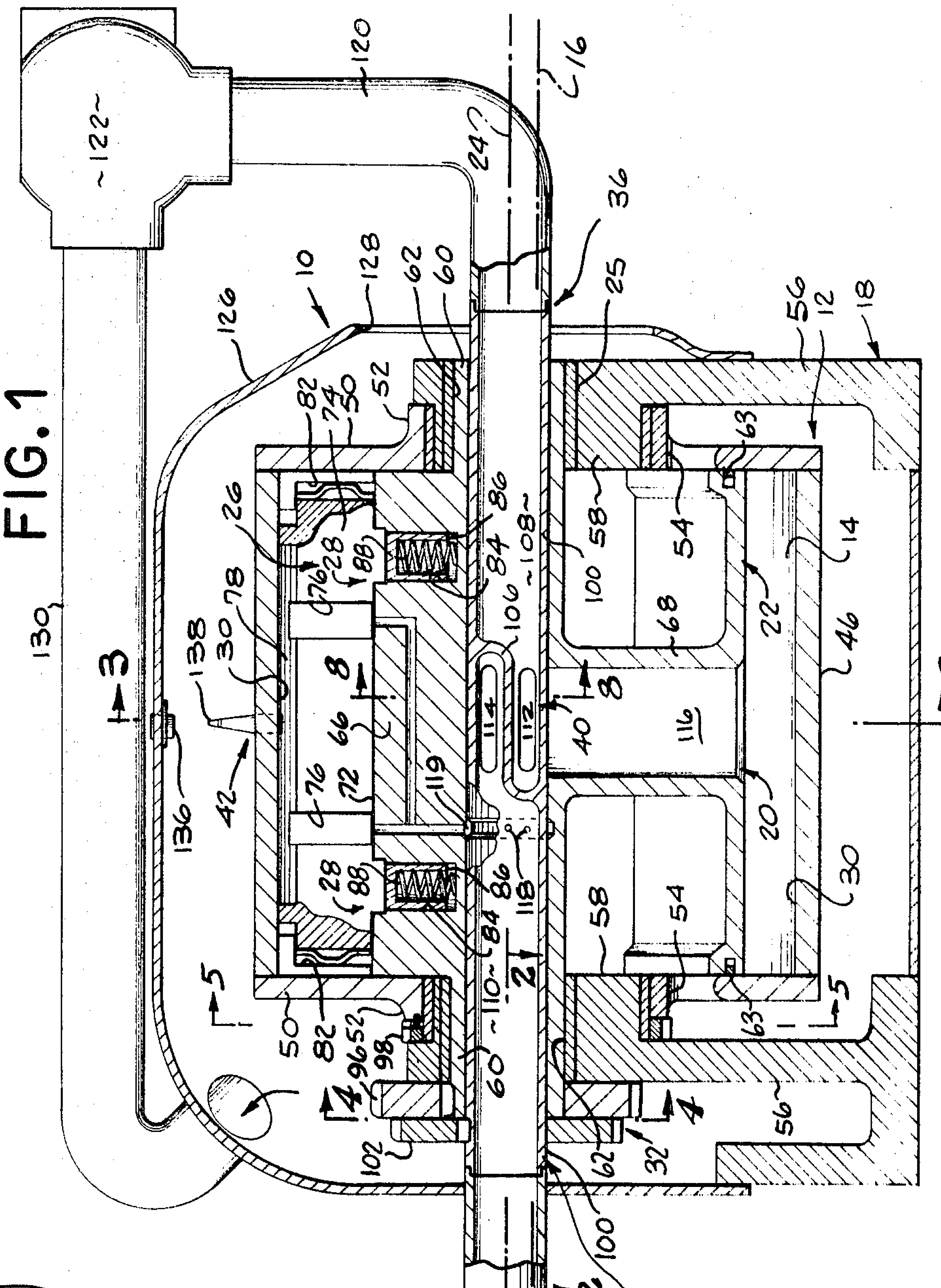

FIG. 2

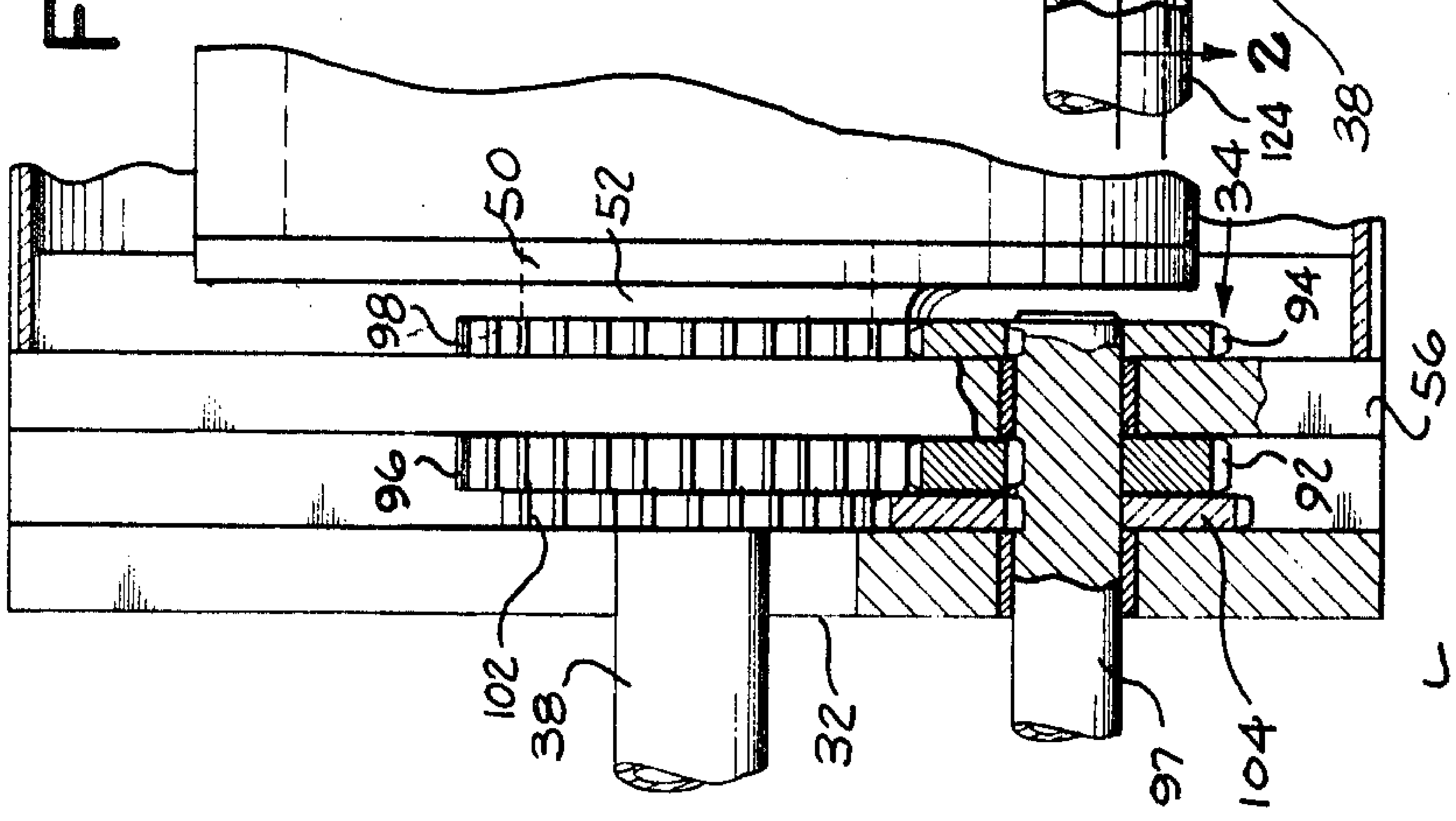

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FIG. 3

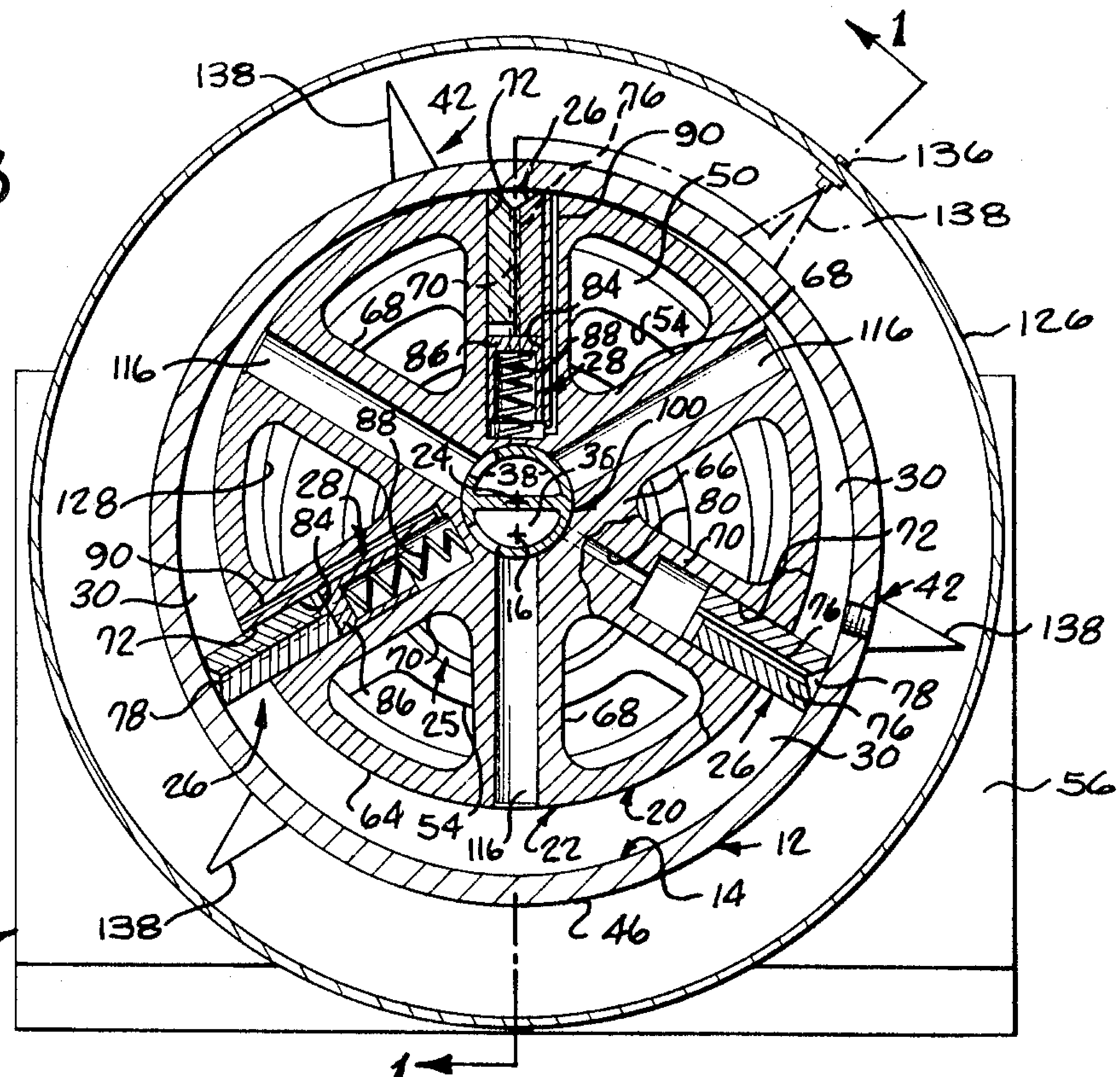

FIG. 3a

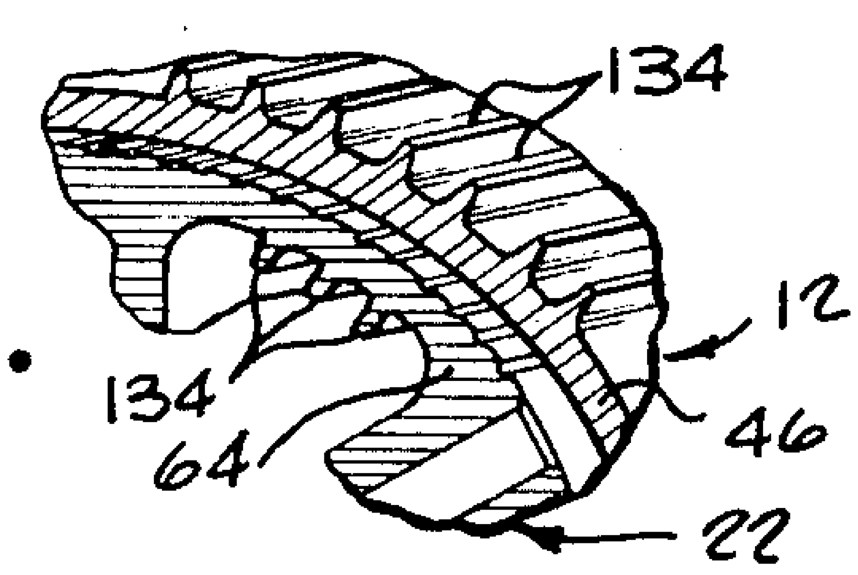

FIG. 5

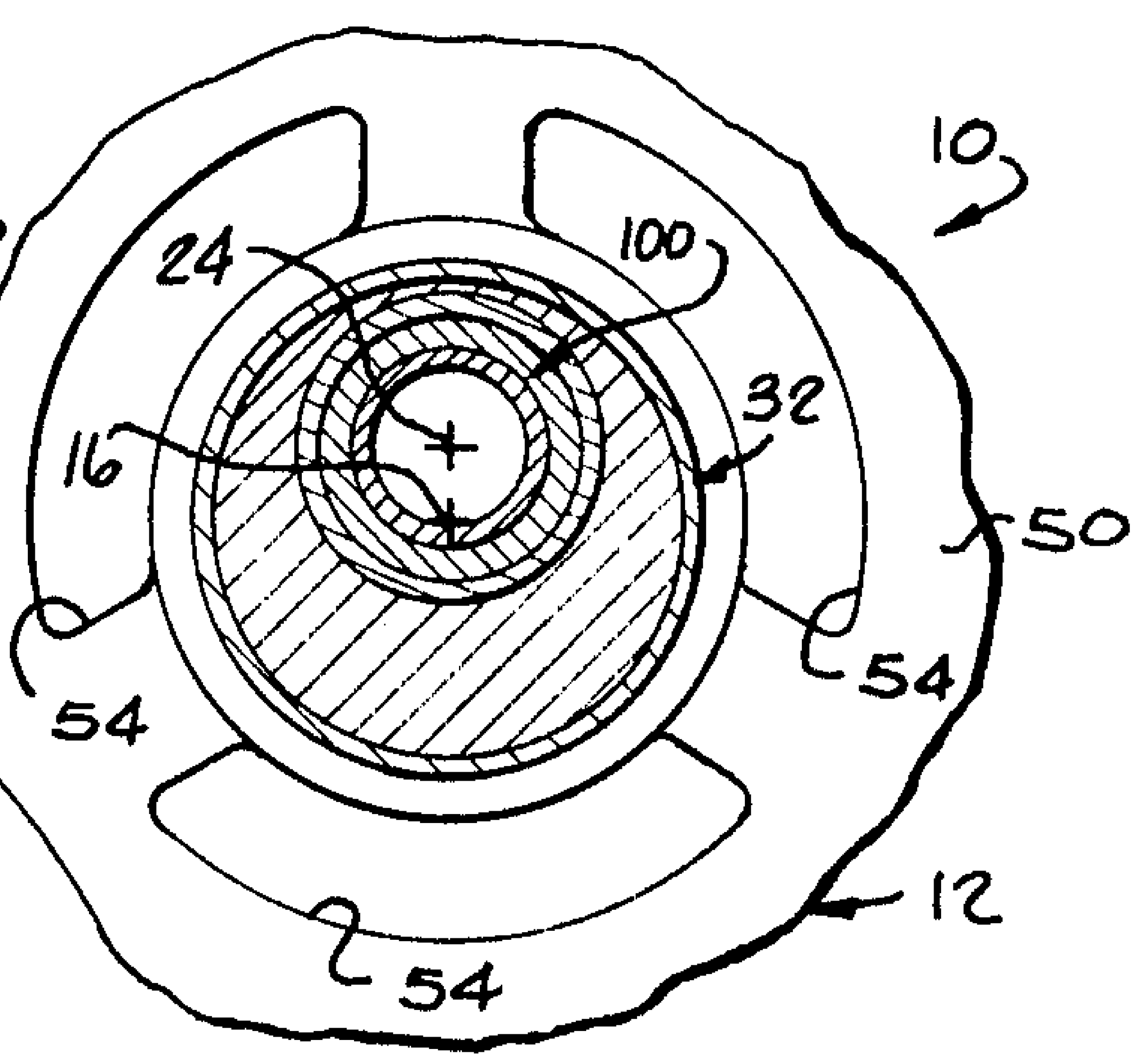

FIG. 4

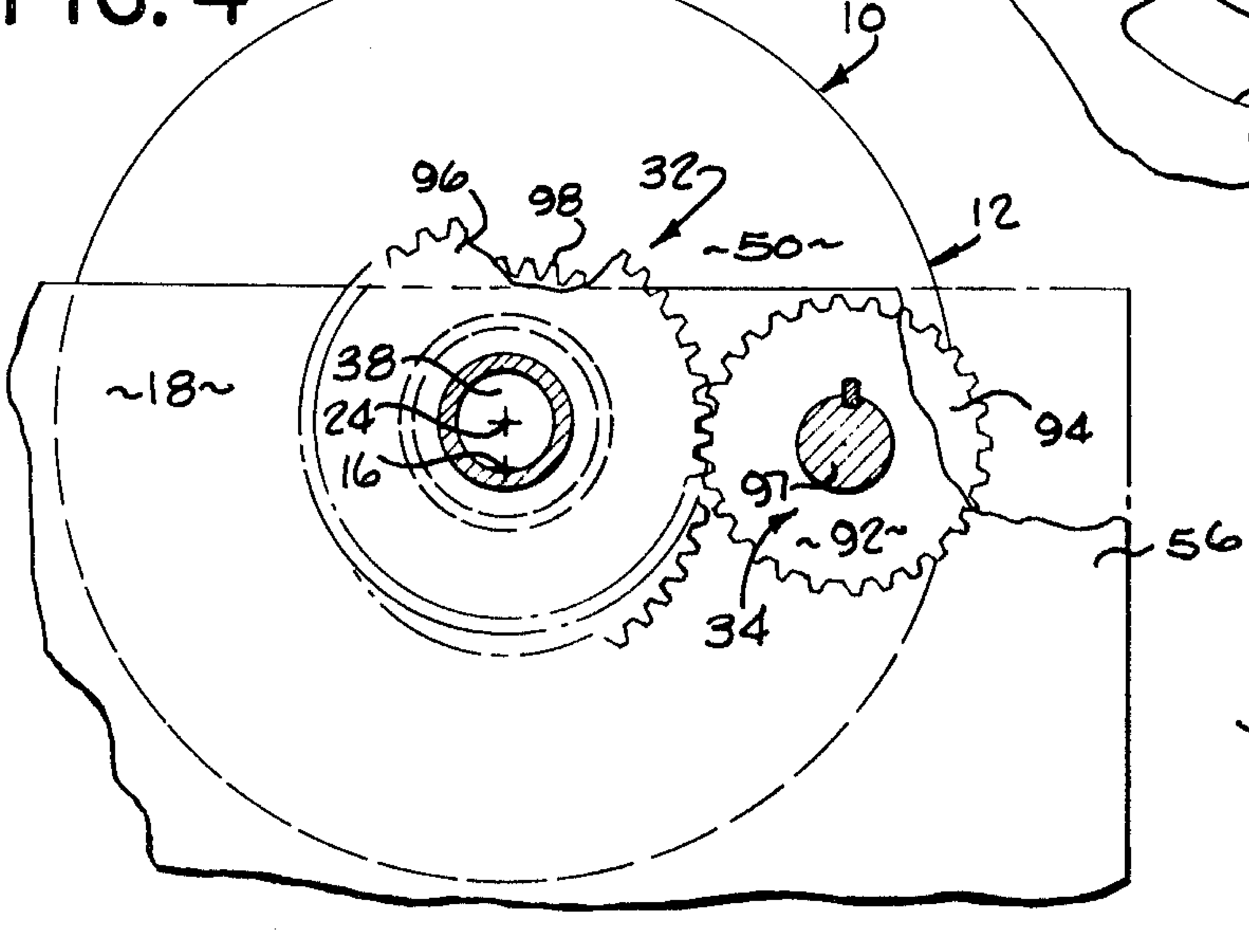

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FIG. 6a

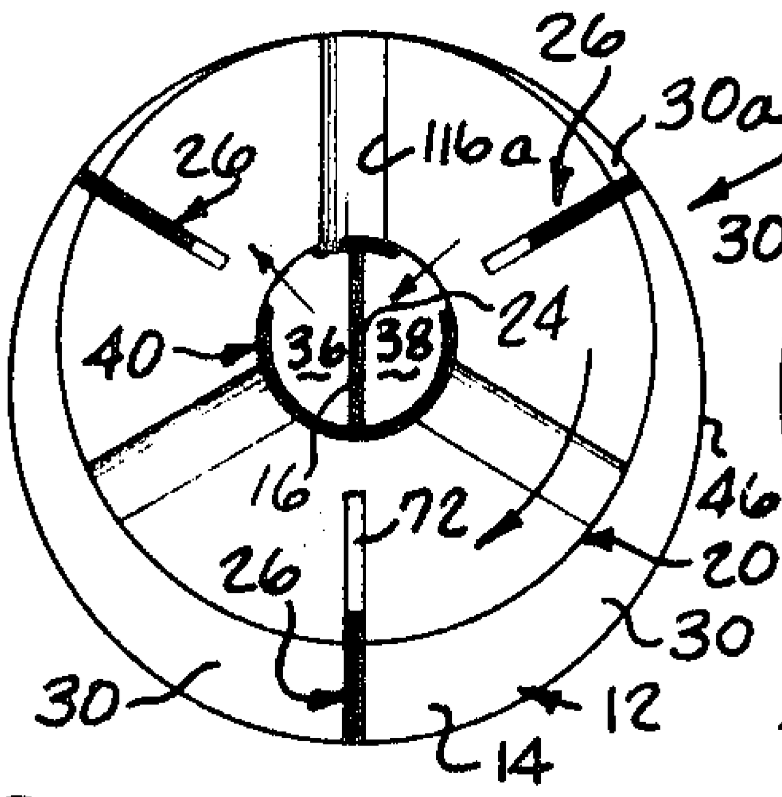

FIG. 6b

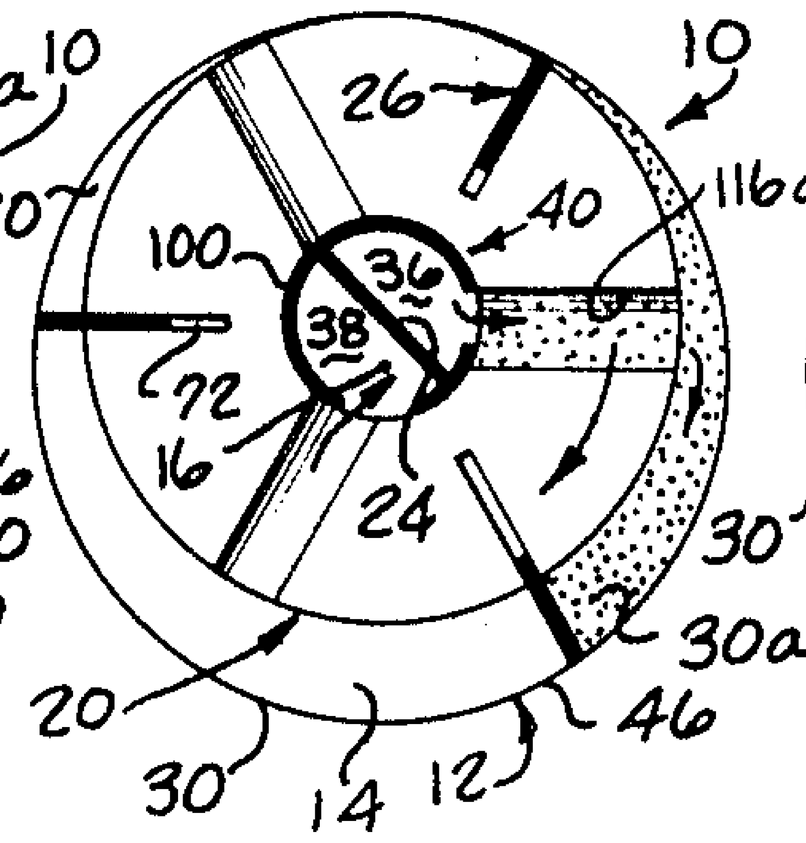

FIG. 6c

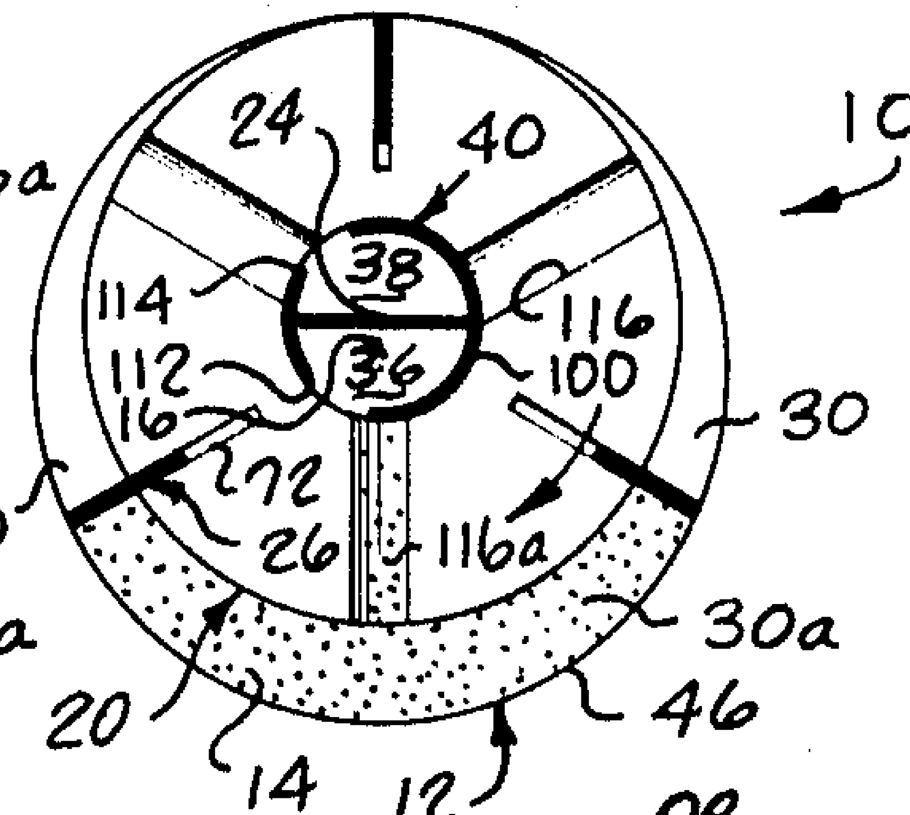

FIG. 6d

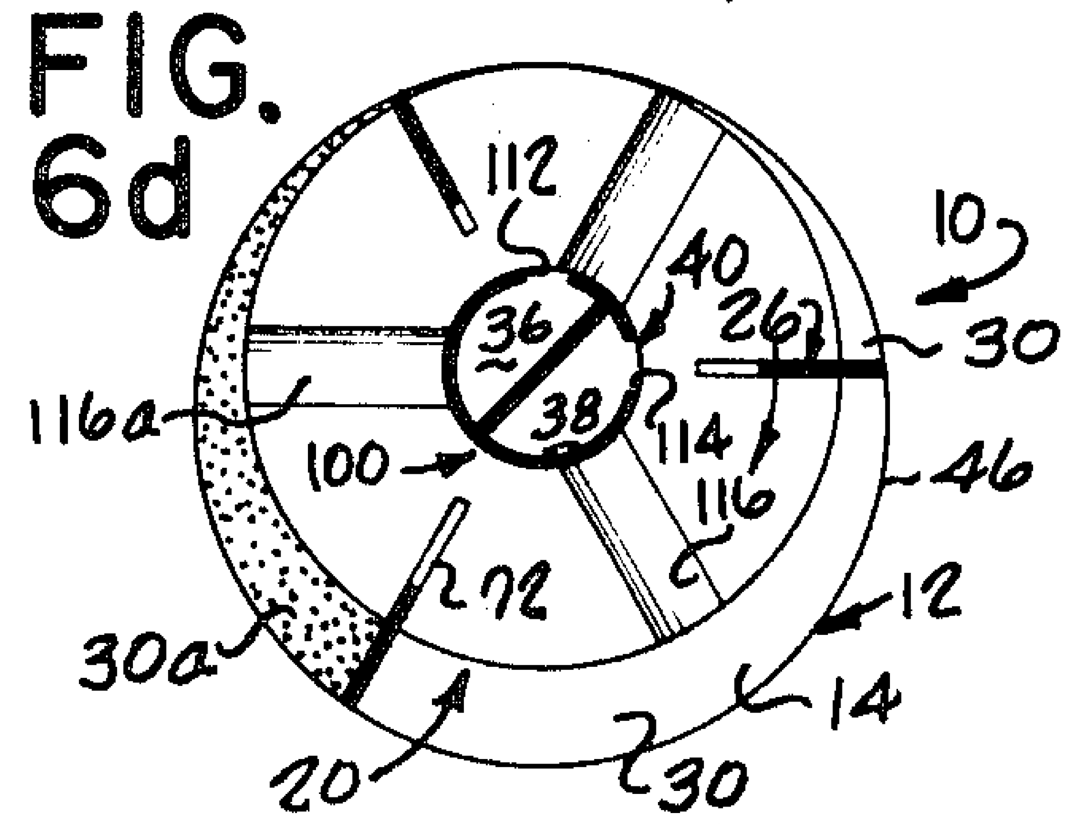

FIG. 7

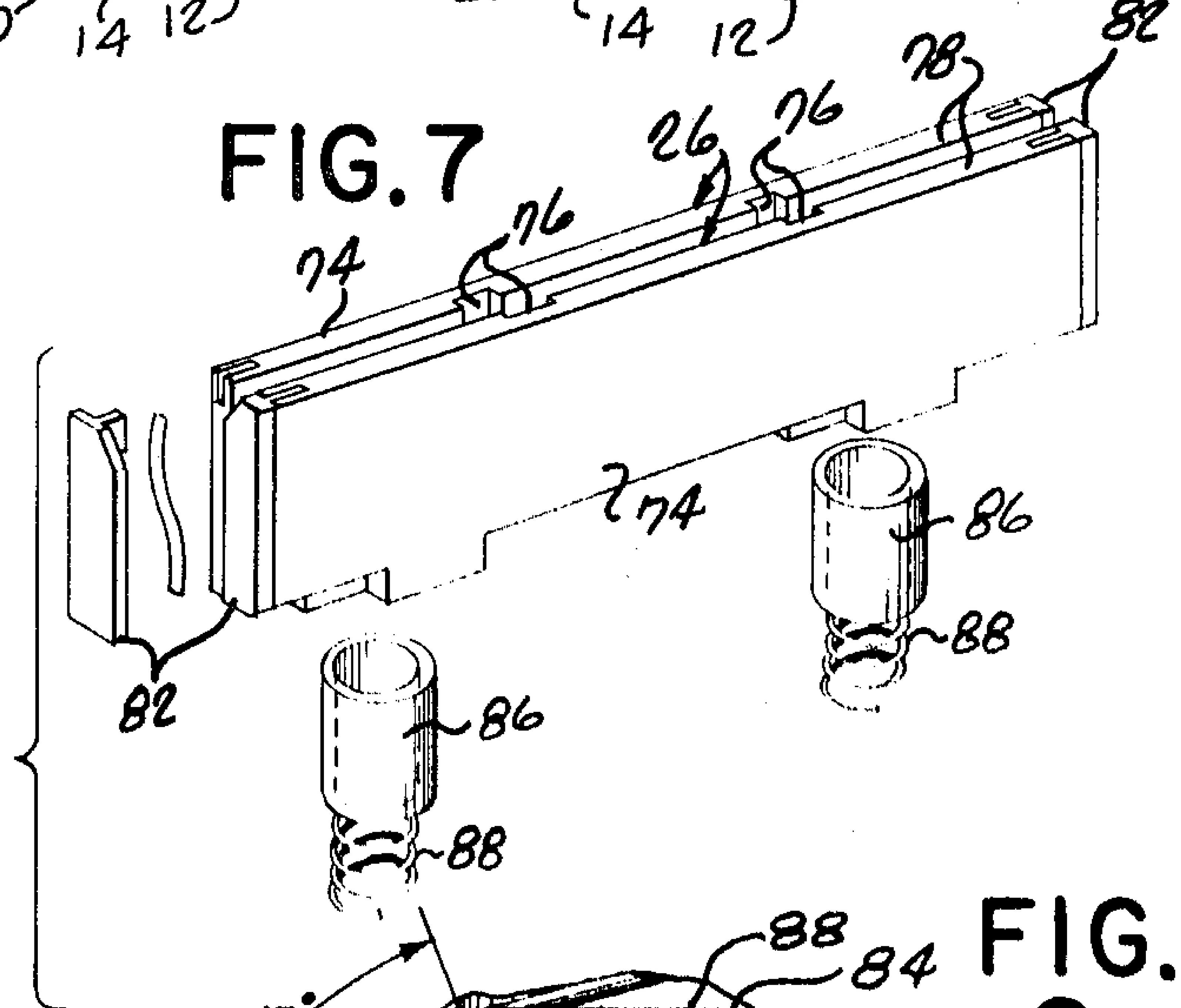

FIG. 6e

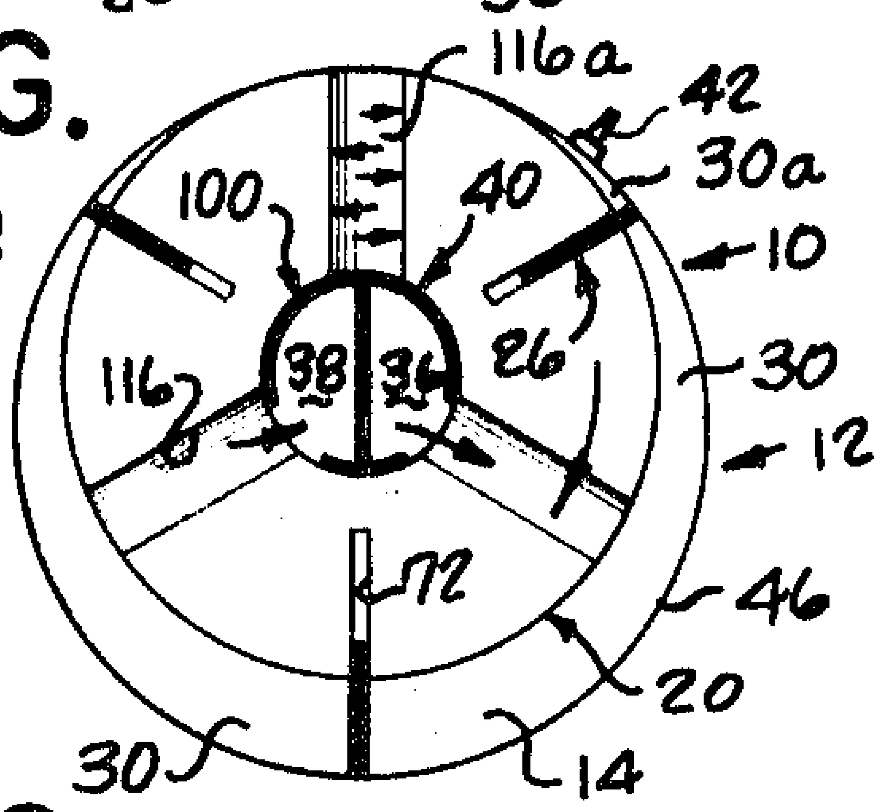

FIG. 8

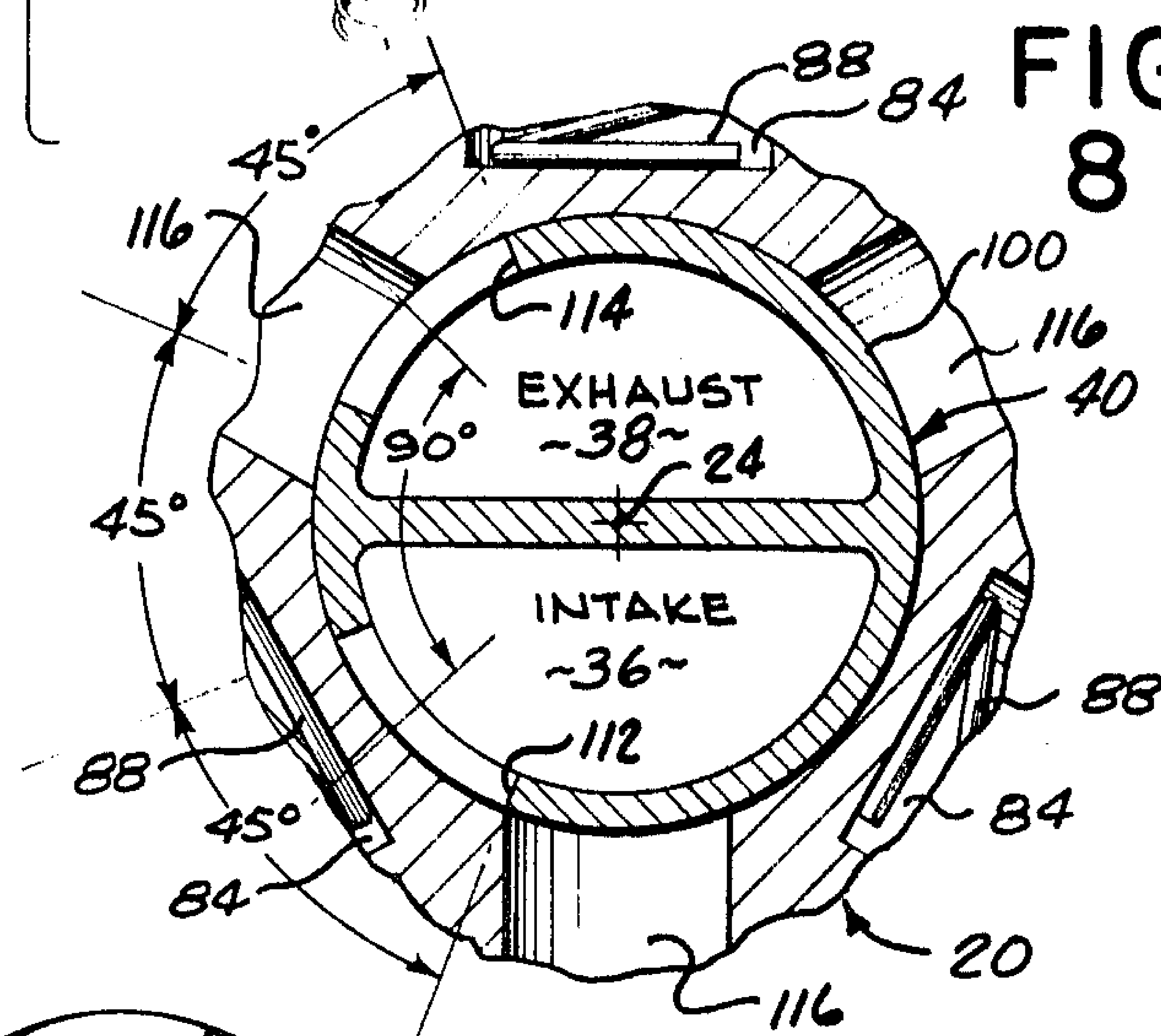

FIG. 6f

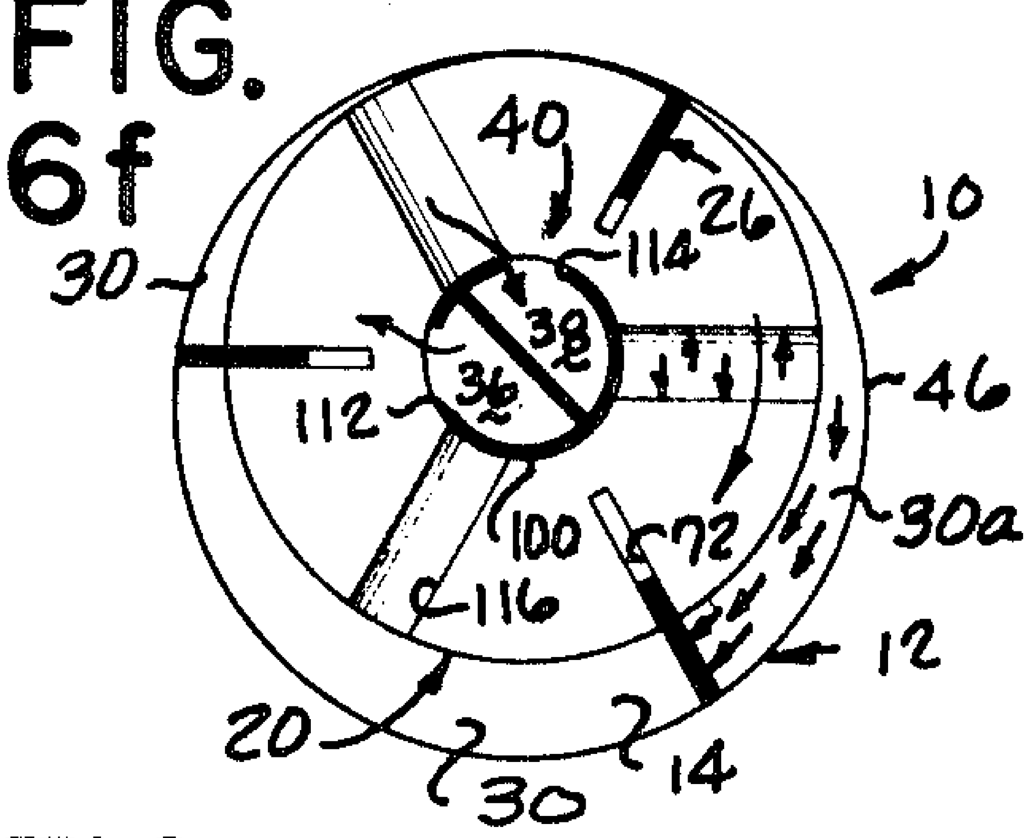

FIG. 6g

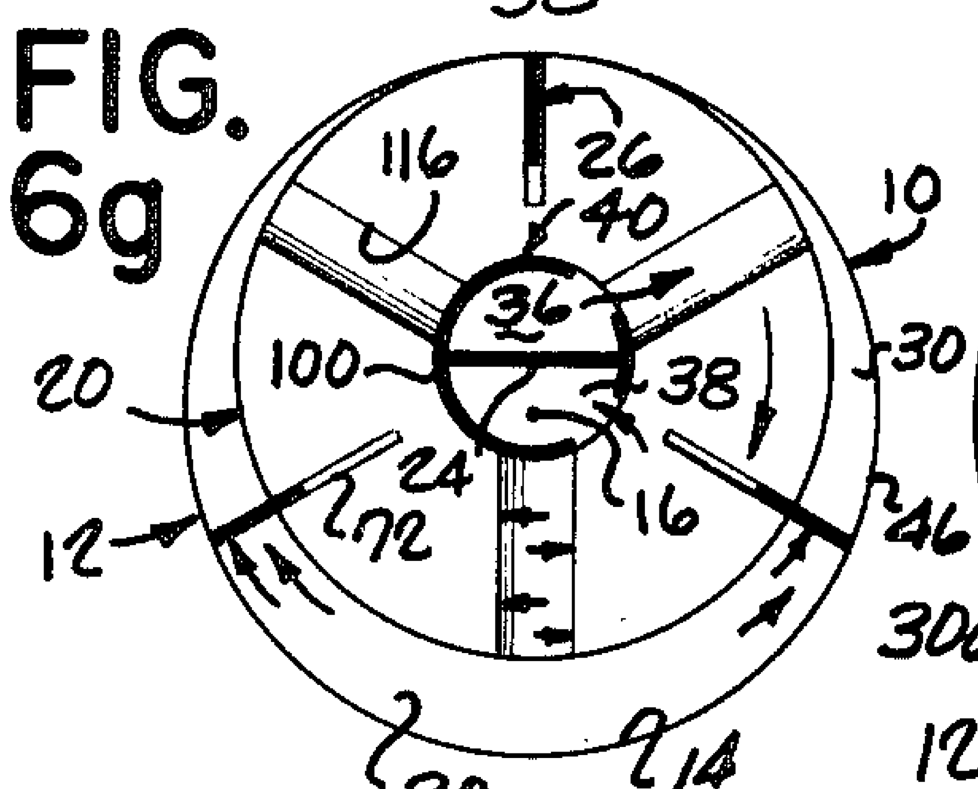

FIG. 6h

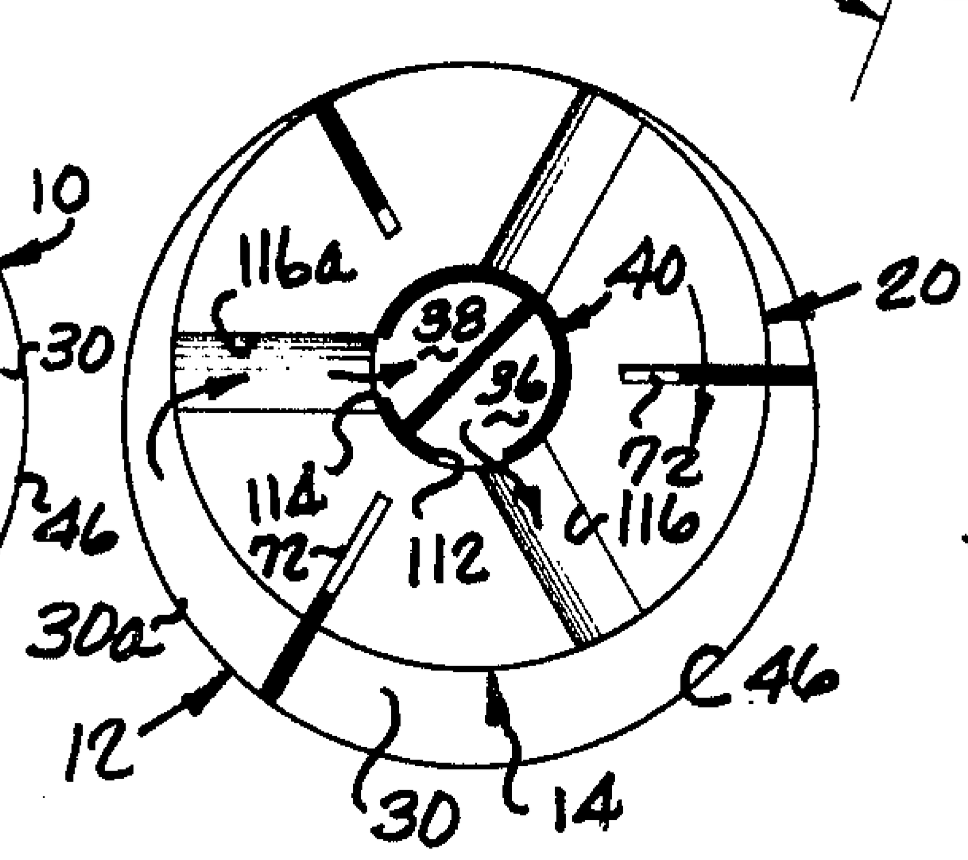

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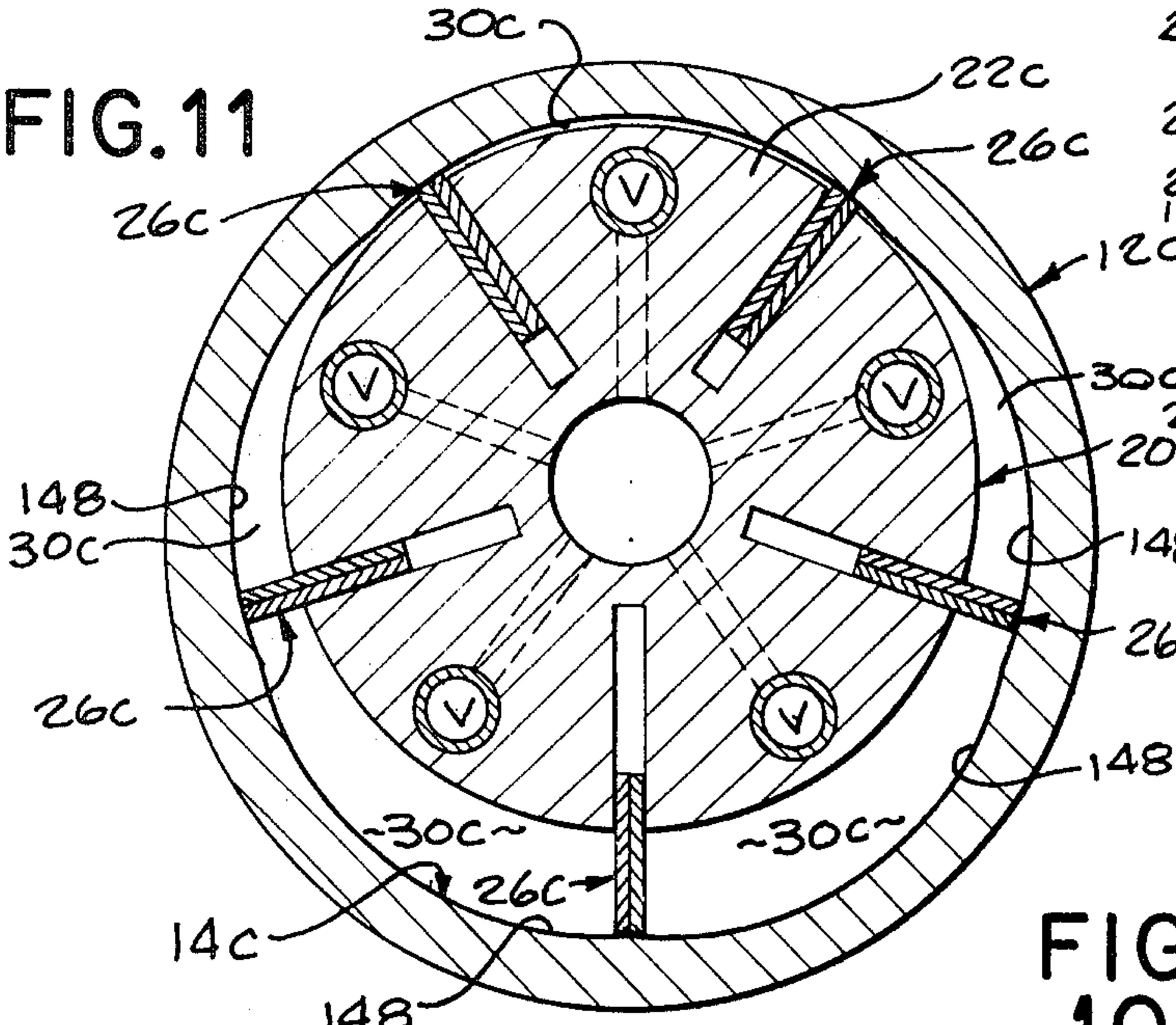
FIG. 11



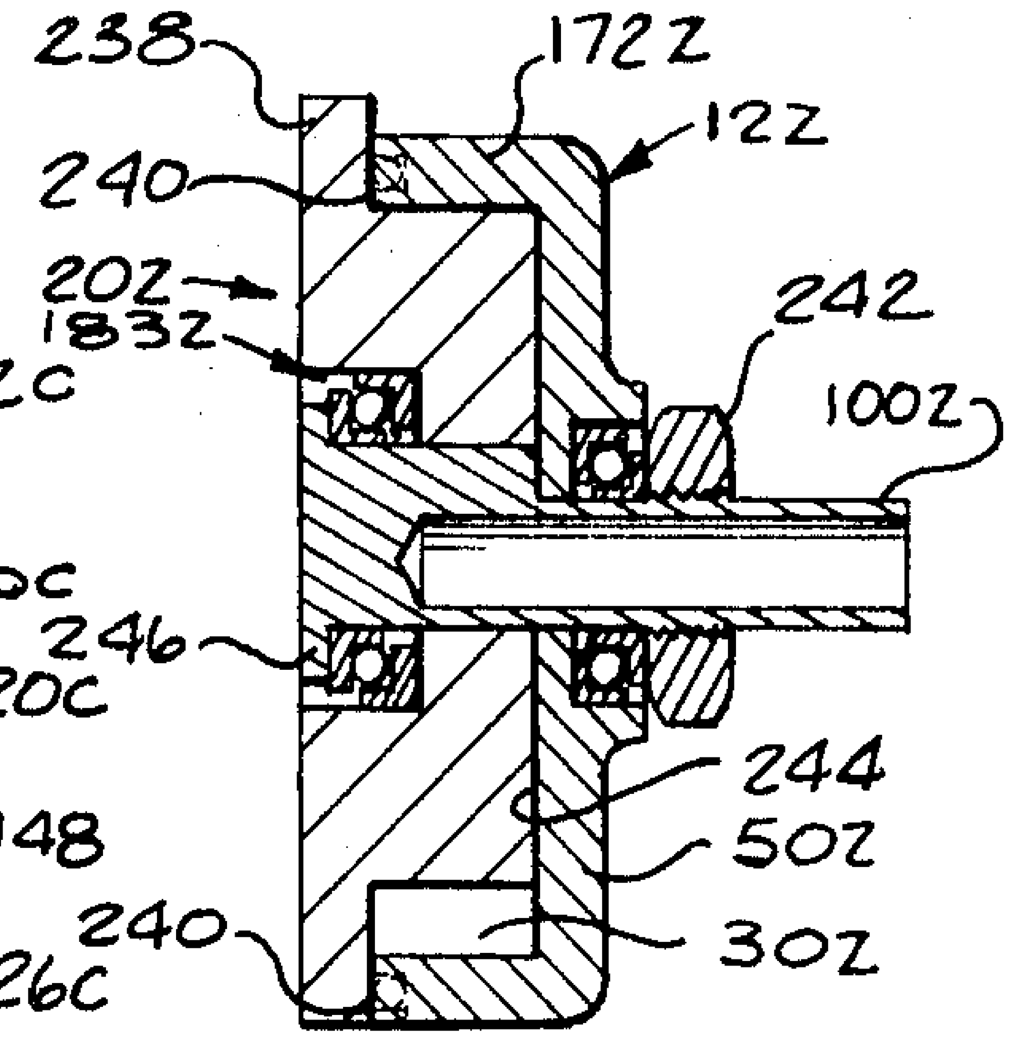
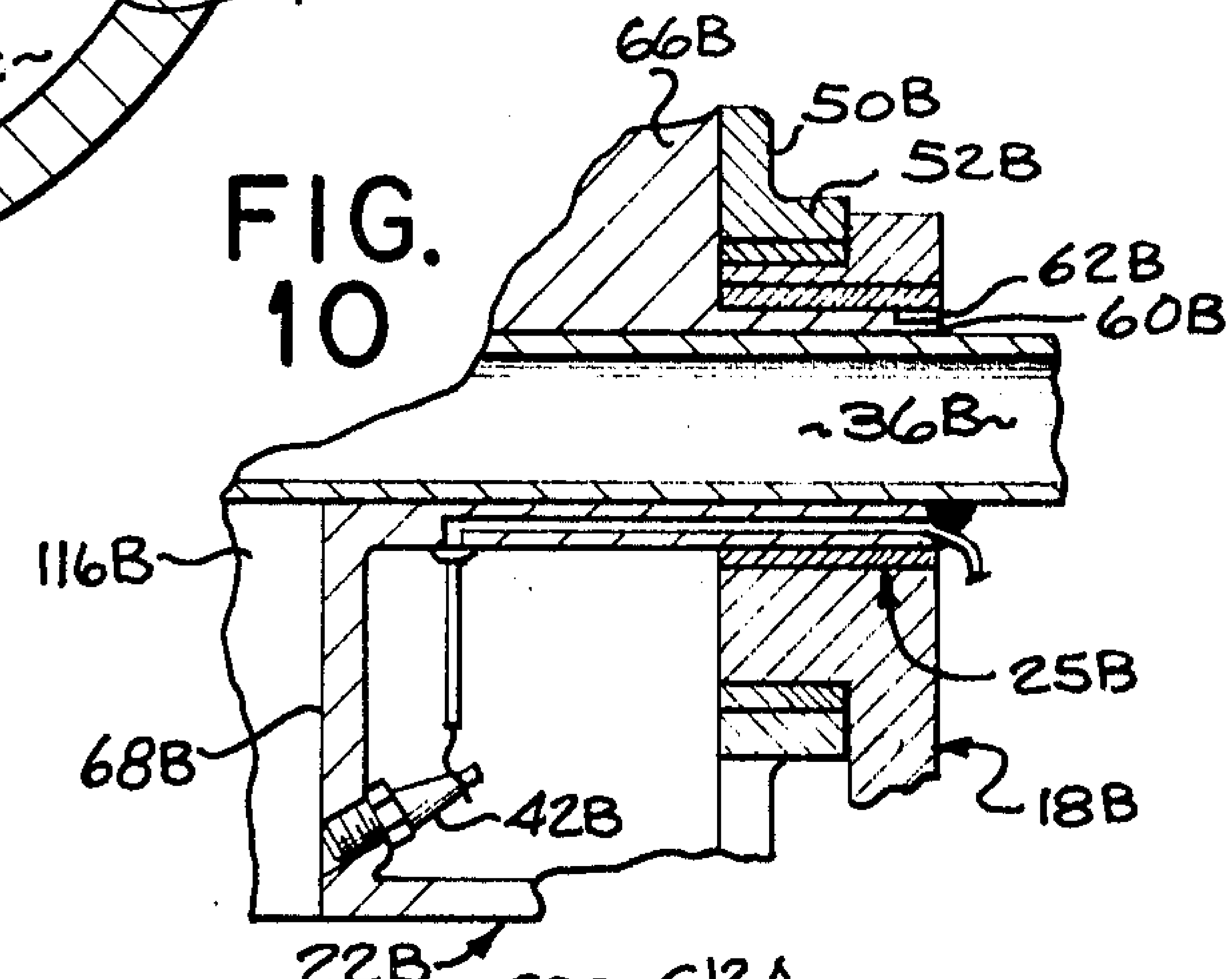


FIG. 46

FIG. 10



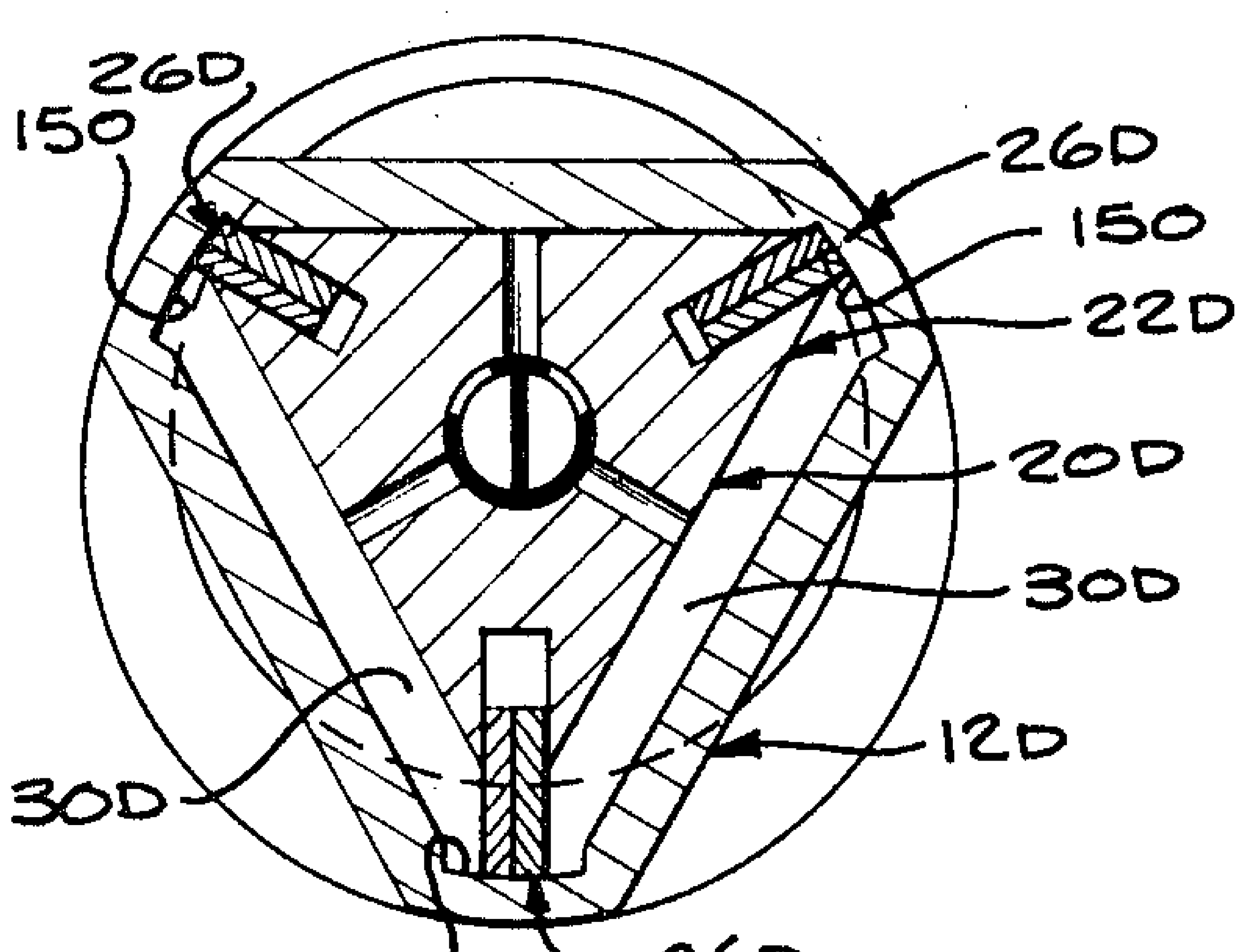


FIG. 12

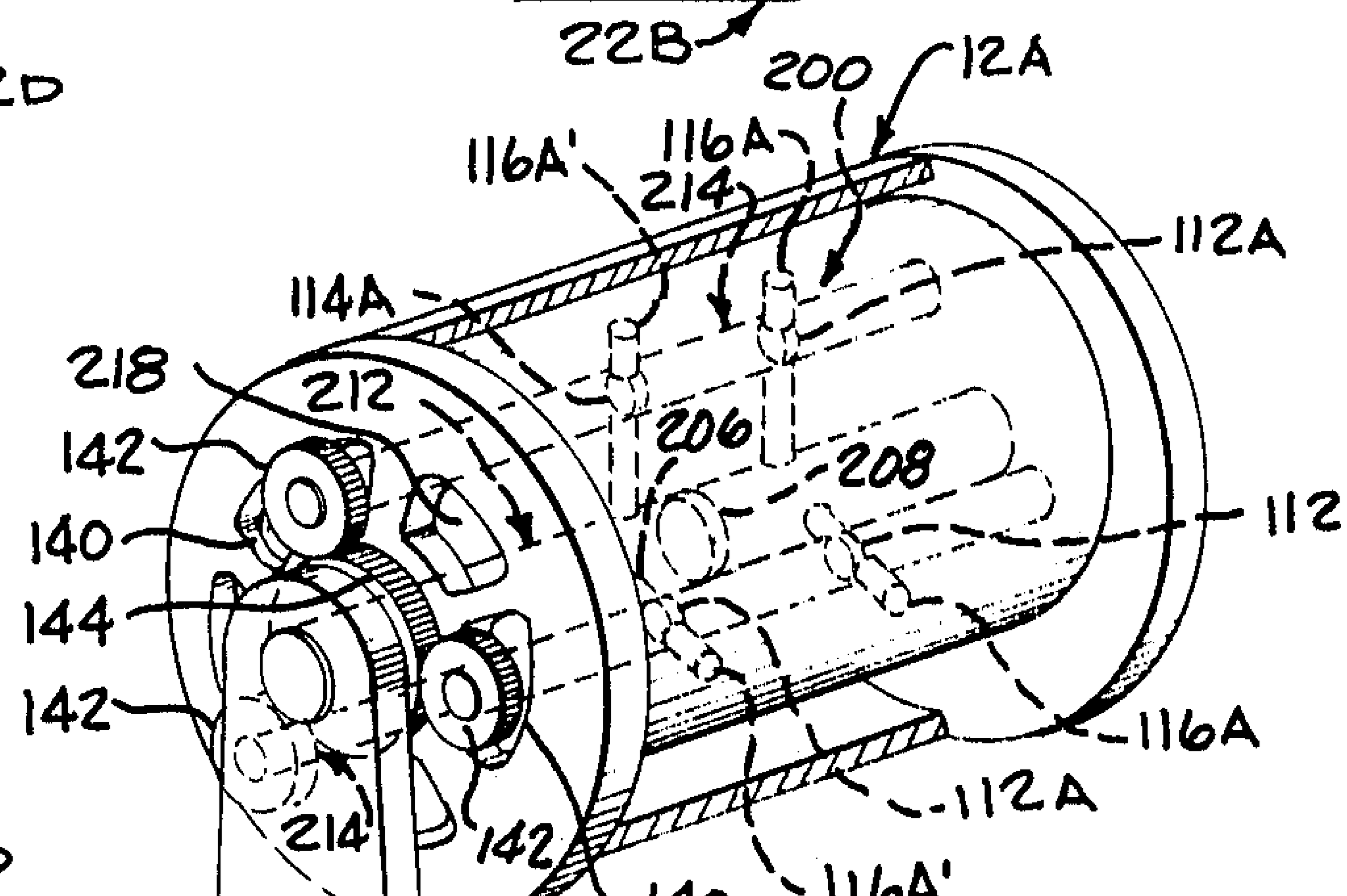


FIG. 9

FIG. 13

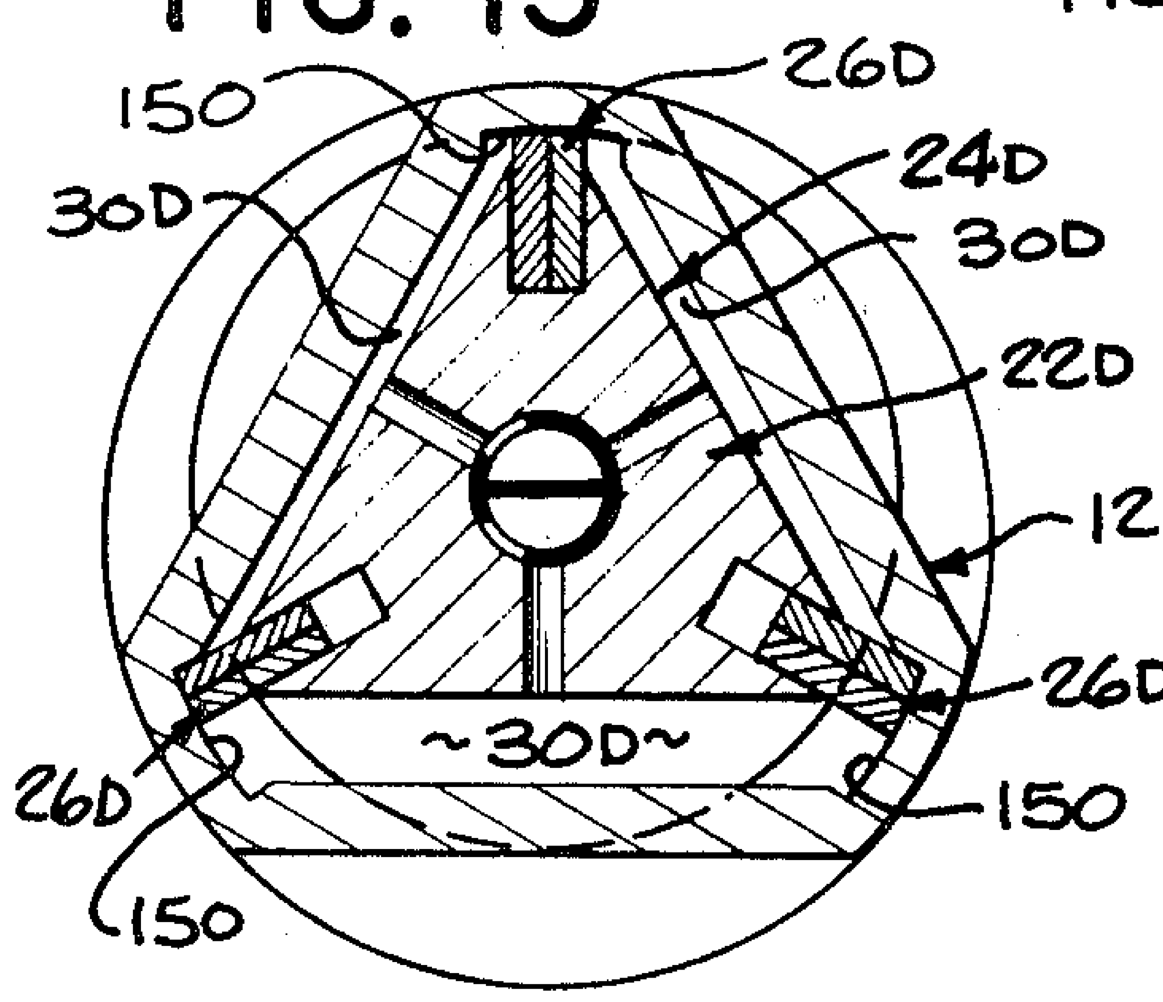


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FIG.14

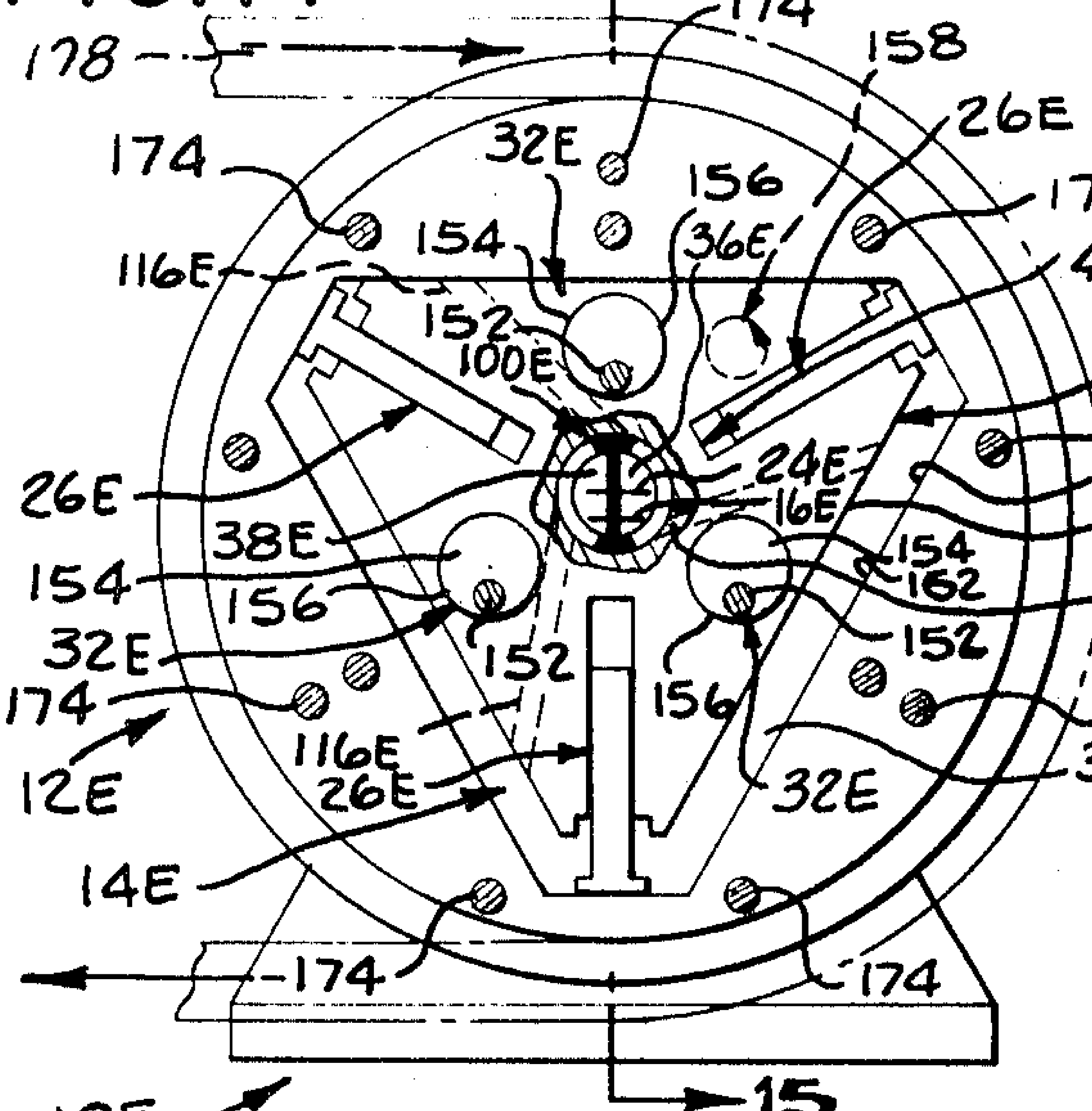
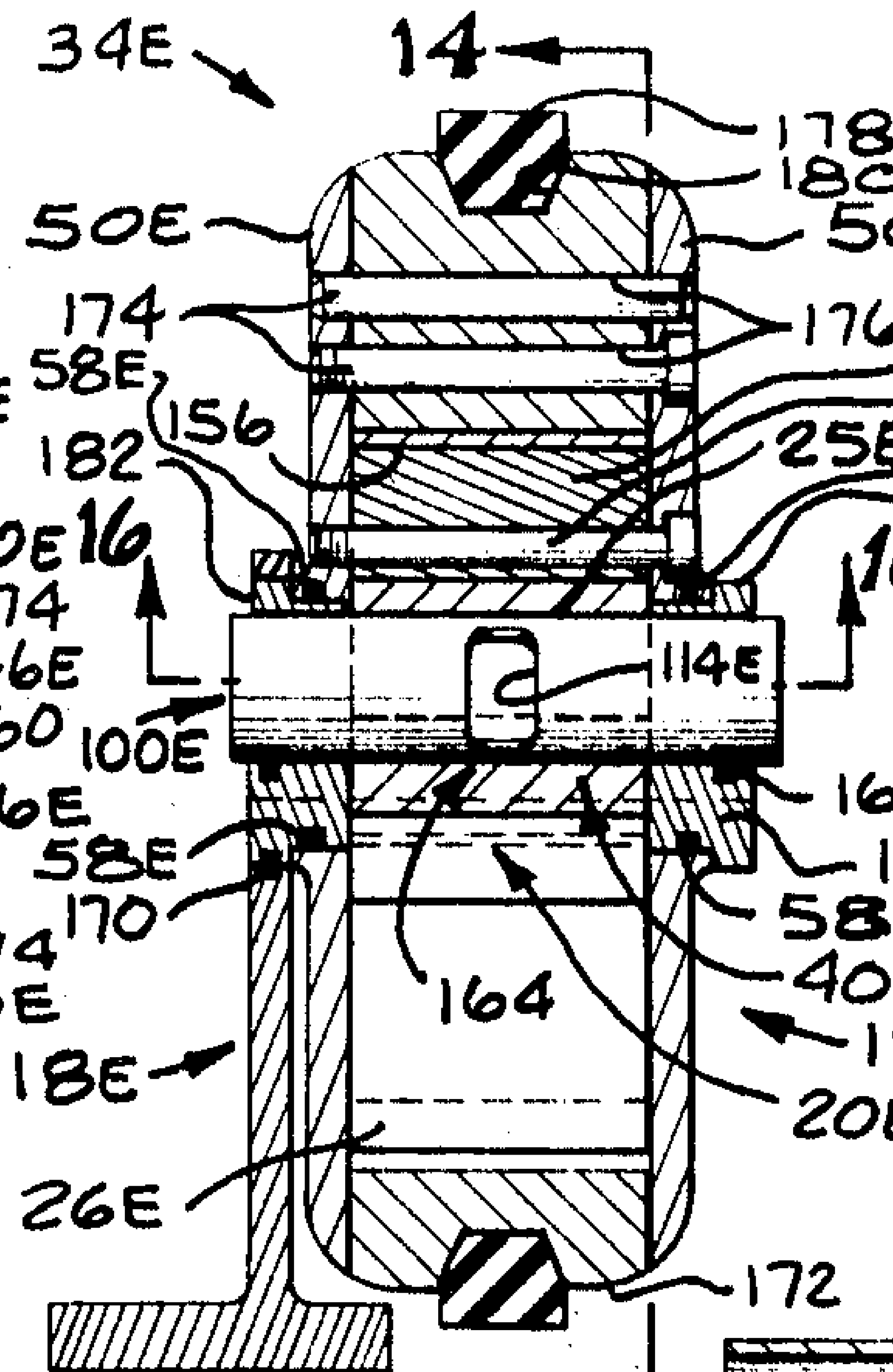


FIG.15



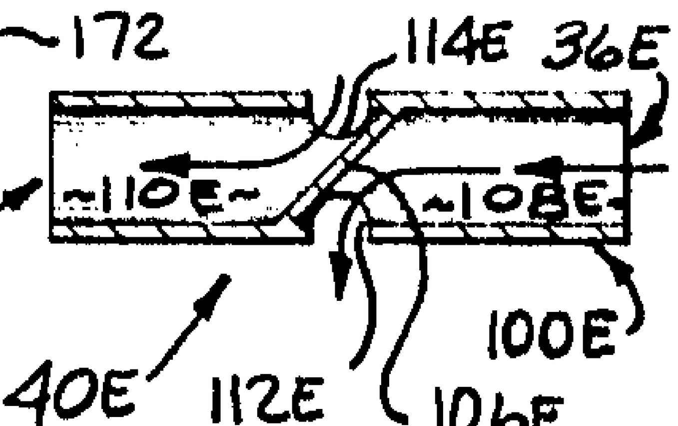


FIG. 16

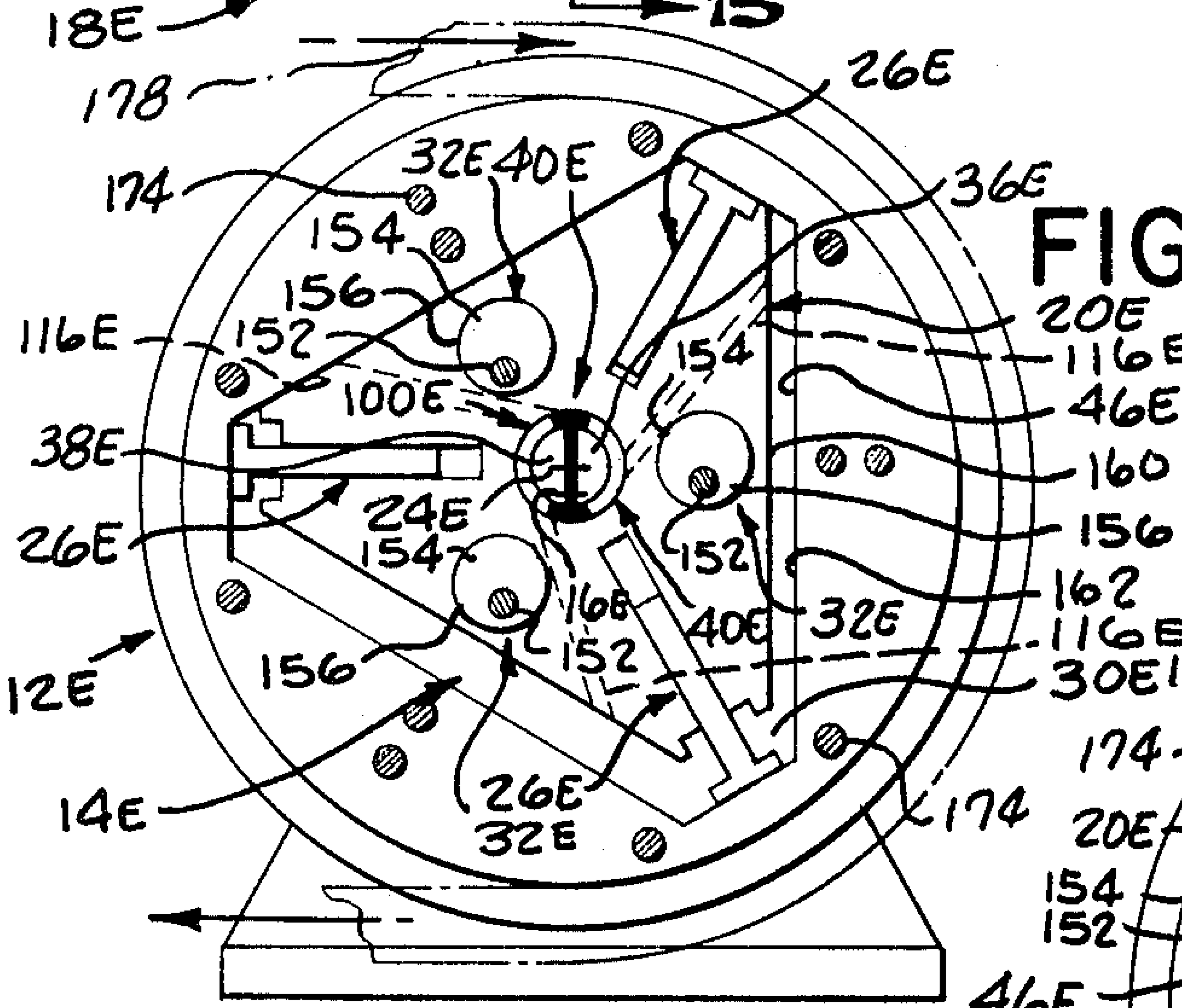
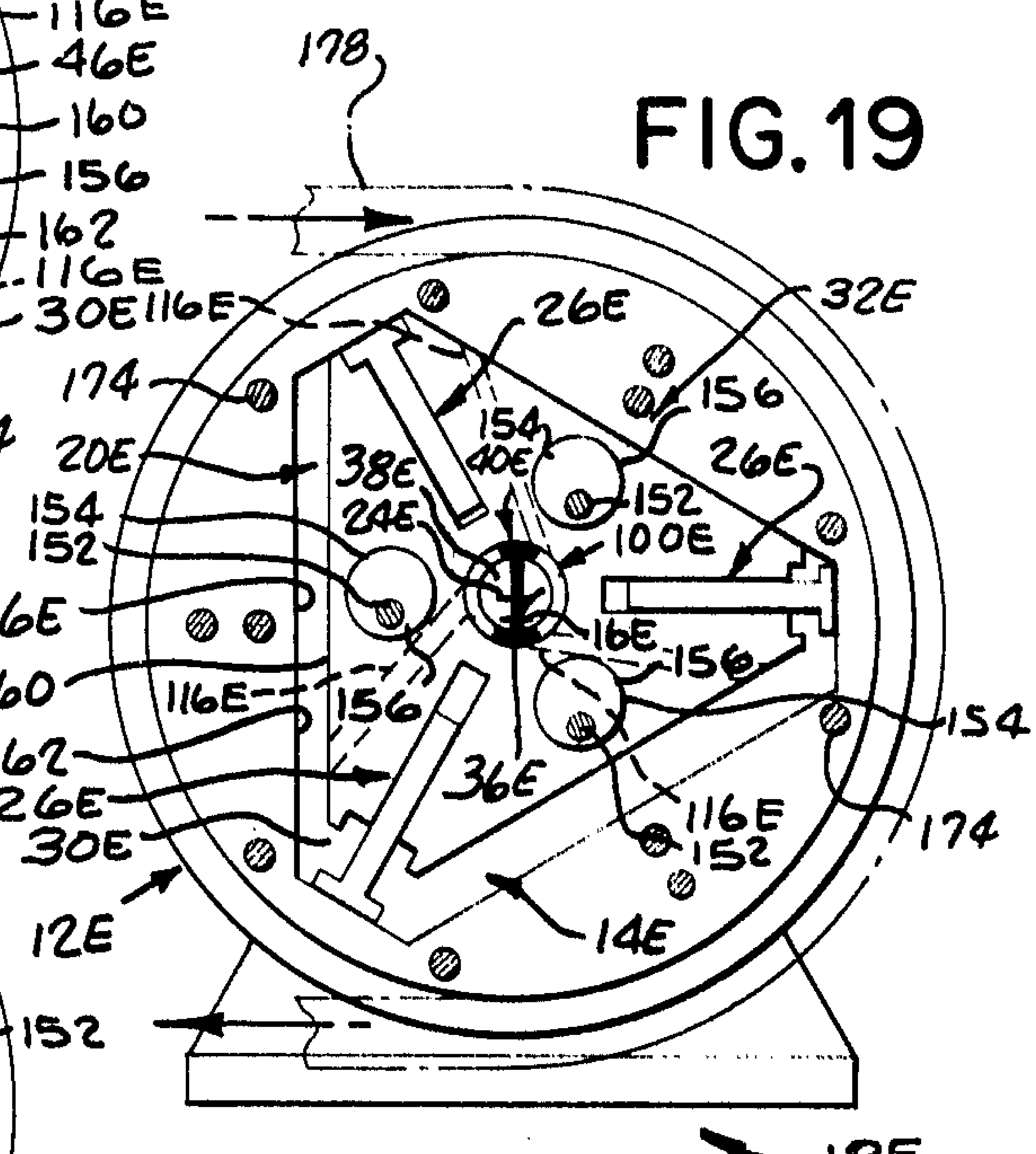


FIG.17

FIG.19



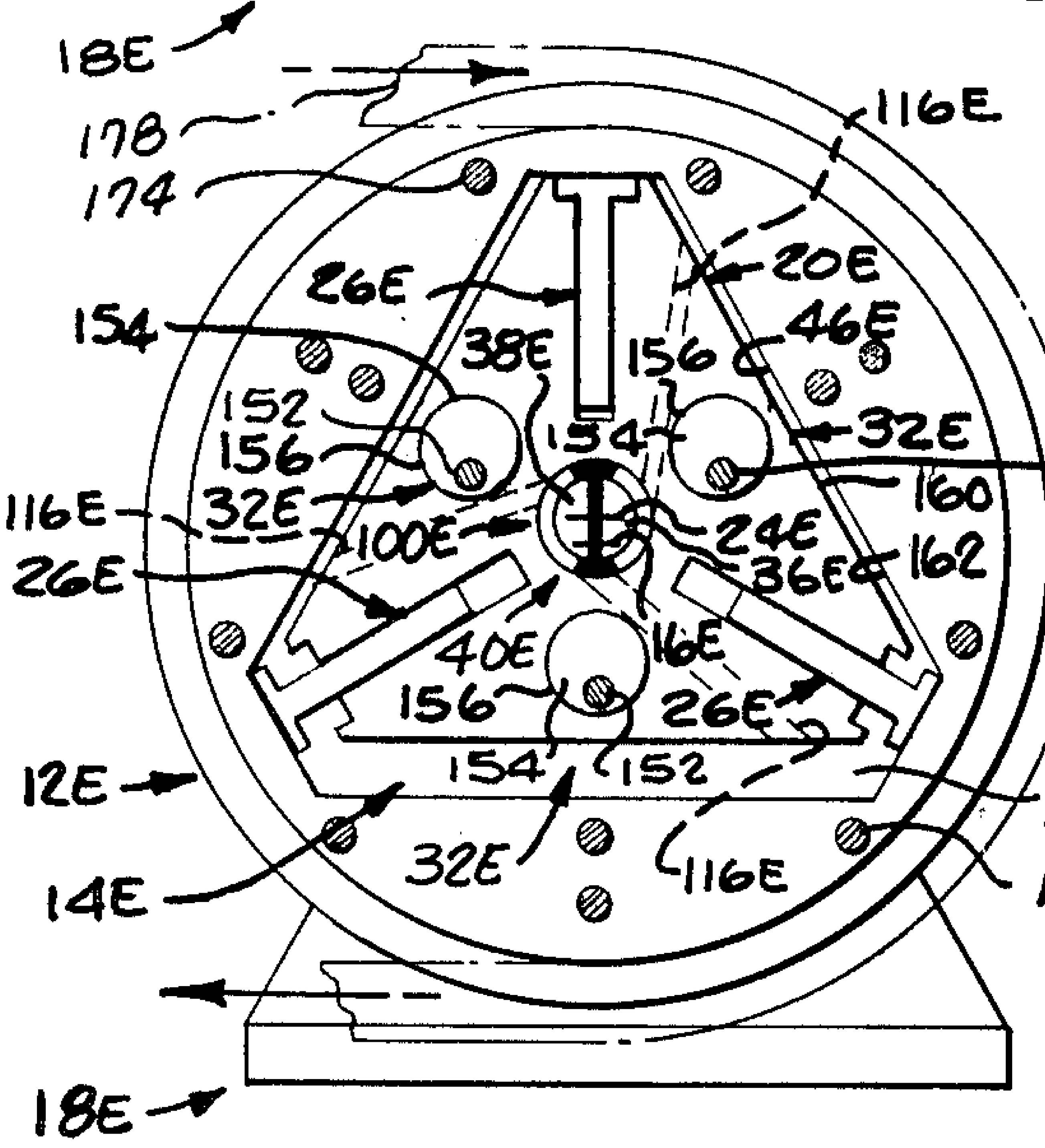


FIG.18

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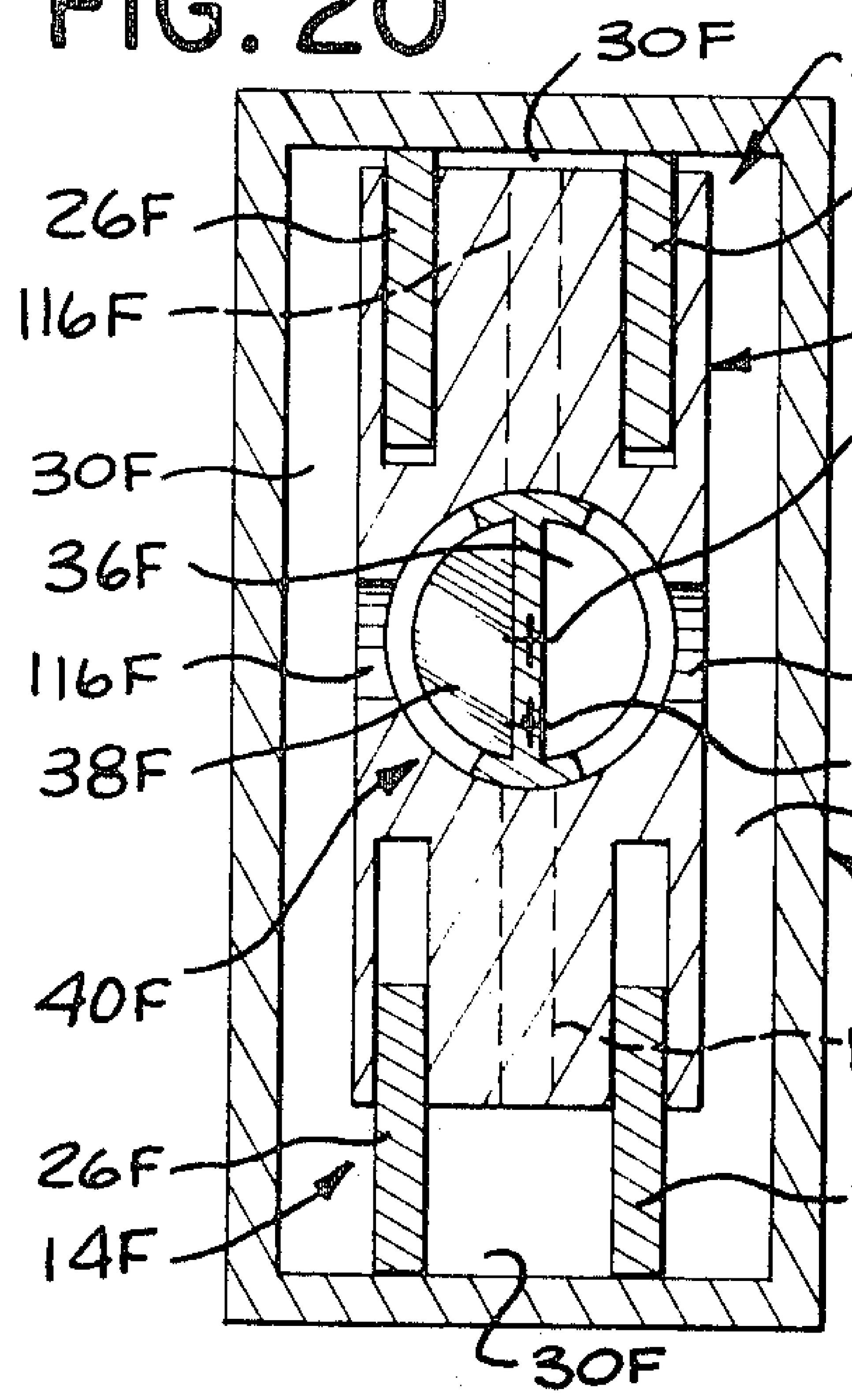
FIG. 20



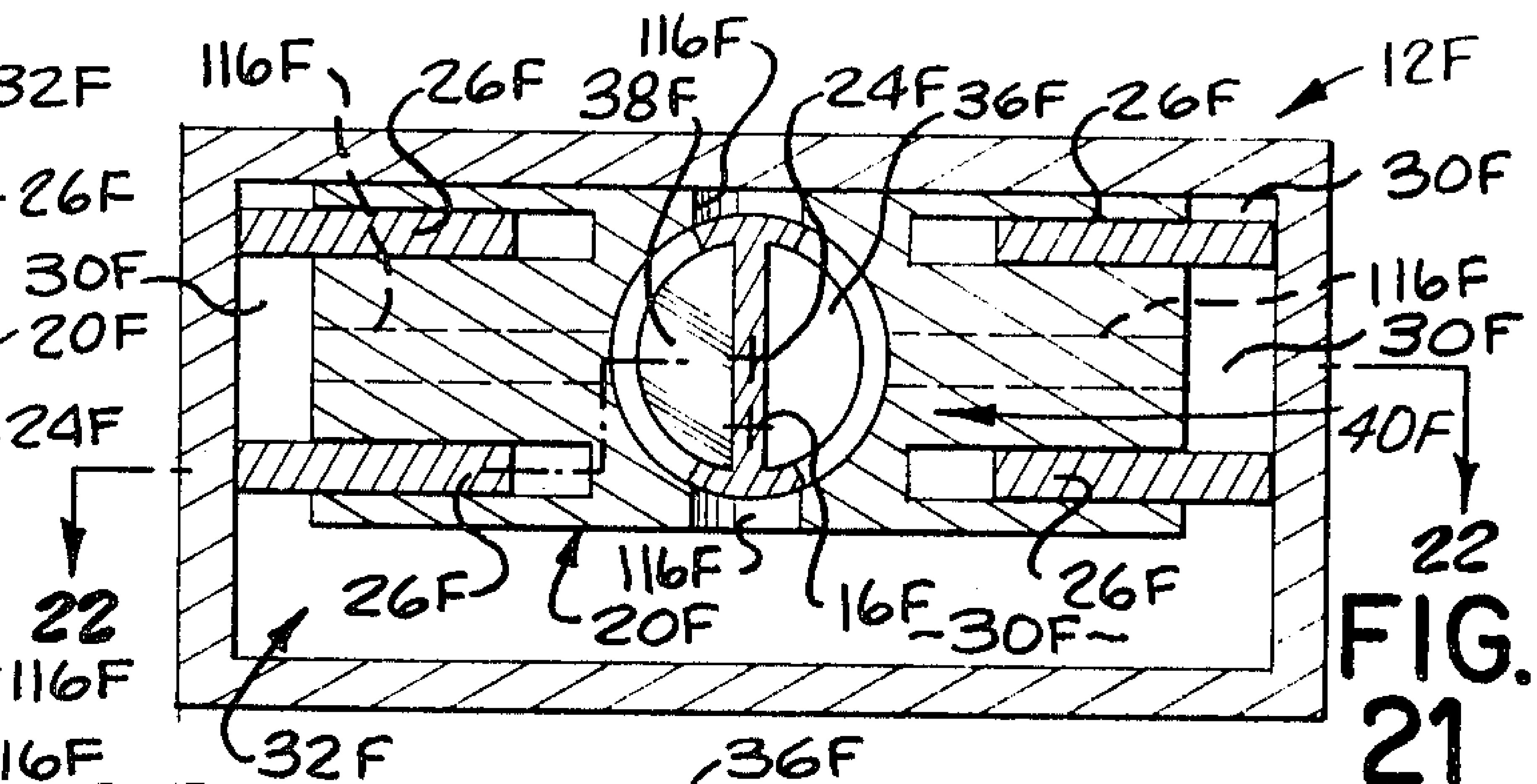


FIG. 21

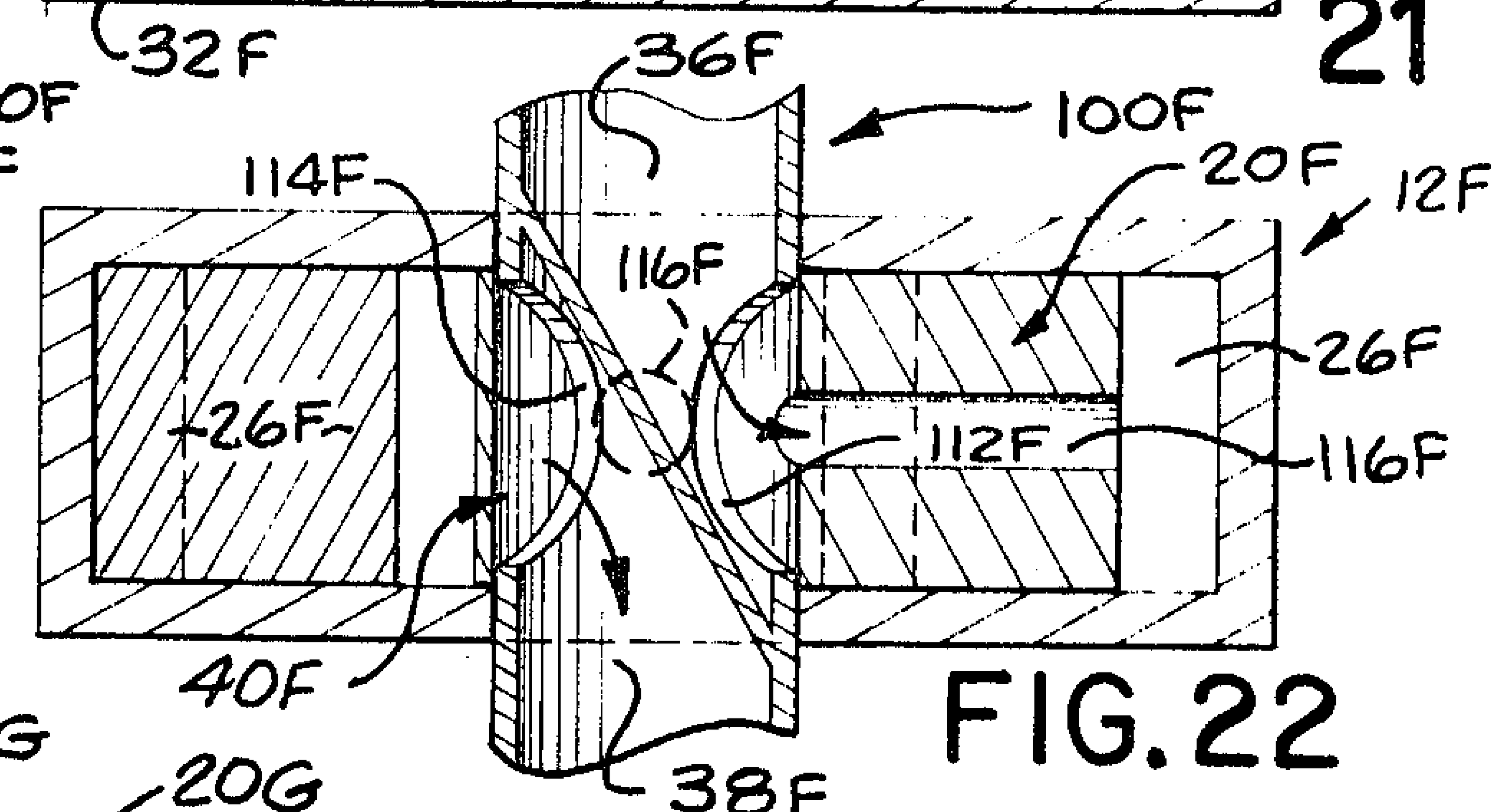


FIG. 22

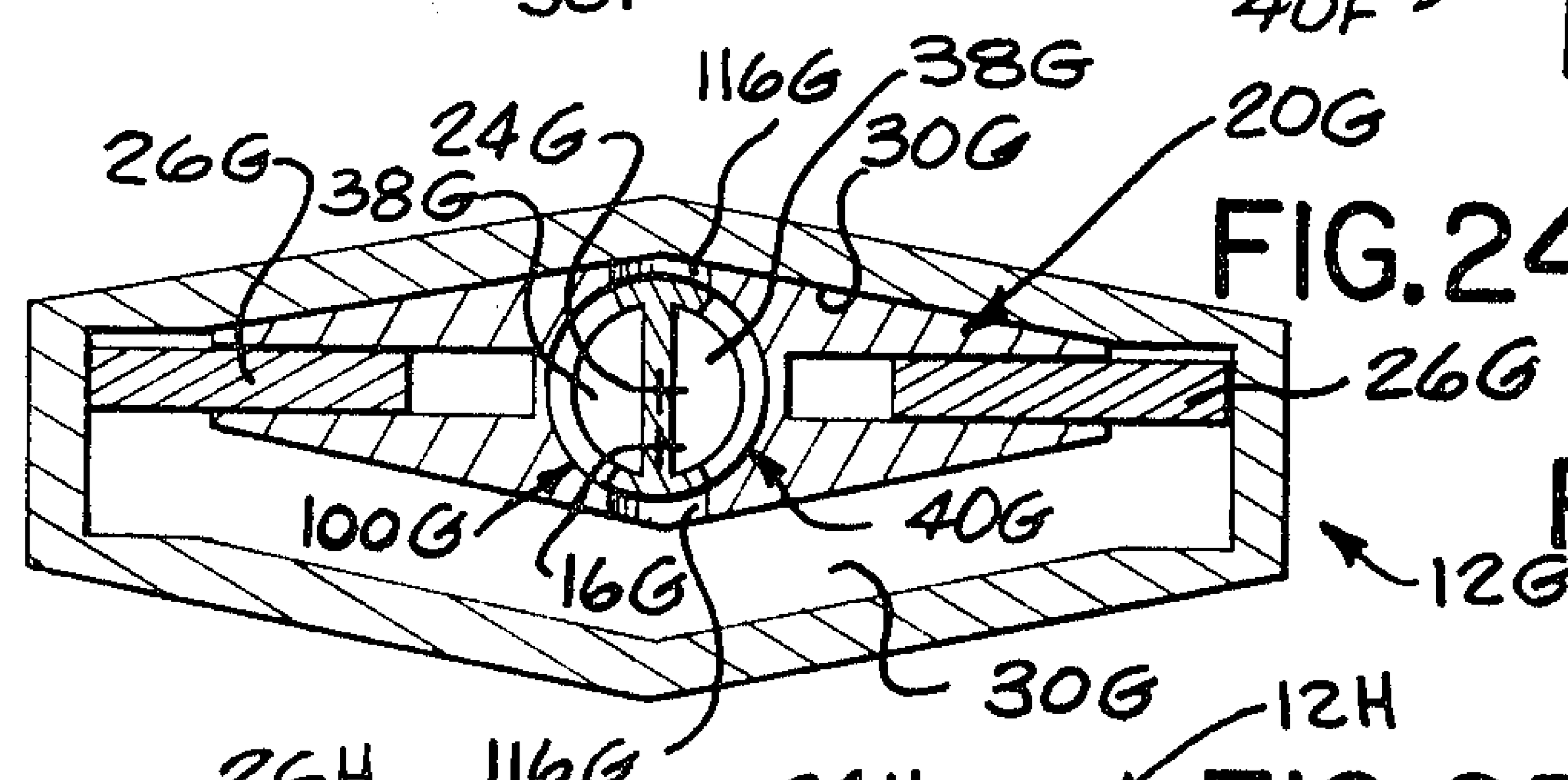


FIG. 24

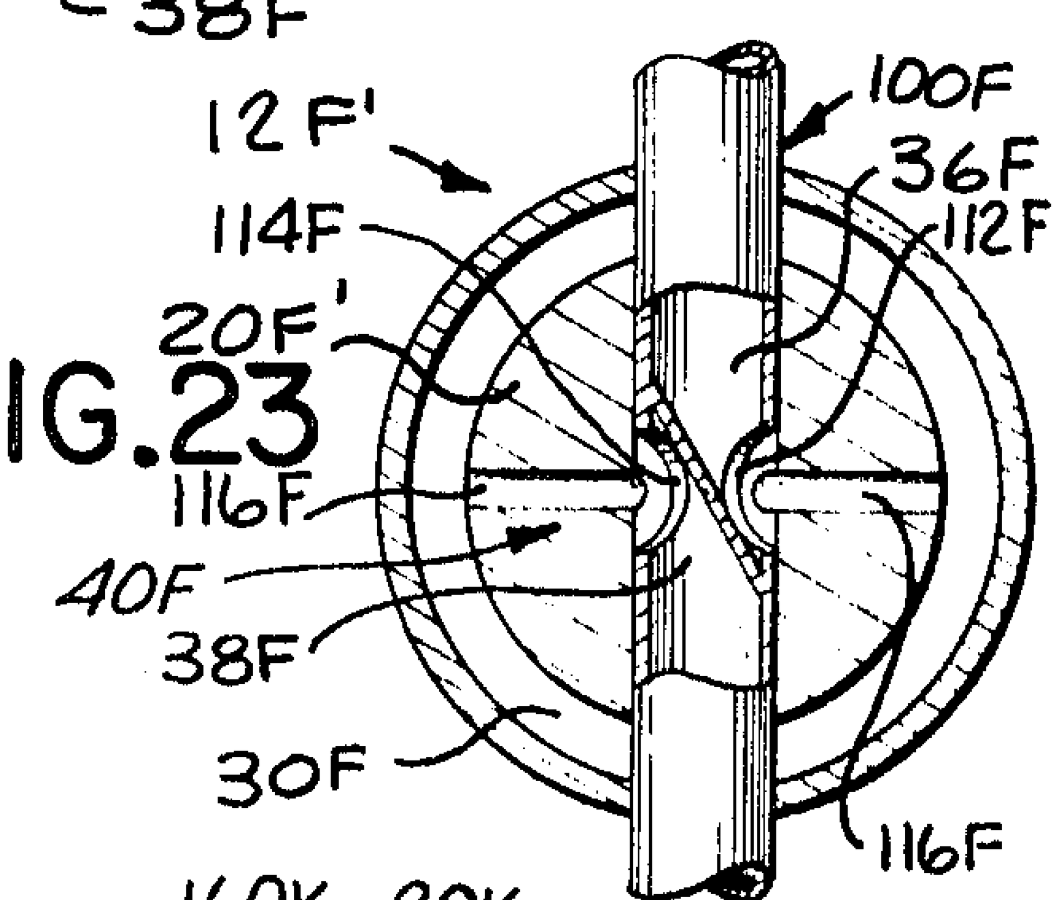


FIG. 23

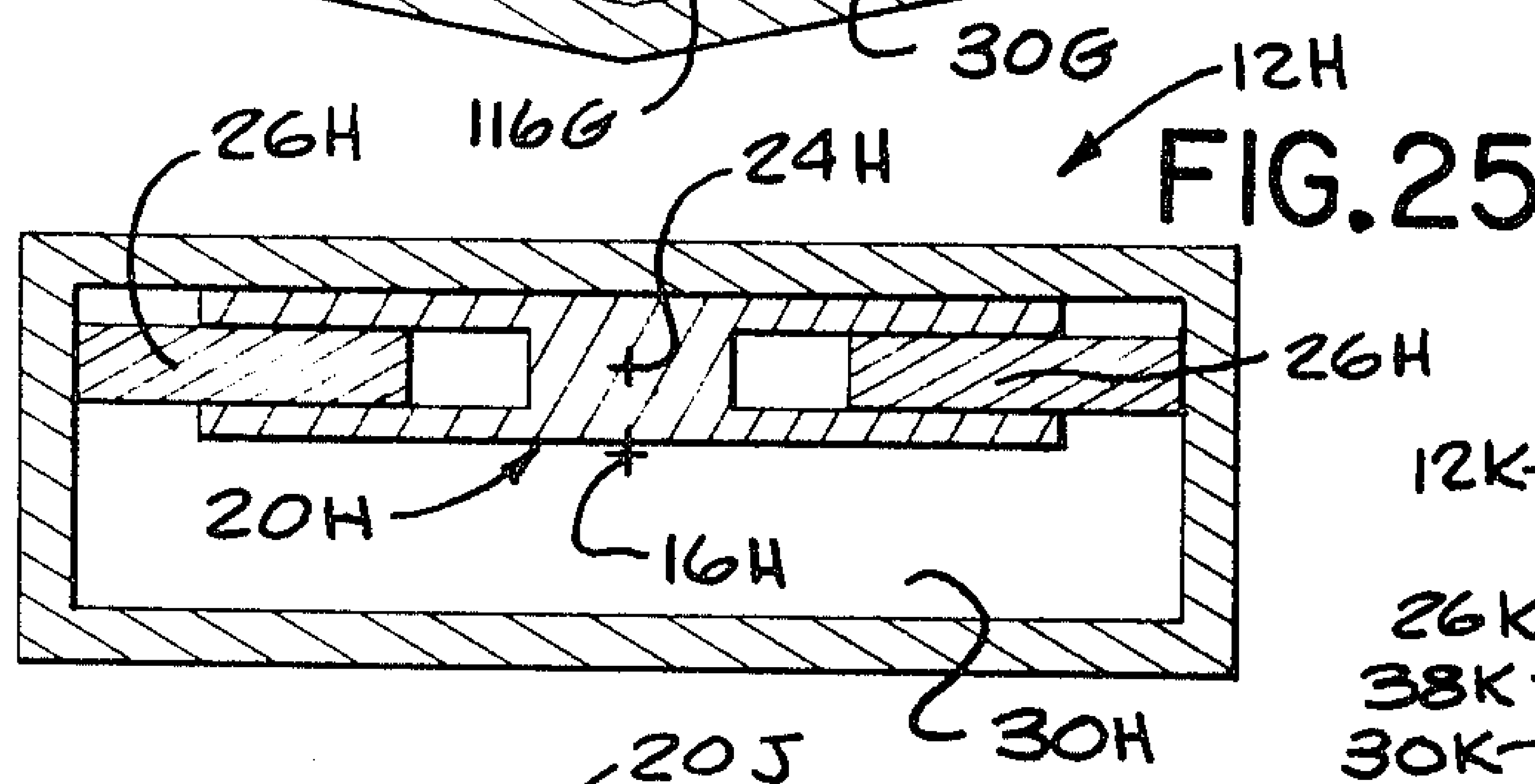


FIG. 25

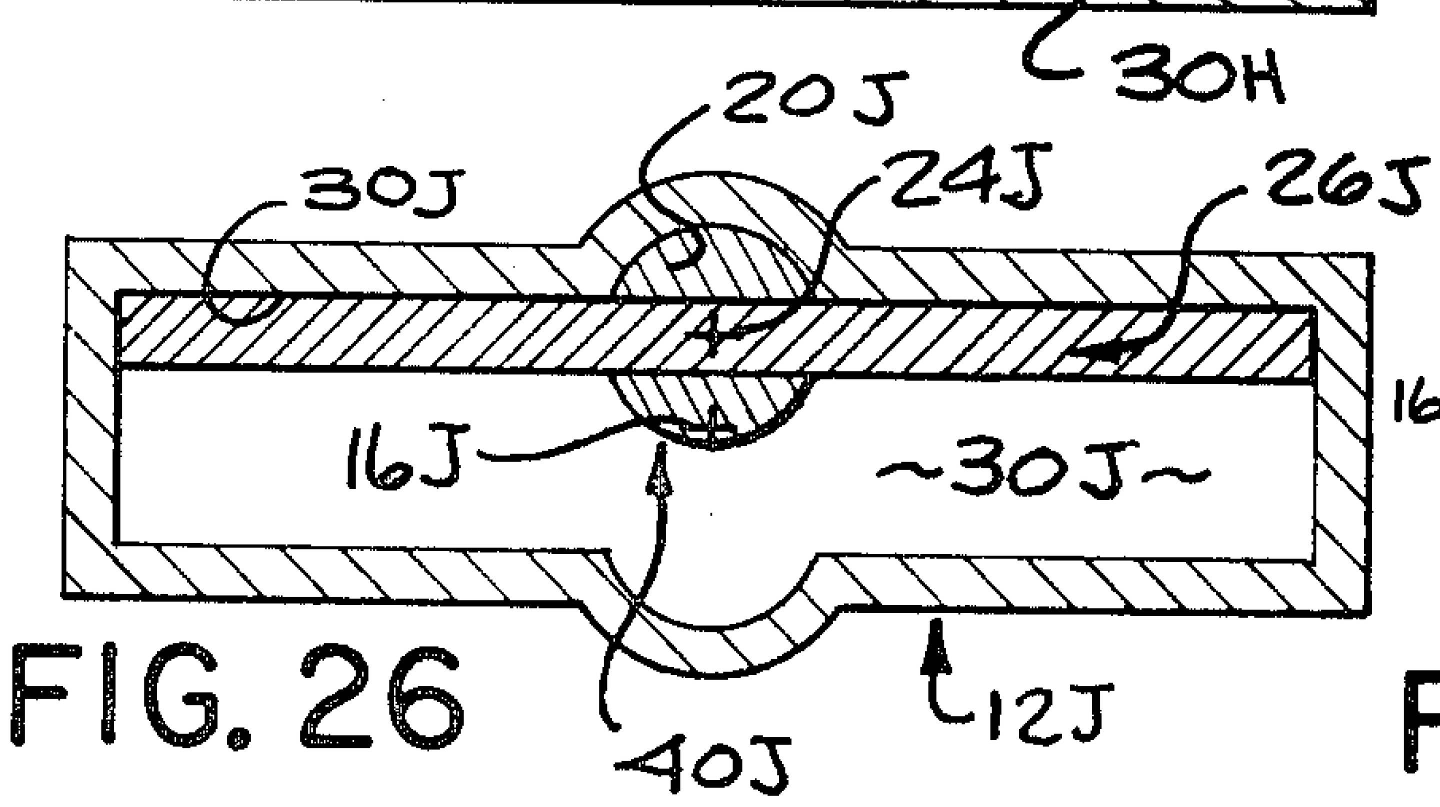


FIG. 26

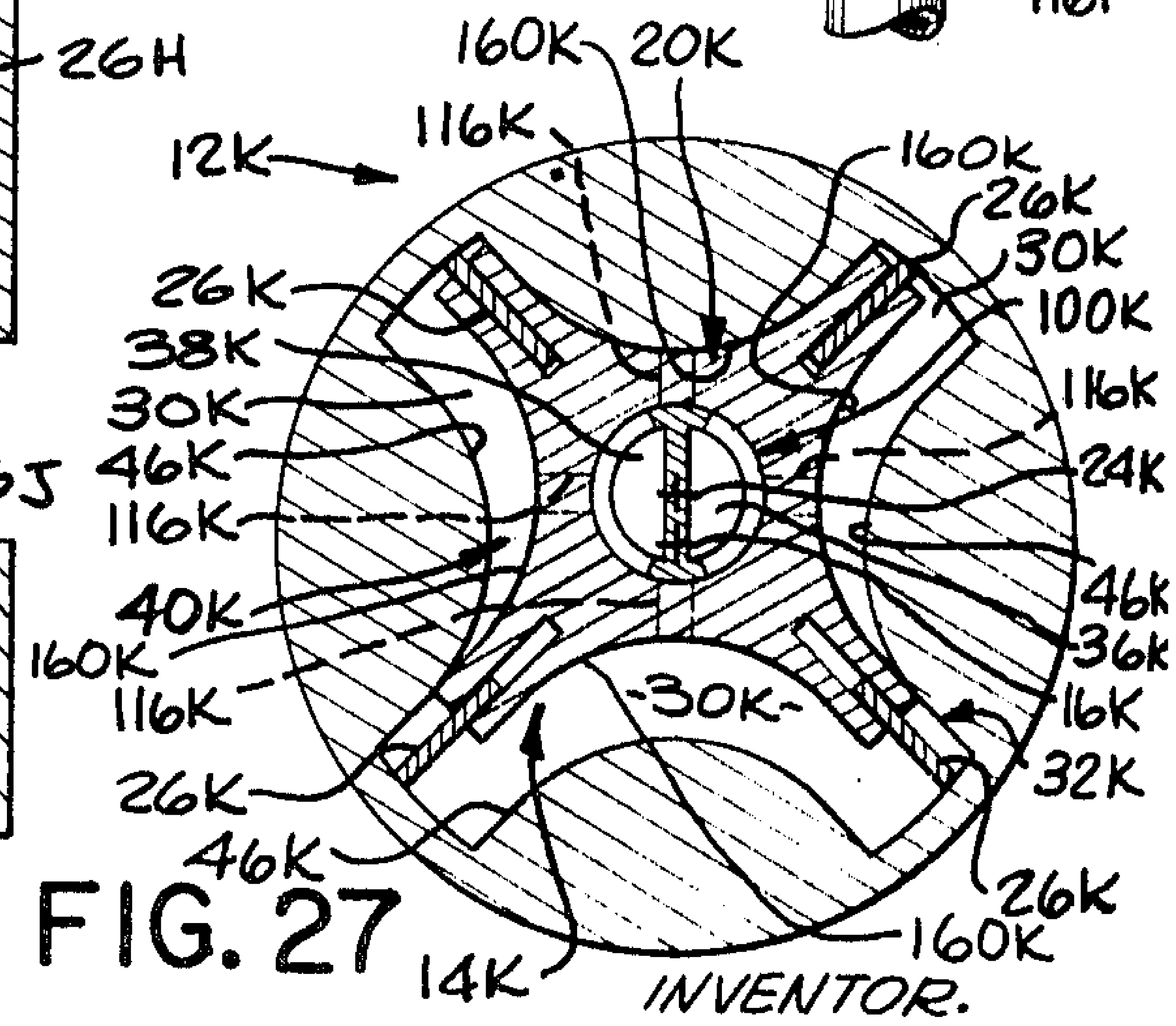


FIG. 27

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FIG. 28

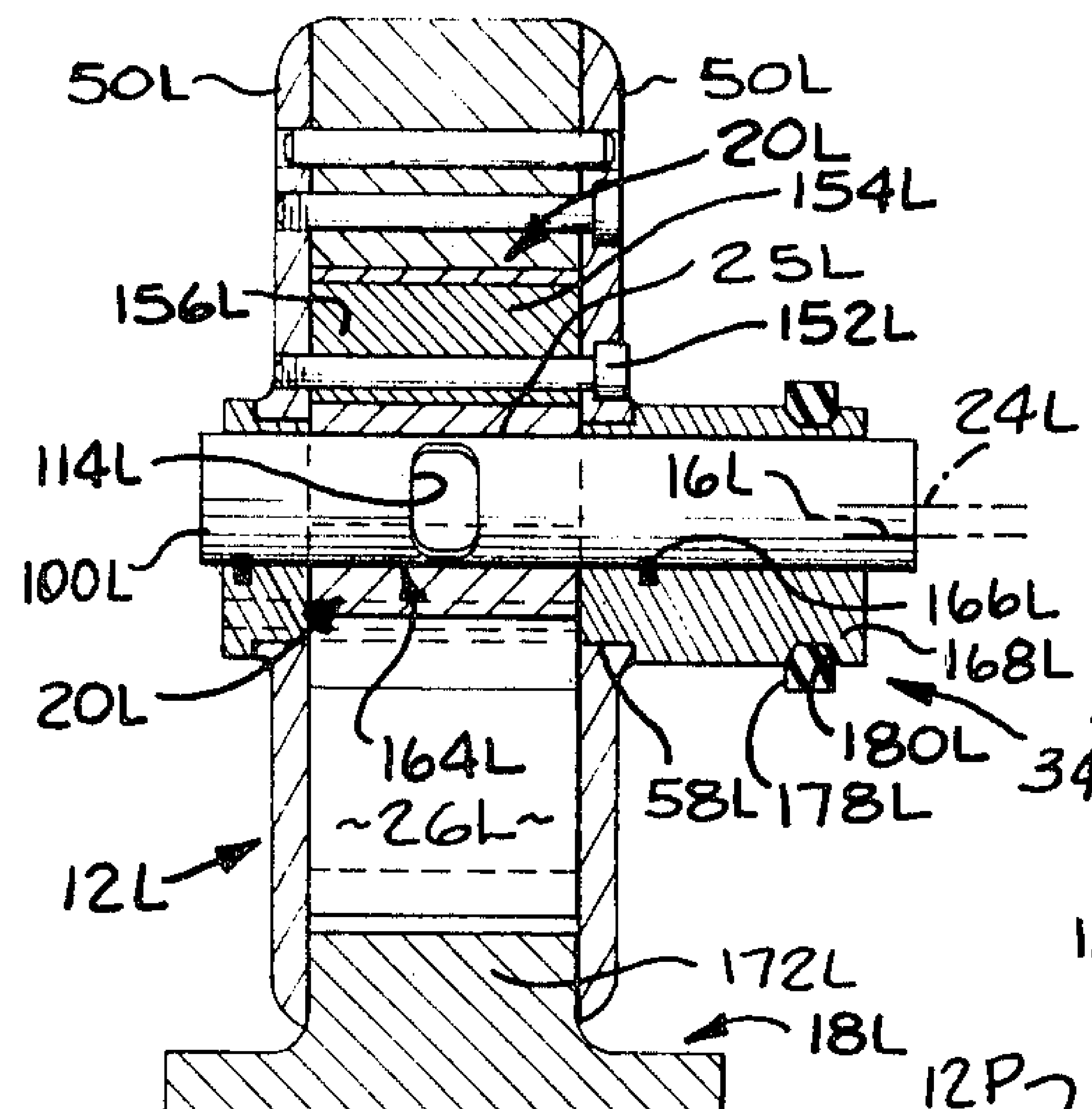


FIG. 29

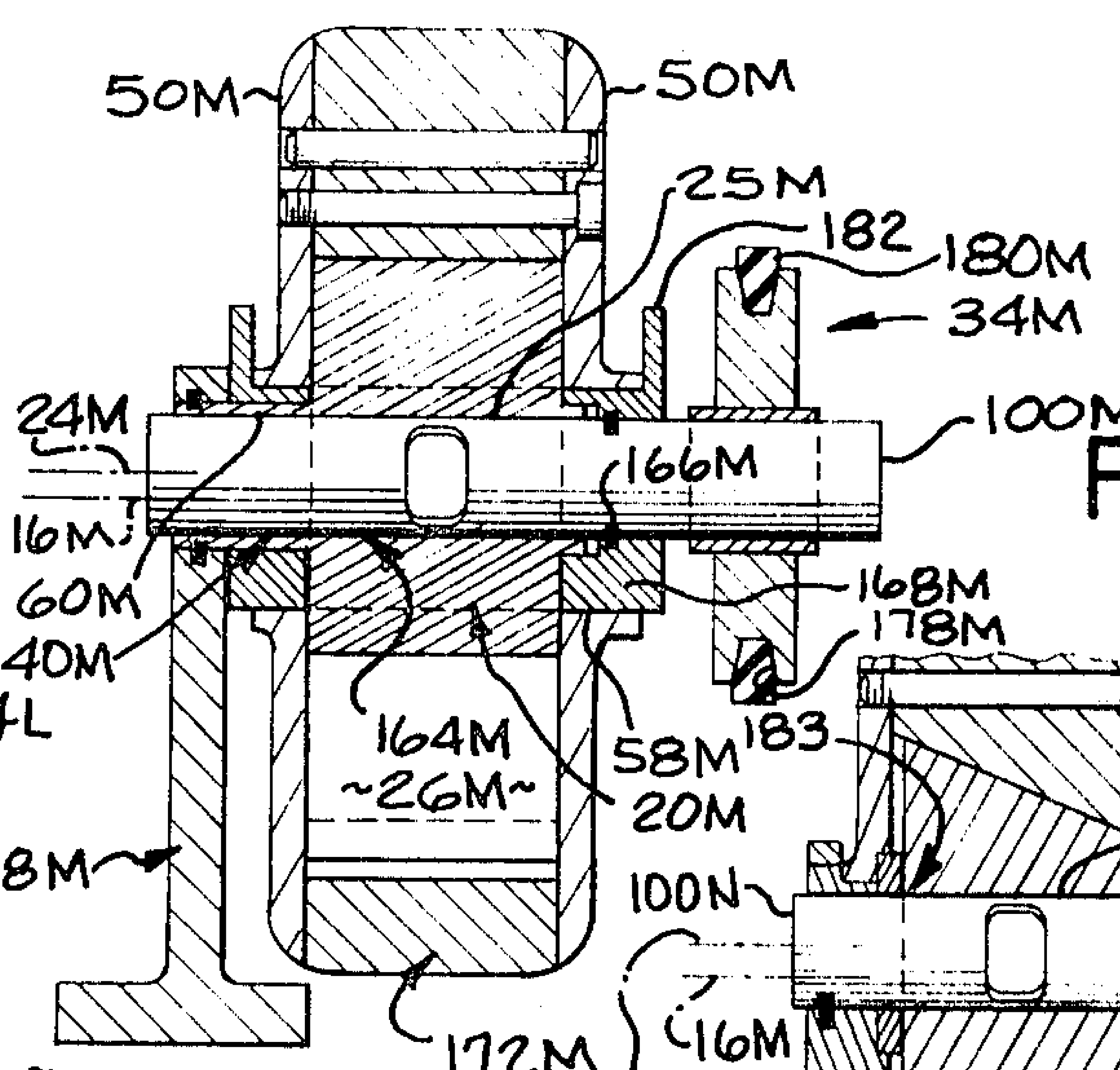
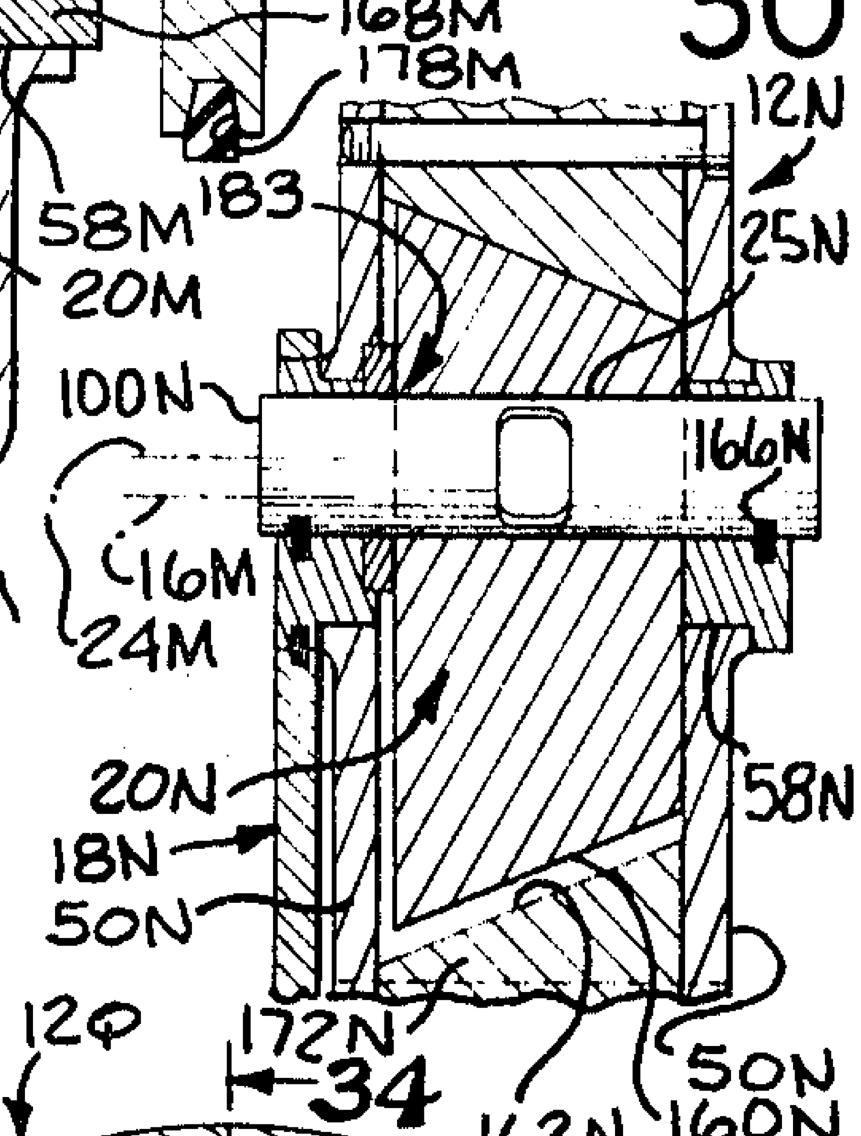


FIG. 30



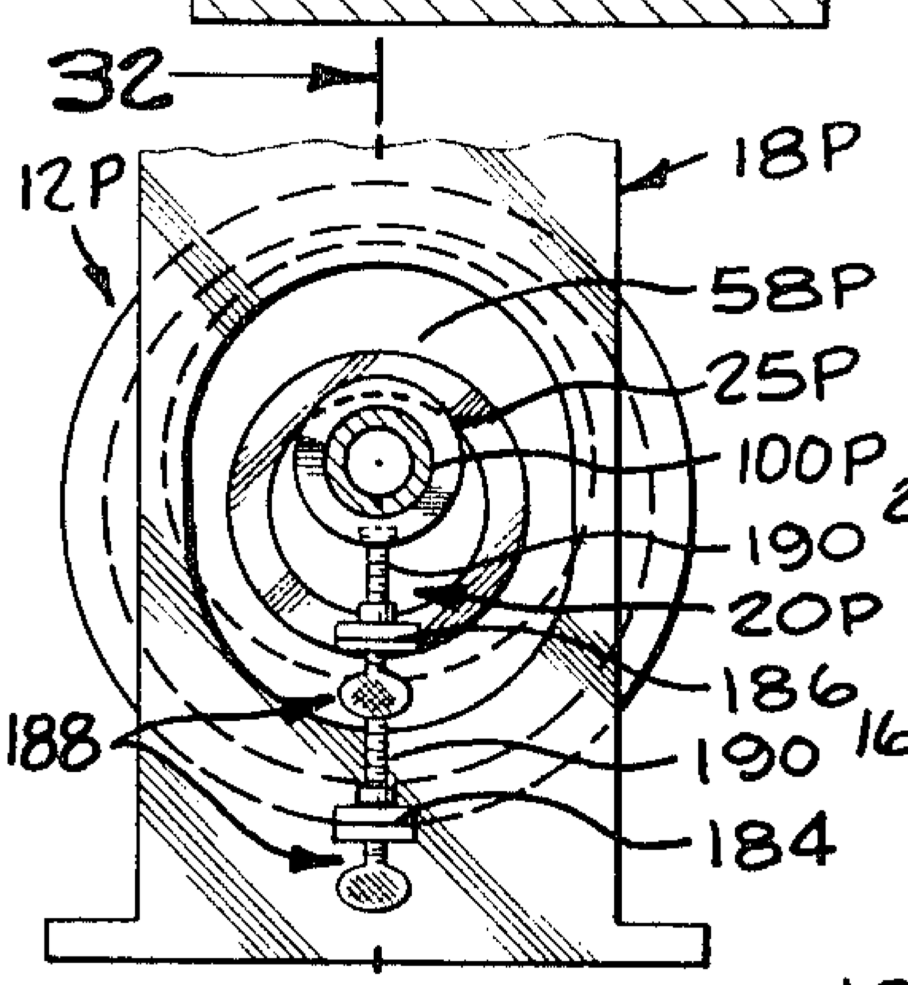


FIG. 31

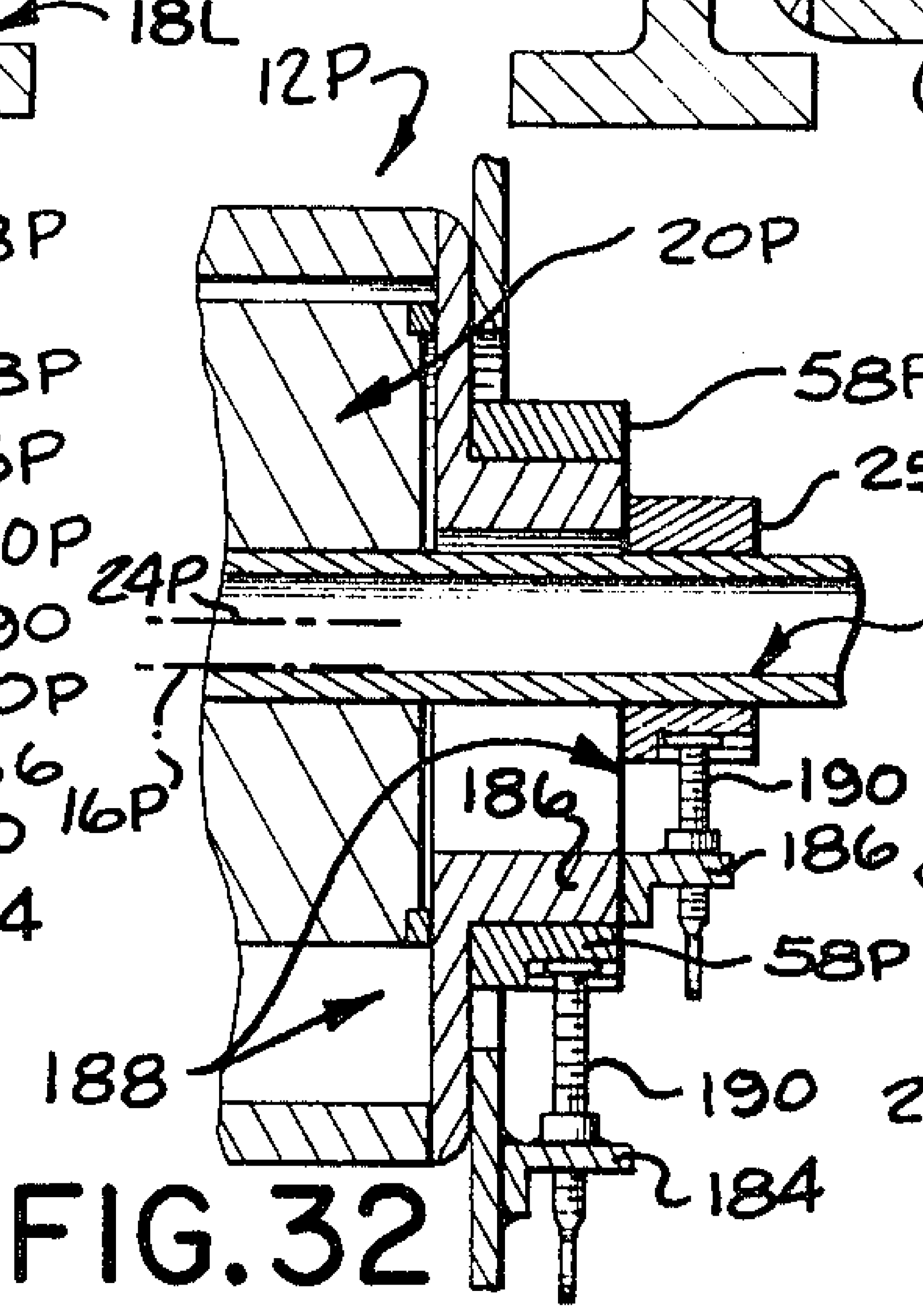


FIG. 32

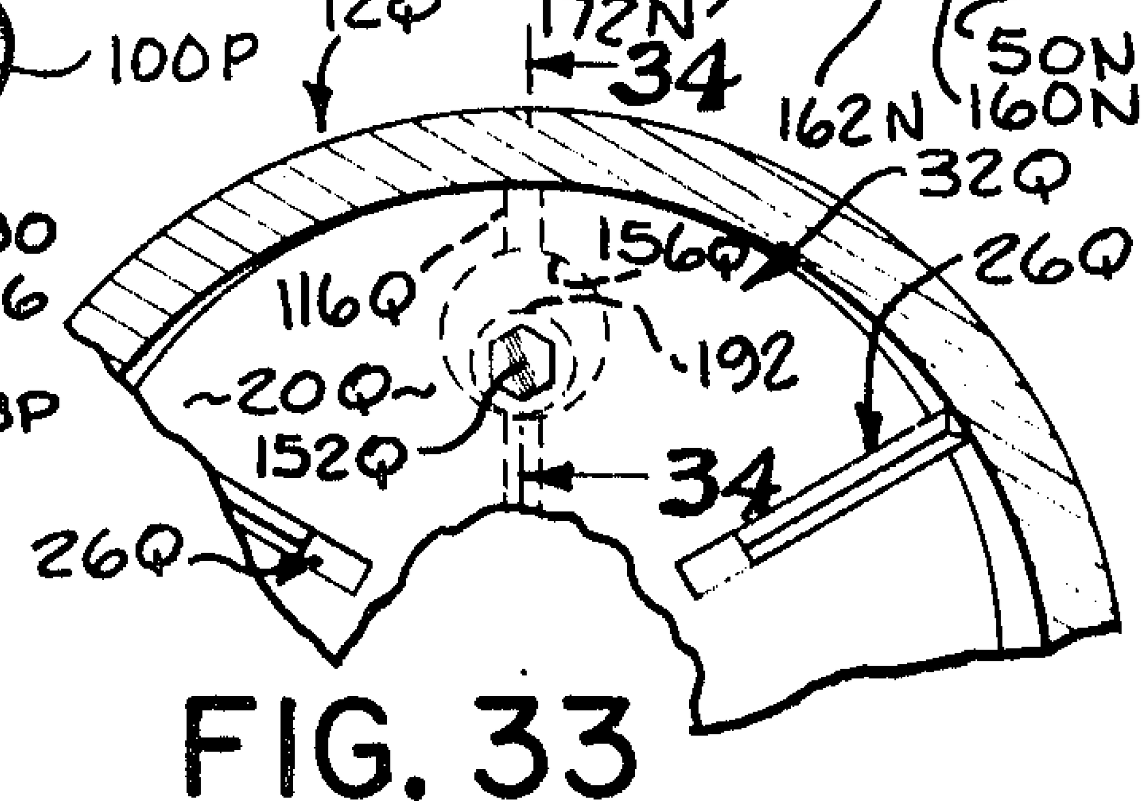


FIG. 33

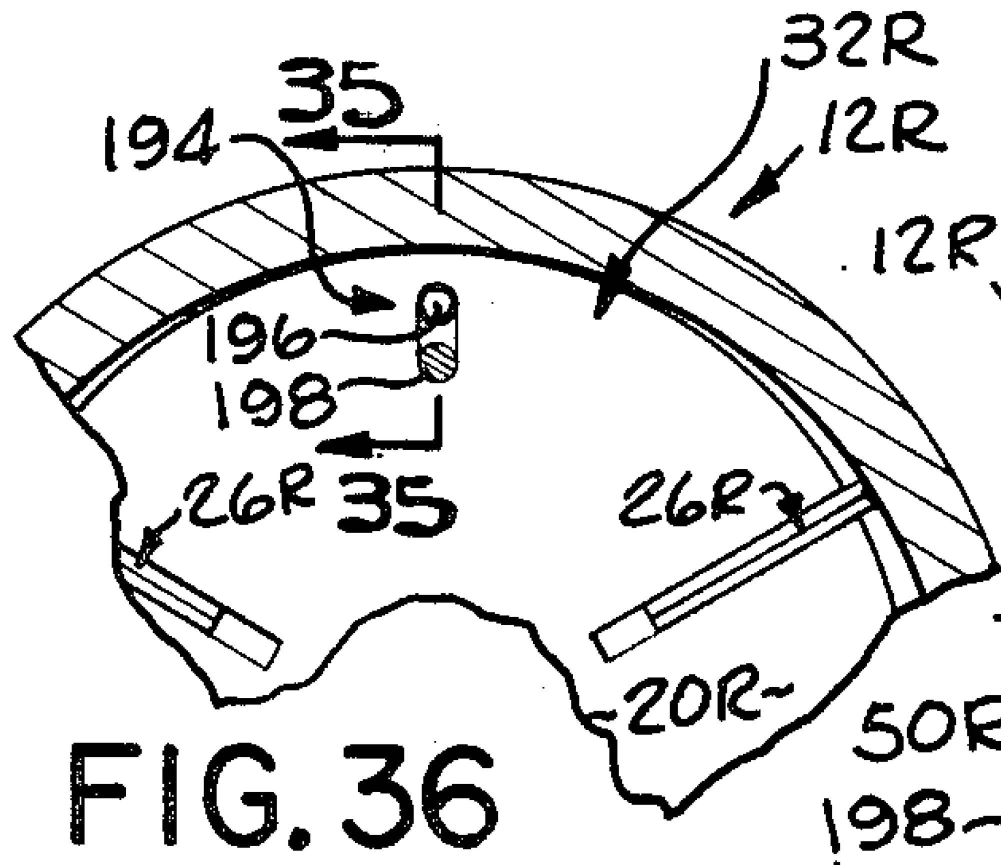


FIG. 36

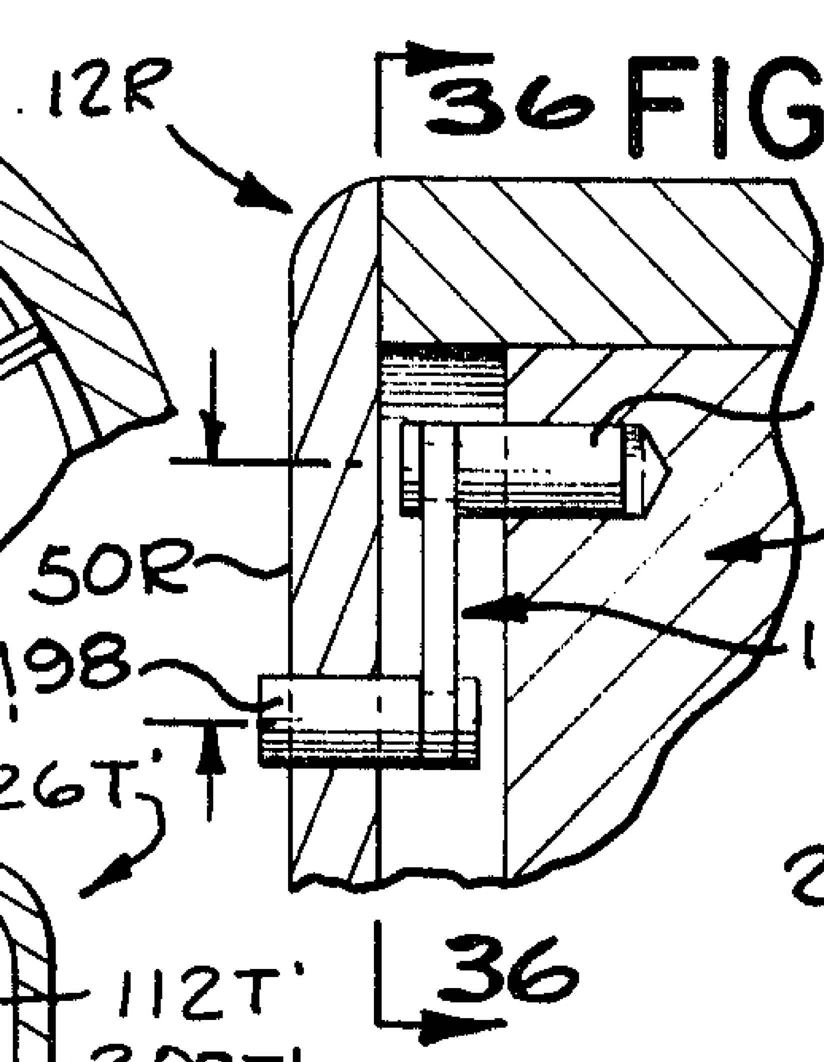
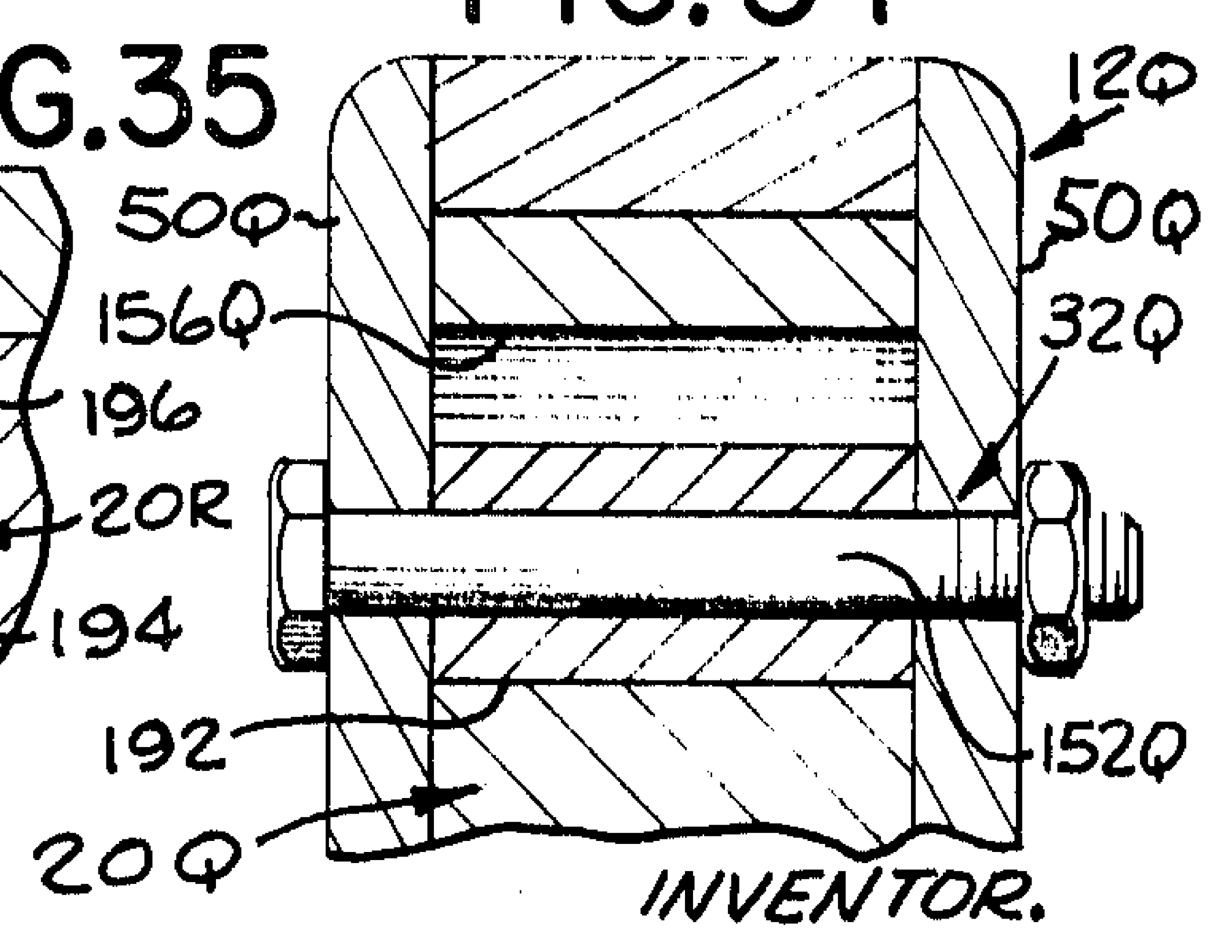


FIG. 35

FIG. 34



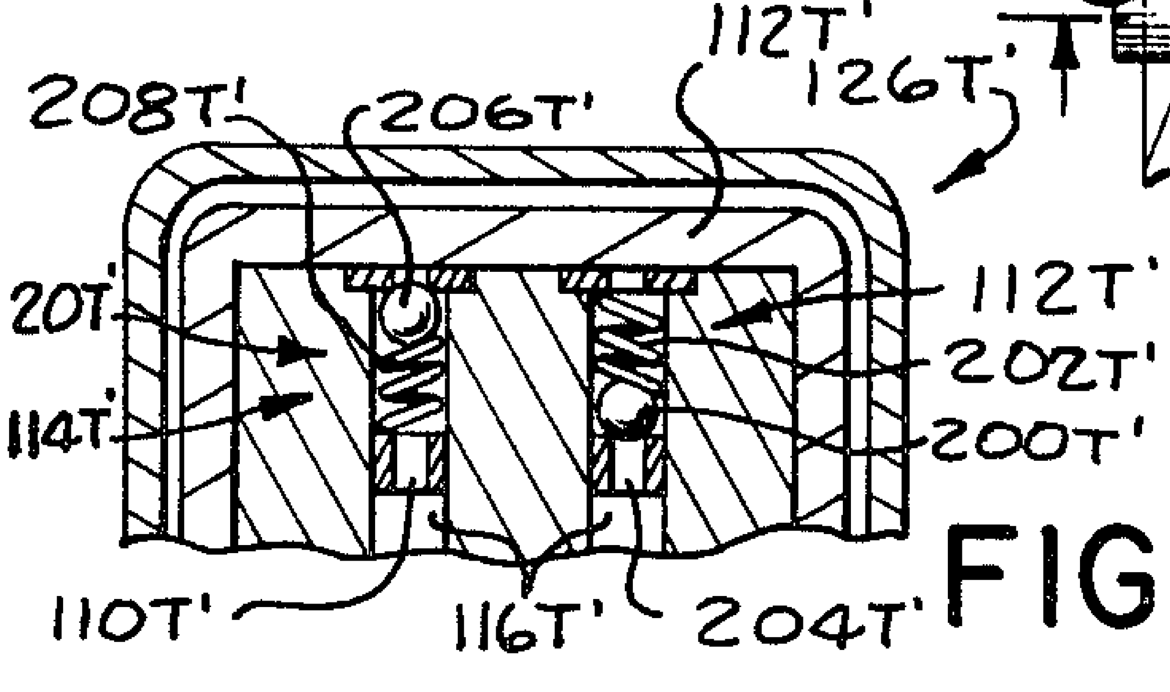


FIG. 38a

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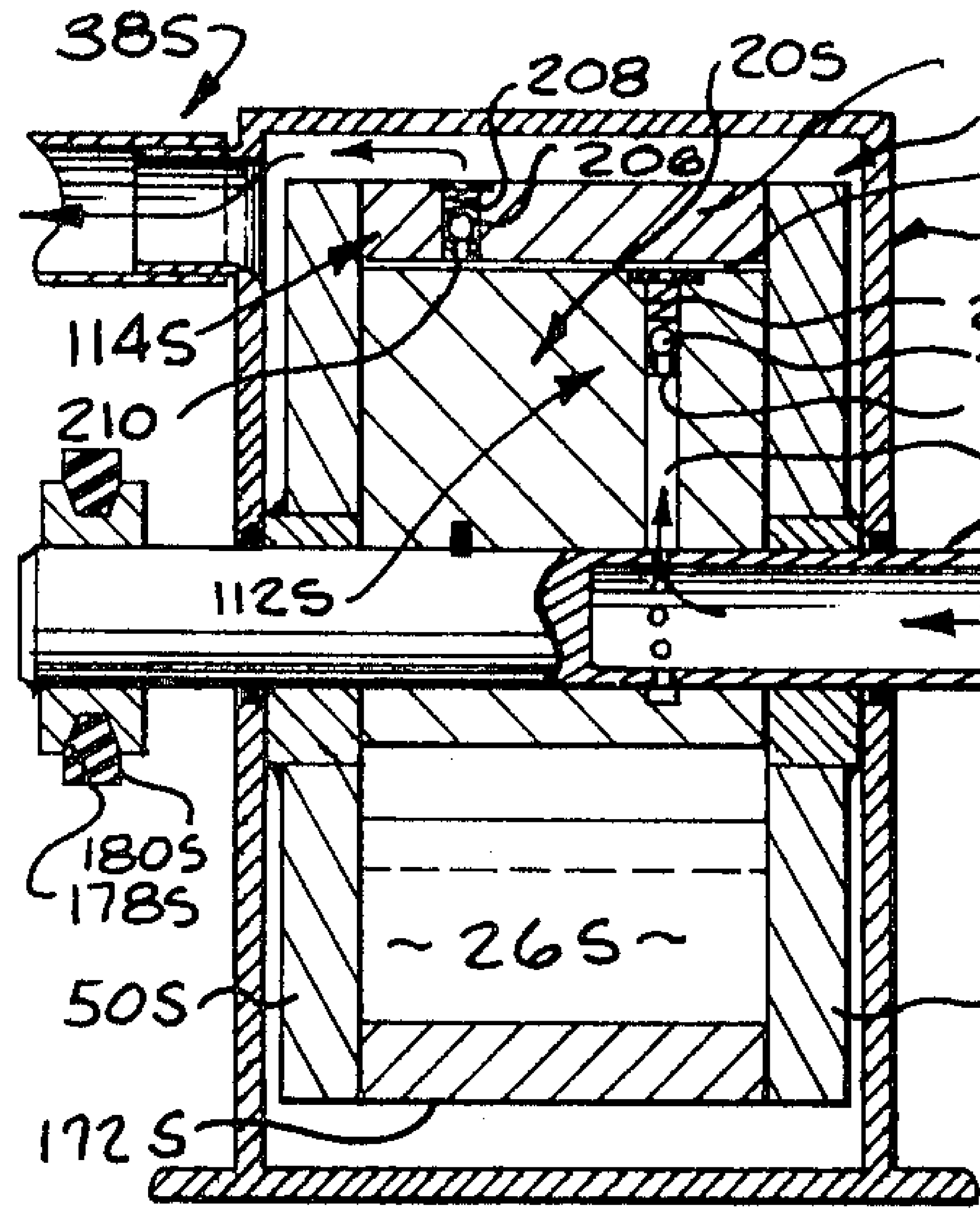
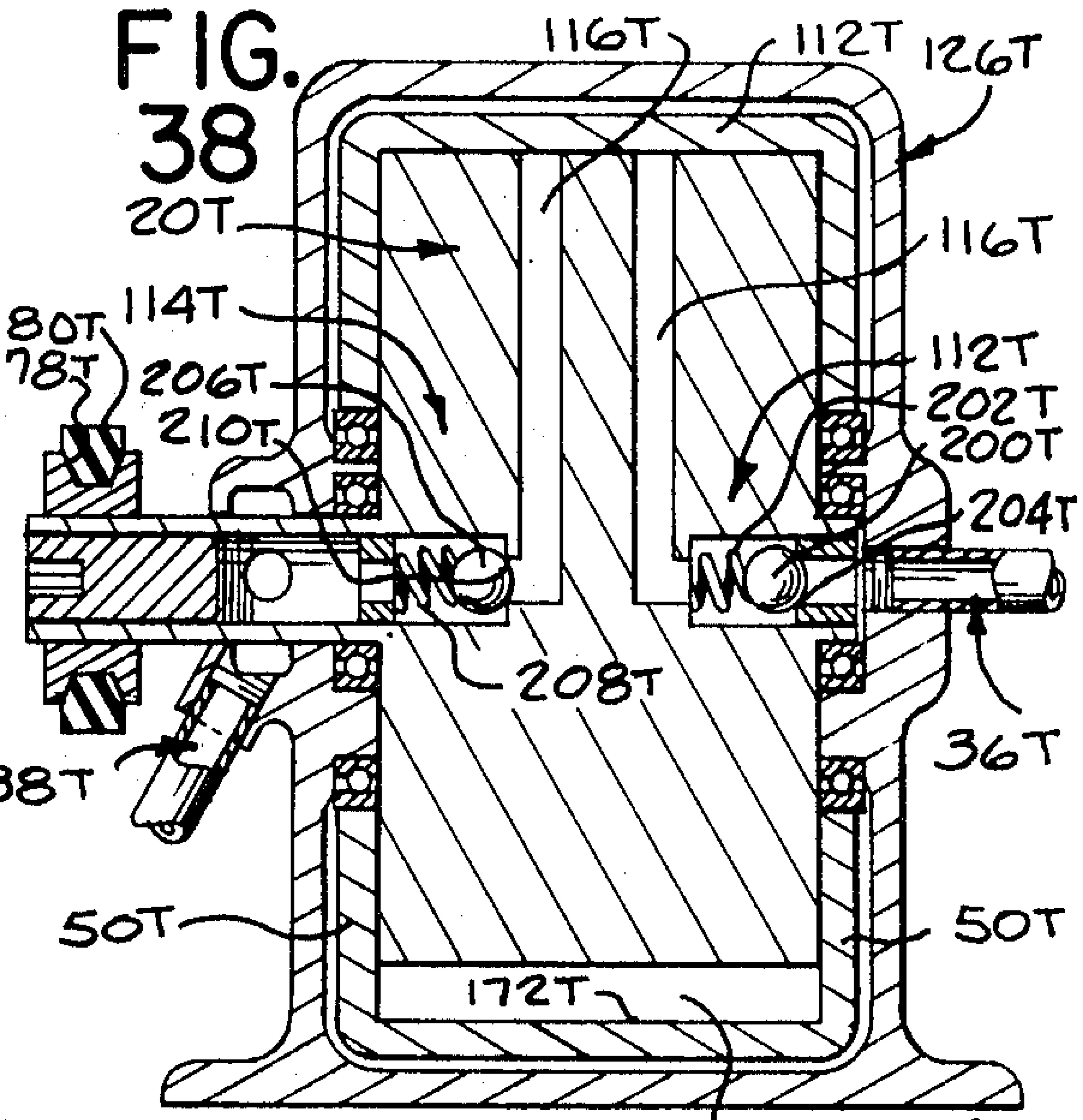


FIG. 37

FIG. 38



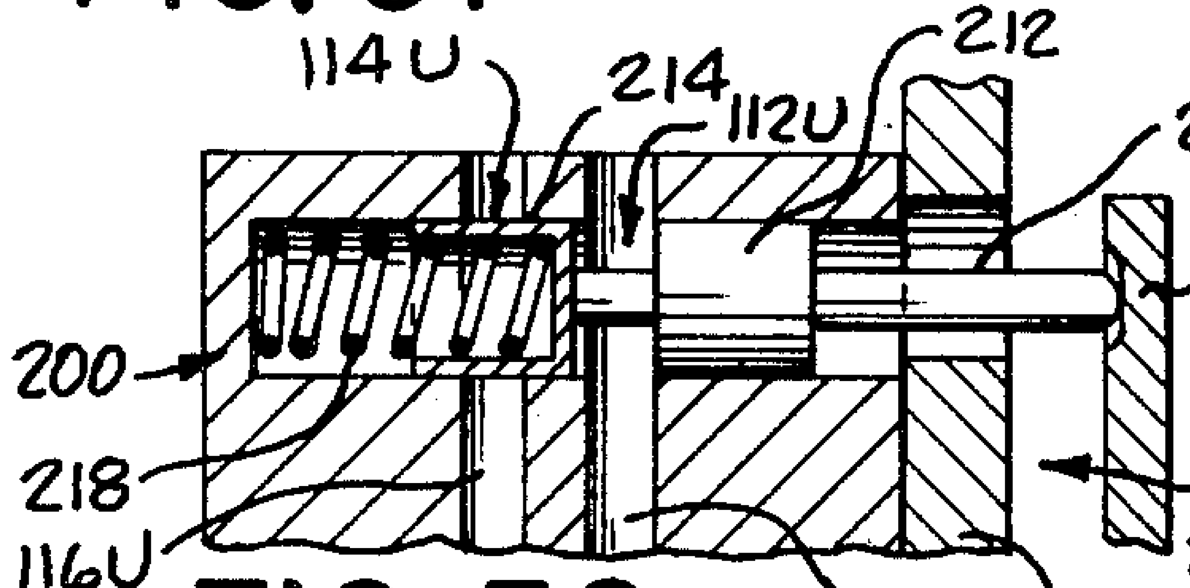


FIG. 39

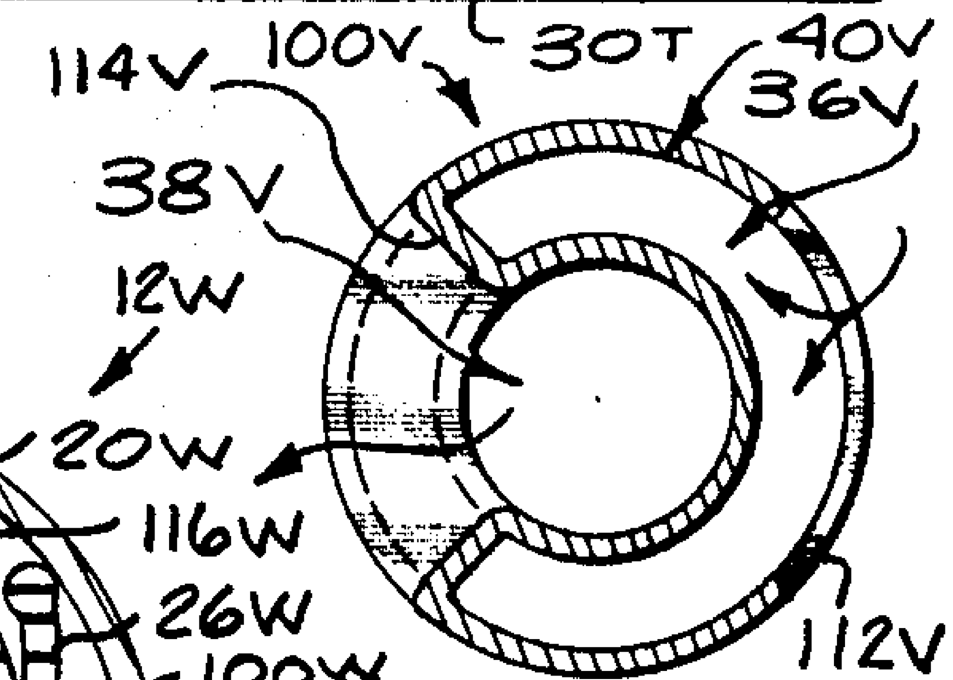


FIG. 40

FIG. 41

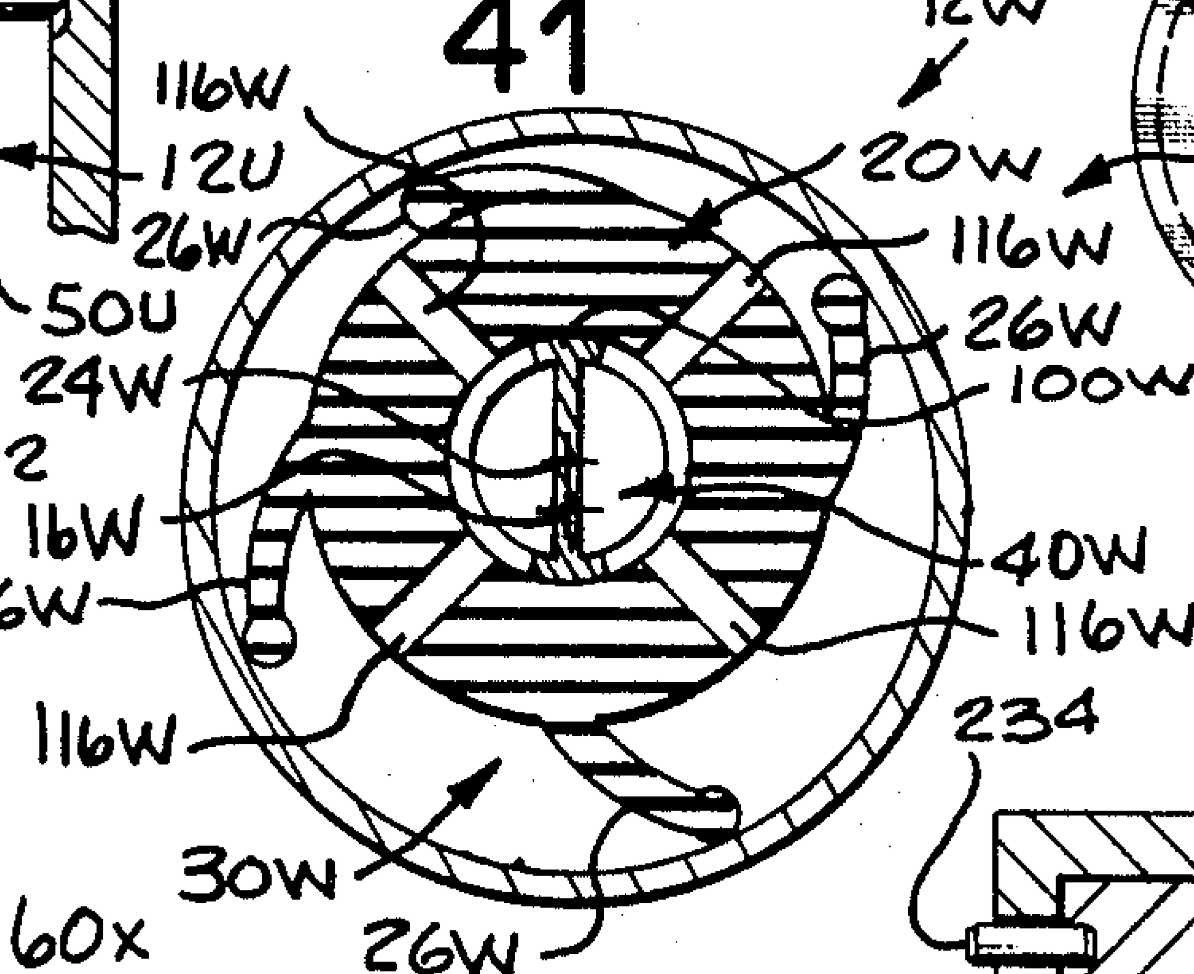
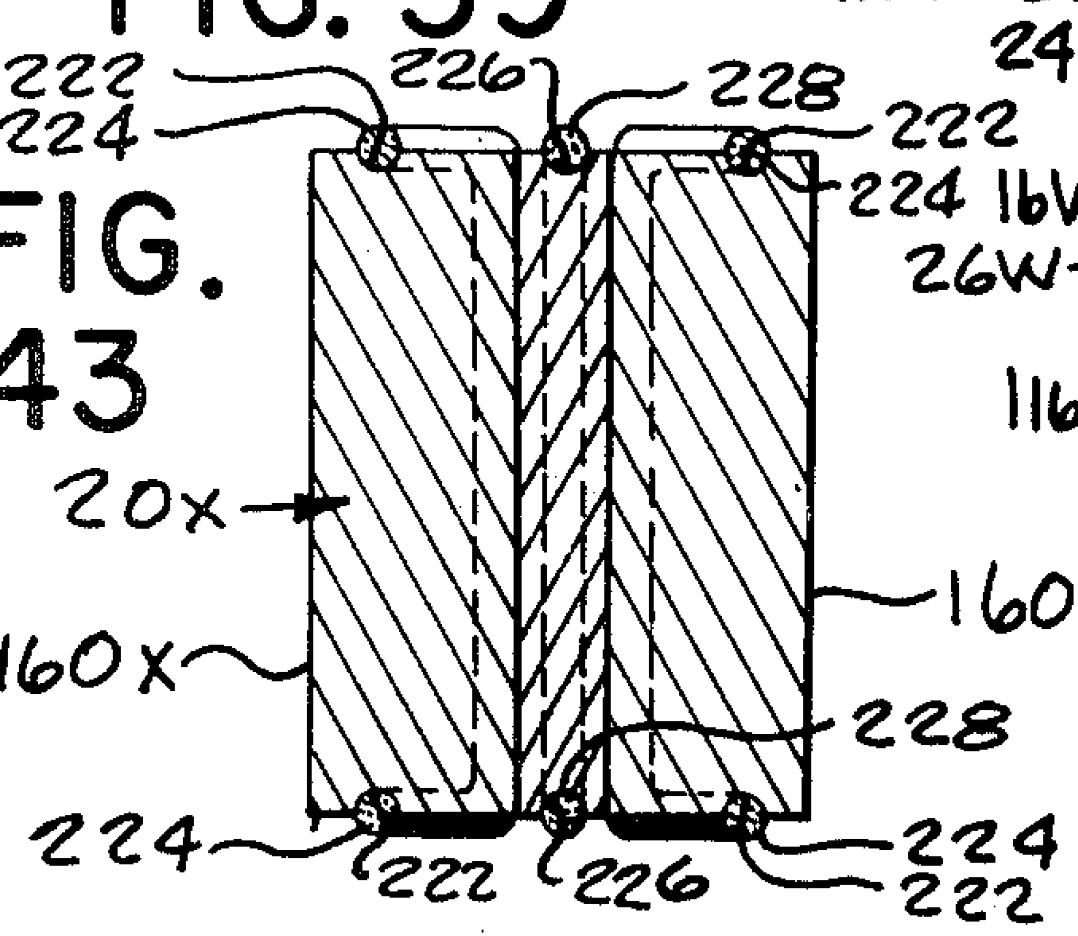


FIG. 43



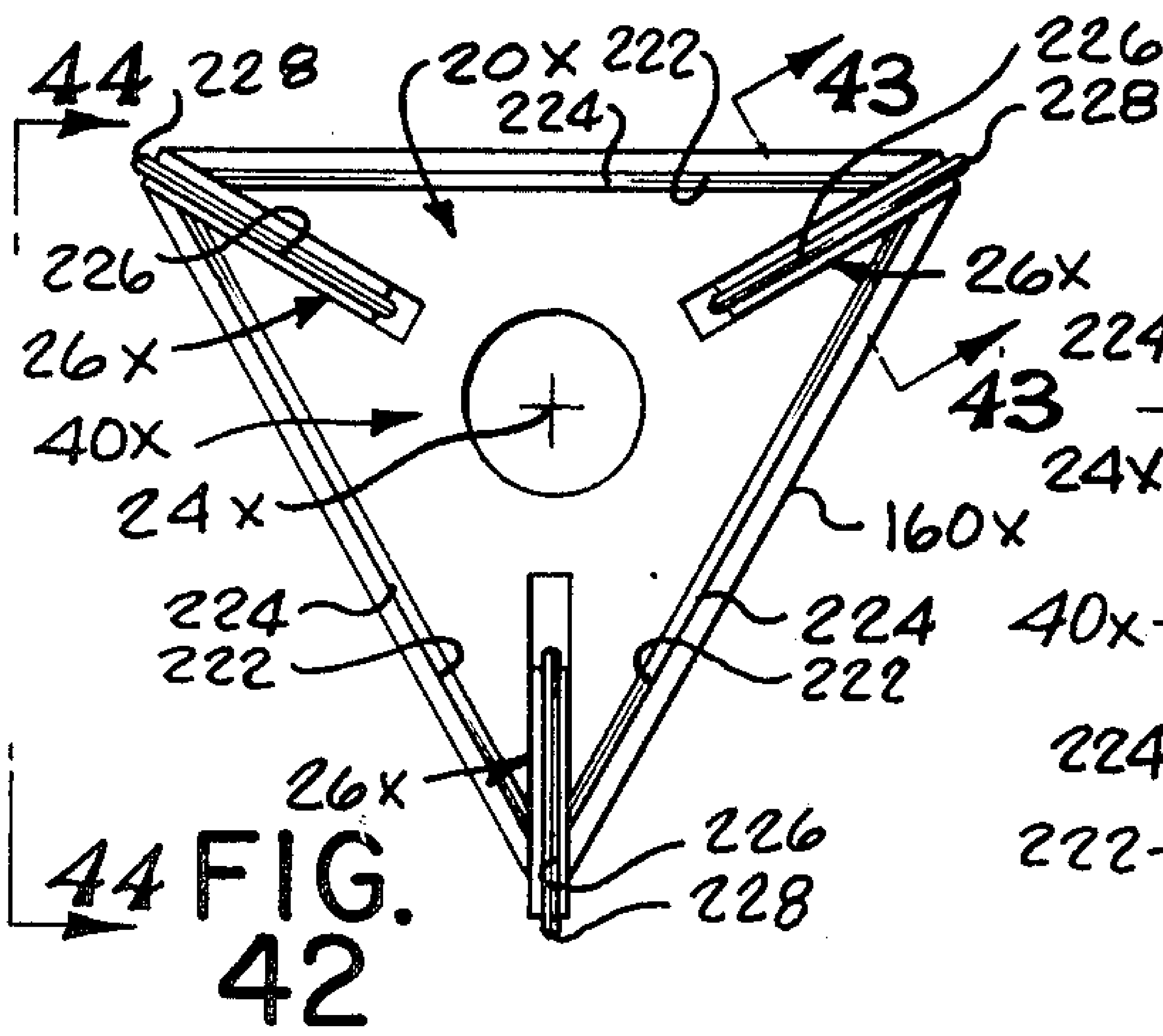


FIG. 42

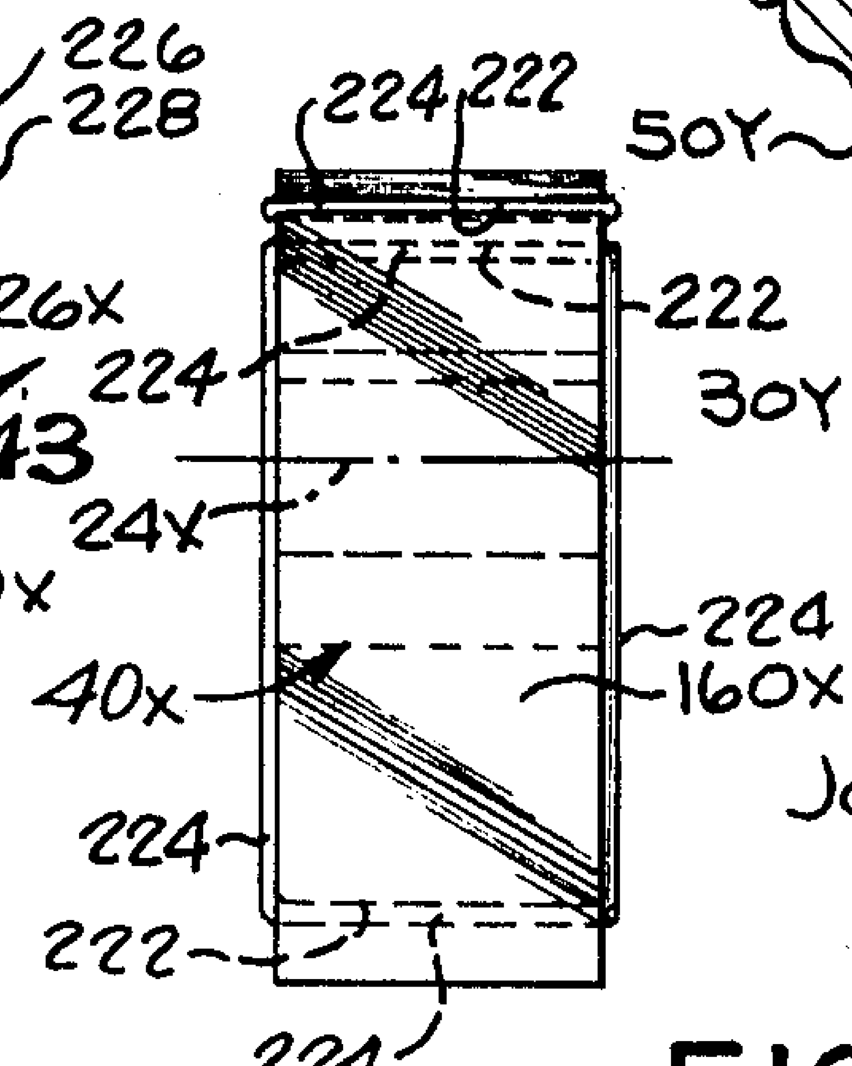


FIG. 44

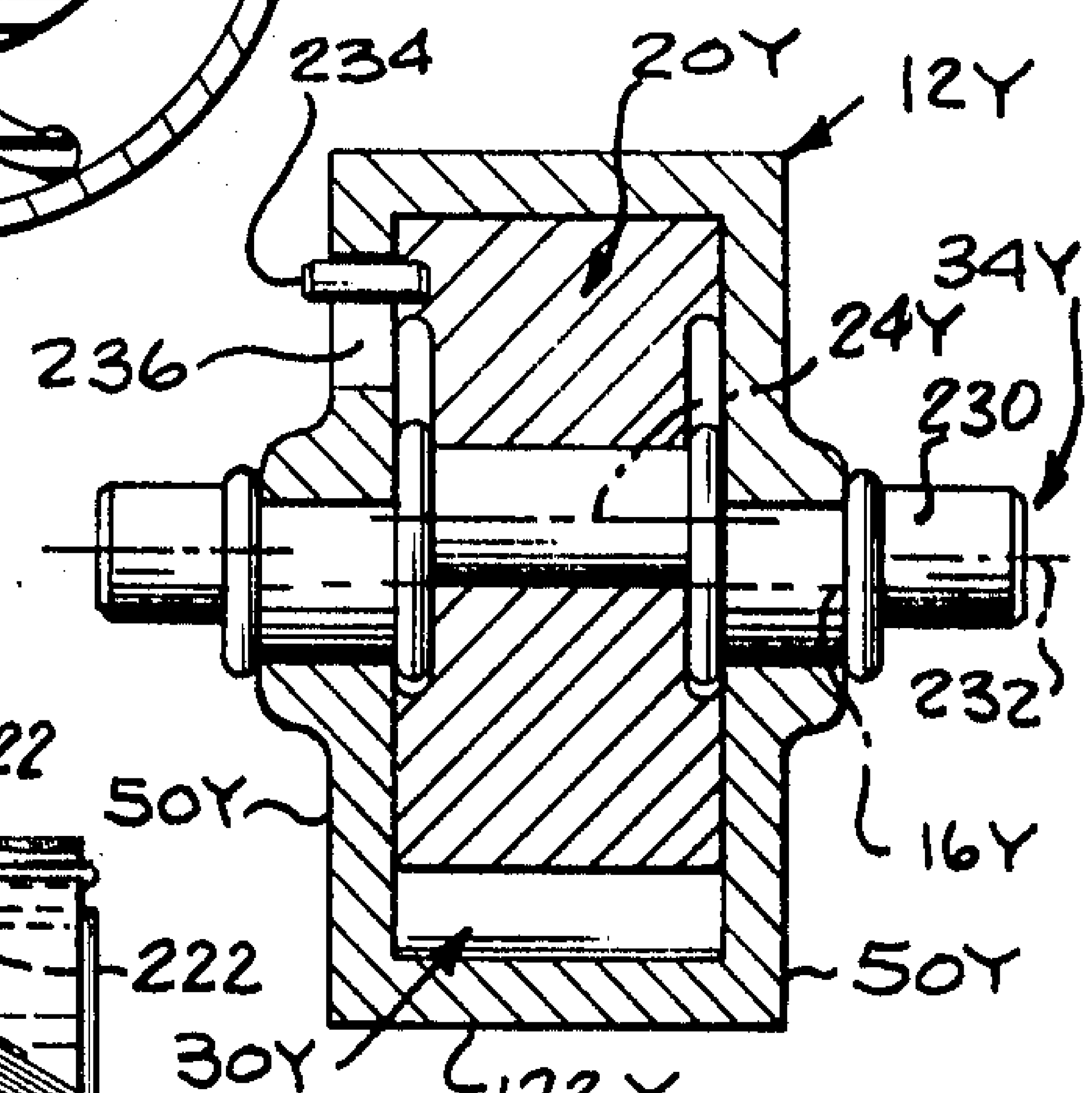


FIG. 45

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RADIAL CHAMBER POSITIVE DISPLACEMENT, FLUID POWER DEVICE

This application is a continuation-in-part of my copending Pat. application, Ser. No. 553,227, filed May 26, 1966, now issued as Pat. No. 3,529,909.

Generally speaking, the present invention relates to a radial chamber, positive displacement, fluid power device comprising housing means defining an internal piston chamber having a transversely directed housing axis (which is usually substantially centrally disposed with respect to the housing means, although not specifically so limited in all forms of the invention); piston means positioned within said chamber and having a transversely directed piston axis substantially parallel with respect to said housing axis (and usually substantially centrally disposed with respect to said piston means, although not specifically so limited in all forms of the invention). The chamber has a larger cross-sectional area than the piston means in a plane perpendicular to the transversely directed housing and piston axes. The device includes a pair of relatively eccentrically related supporting means having two eccentrically related substantially parallel axes coaxial, respectively, with said housing axis and said piston axis (and being similarly identified herein) and having a substantially parallel axis of operation of the complete device or system positioned in a plane terminating at one end and being coincident with said housing axis and terminating at the other end and being coincident with said piston axis and relatively rotatively supporting said housing means around said housing axis, relatively rotatively supporting said piston means around said piston axis, and supporting both said housing means and said piston means, as a system, for relative rotation around said axis of operation. The arrangement is such that the axis of operation may actually be coincident with and effectively comprise the housing axis in certain forms of the invention, may be coincident with and effectively comprise the piston axis in other forms of the invention, or may be positioned between the housing and piston axes in further forms of the invention. The relatively eccentric positioning of the piston means and the one of said pair of supporting means relatively rotatably supporting said piston means, and the relative cross-sectional shape of said piston means with respect to the larger cross-sectional shape of said chamber being so related as to provide and define radially varying chamber spaces at different relatively angularly shaped locations between said piston means and said housing means defining said chamber, with each such chamber space radially varying in extent as a function of relative rotative angular location of one relatively rotated axis of said housing and piston axes around said axis of operation, with said chamber space lying between the corresponding radially spaced portions of said piston means and said housing means. The device also includes at least one movable vane (usually more than one movable vane) sealingly cooperating with the piston means and a corresponding outwardly spaced inner wall of the housing means defining the chamber and circularly angularly dividing that portion of the chamber between the piston means and the inner wall of the housing means defining said chamber into at least two angularly adjacent ones of the above-mentioned chamber spaces. The device also includes means for effecting (which shall also mean allowing only) substantially simultaneous relative rotation of the housing means and the piston means with respect to the supporting means and centered on said axis of operation thereof while simultaneously effecting relative rotation of said housing means with respect to said supporting means centered on said housing axis and for simultaneously effecting relative rotation of said piston means with respect to said supporting means in a manner centered on said piston axis, while also effecting relative rotation of at least one of said housing and piston axes of said supporting means relative to said housing means and said piston means around said axis of operation of said supporting means in an opposite direction in a manner such as to effect cyclic contraction and expansion of said chamber spaces without any substantial relative angular

movement between said piston means and said housing means. As pointed out above, the axis of operation may comprise the housing axis, in which case the piston axis of the supporting means revolves around the housing axis relative to the housing means and piston means in a direction opposite from the relative rotation of said housing means and said piston means around said housing axis of said supporting means. As pointed out hereinabove in an alternate arrangement, the axis of operation may comprise the piston axis of the supporting means, in which case the housing axis of the supporting means revolves around the piston axis relative to the housing means and piston means in a direction opposite from the relative rotation of said housing means and said piston means around said piston axis of said supporting means. As pointed out hereinabove in a further alternate arrangement, the axis of operation may lie between the piston axis and the housing axis, in which case both the housing axis and the piston axis of the supporting means revolve around the axis of operation relative to the housing means and the piston means in directions opposite from the relative rotation of said housing means and said piston means around said axis of operation of said supporting means. The device also includes means for admitting a working fluid into and venting a working fluid from the chamber spaces, respectively, in timed relation to chamber-space-modifying relative movement of said piston means and said housing means in response to said substantially simultaneous relative rotation of said housing means and said piston means around said axis of operation of said supporting means and said simultaneous relative rotation of at least one of said piston and housing axes of said supporting means around said axis of operation of said supporting means in said opposite direction.

Broadly speaking, the structure generally defined above may be said to comprise a driving device or a driven device insofar as the working fluid is concerned. In other words, the working fluid may be driven by the device (which must, of course, be independently powered or driven) or the device may be driven by the working fluid (which must be appropriately supplied with the necessary driving energy). In the first instance, the device may comprise a fluid pumping device for any effective fluid, such as plasma, gas, vapor, liquid, semiliquid, or liquid-solid slurry, or even finely divided particulate solid material—in fact, material in any form of other than rigid solid material in large masses. In the second instance, the device may comprise what might be termed a pressurized-fluid-actuated motor (adapted to be operated by a separately pressurized effective fluid such as defined above) or a combustion engine adapted to produce, by fuel combustion, its own pressurized fluid (burned combustion gasses) operating the engine so as to cause powered rotation of a power transmission portion or member of the motor or engine, which in this case comprises a mechanical output power transmission portion or member of the motor or engine, such as an output shaft, for example. The effective fluid may be pressurized in any suitable manner at any location, local or remote, and the engine may be of an internal combustion type or an external combustion type and may be of either an open-thermal-cycle type or a closed-thermal-cycle type.

The above-mentioned substantially simultaneous relative rotation of said housing means and said piston means around said axis of operation of said supporting means while simultaneously effecting relative rotation of one (and, in certain cases, both) of said piston and housing axes of said supporting means around said axis of operation of said supporting means in the opposite direction may be caused to occur in any of several different manners or modes of operation.

A first mode of operation of the device as referred to in the preceding paragraph occurs when said pair of relatively eccentrically related supporting means, and the two eccentrically related housing and piston axes thereof, together with the axis of operation thereof, are nonrotatably mounted and at all times remain in fixed relationship to each other, while the housing means and the piston means are actually physically (and consequently also relatively) rotatably mounted by said pair of eccentrically related supporting means so as to simultaneously rotate around said axis of operation of said supporting means while said housing means rotates around said housing axis and said piston means rotates around said piston axis and one or the other of said housing and piston axes (and, in certain cases, both of same) of said supporting means relatively rotate around said axis of operation with respect to the actually physically rotating housing means and piston means and in a direction opposite to the actual physical rotation of said housing means and said piston means around said axis of operation. In the first form of the invention, which operates in accordance with the so-called first mode of operation, the piston means may properly be referred to as a rotor or rotor means (although the housing means also physically rotates) and both supporting means remain completely stationary and immovable. Also, in this first form of the invention, the device may be quite properly referred to as a rotary device and/or as a rotary chamber device, since the chamber (in particular, each chamber space thereof) does actually physically rotate around the axis of operation during operation of the device.

A second form of the invention, which operates in accordance with a second mode of operation comprises an arrangement such that the housing means and the piston means are mounted so as to be substantially actually physically rotatively immobilized by any means adapted to prevent actual physical rotation thereof as distinguished from relative rotation thereof with respect to the pair of supporting means. In this second form of the invention, which operates in accordance with the second mode of operation, the pair of relatively eccentrically related supporting means and the two eccentrically related axes thereof are arranged to actually physically rotate around the axis of operation thereof, which, as previously pointed out, may be coincident with the housing axis coincident with the piston axis, or positioned therebetween in a manner such that at least one of said housing and piston axes (and, in certain forms of the invention, both of same) actually physically rotates around the axis of operation of said supporting means and causes the piston means and the housing means to relatively move outwardly and inwardly with respect to each other in a chamber-space-modifying manner not accompanied by any actual physical rotation of said piston means and said housing means around said supporting means. In this second form of the invention, which operates in accordance with the above-mentioned second mode of operation thereof, despite the fact that the piston means, the housing means, the chamber (and, in particular, each chamber space thereof) do not actually physically rotate, the device can still be referred to as a rotary device because the pair of eccentrically related supporting means do actually physically rotate around the axis of operation.

The foregoing definition of the so-called second form of the invention, which operates in accordance with the so-called second mode of operation, is defined in generic terms and actually covers both a second and a subsequently described third mode of operation of the device.

In the specific form and mode of operation of the device, which hereinafter will be referred to as the second form of the device and the second mode of operation of the device, the above generically referred to axis of operation of the device is coincident with the housing axis of the supporting means and, therefore, the piston axis of the supporting means actually is the one which physically rotates around the combination axis of operation and housing axis of said supporting means and causes the above-described cyclic chamber-space-modifying relative movement of the nonrotating piston means and housing means.

In another form and mode of operation of the above broadly defined form and mode of operation of the device, which will hereinafter be specifically referred to as a third form of the device and a third mode of operation of the device, the axis of operation is coincident with the piston axis and the housing means and piston means are rotatively immobilized while the supporting means actually physically rotates around the piston axis. This specific third form of the device and third mode of operation thereof is more specifically defined immediately hereinafter.

The above-mentioned third form of the invention, which operates in accordance with the above-mentioned third mode of operation, comprises an arrangement such that the housing means and the piston means are again substantially rotatively immobilized or prevented from actual physical rotation (as distinguished from relative rotation with respect to the supporting means) by any suitable means and the pair of eccentrically related supporting means (and the two eccentrically related piston and housing axes thereof) are arranged to rotate in a manner such that the housing axis actually physically rotates around the piston axis thereof in a manner such as to cause the housing means and the piston means to relatively move inwardly and outwardly with respect to each other in a chamber-space-modifying manner not accompanied by any actually physical rotation of said housing means and said piston means around said supporting means. In this third form of the invention, the device may also be referred to as a rotary device for substantially the same reasons as set forth in connection with the second form of the invention.

Also, the version of the invention wherein the supporting means actually physically rotates, while the housing means and the piston means do not, may take a fourth form which operates in accordance with what might be termed a fourth mode of operation. In this fourth form of the invention, the axis of operation lies between the housing axis and the piston axis of the supporting means and, thus, actual physical rotation of the supporting means around said operation axis causes both said piston axis and said housing axis to rotate around said axis of operation in a direction opposite to the relative rotation of said housing means and said piston means with respect to said supporting means (although, of course, it should be understood that actually said housing means and said piston means do not rotate physically at all in this exemplary, but nonspecifically limiting form of the invention). In this form of the invention, said actual physical rotation of said supporting means around said axis of operation positioned between said piston axis and said housing axis causes both the housing means and the piston means to actually physically move relative to said operation axis and relative to each other inwardly and outwardly in a chamber-space-modifying manner not accompanied by any actual physical rotation of said housing means and said piston means around said supporting means.

It should be noted that in the second and third forms of the invention referred to above, the piston means and the housing means, respectively, are, in effect, actually physically moved in an oscillatory manner by the actual physical rotation of the eccentrically related supporting means which, thus, provides a rotary in balance to the complete device which may be fully compensated for by the provision of oppositely positioned counterweight means so as to provide a fully dynamically balanced operating device. In the case of the fourth form of the invention broadly defined above, it will be noted that there are two unbalanced moving masses provided by the effective oppositely positioned eccentric portions of the supporting means lying on each side of the axis of operation and causing oppositely directed oscillatory movement of the housing means and the piston means and these may be so positioned and quantitatively arranged as to exactly cancel each other out as far as net imbalance to the complete operating device is concerned. It should also be noted that in the case of the second and third forms of the invention, more than two such rotary devices may be connected by structural means such as a common driving shaft, or the like, so that their imbalances are effectively oppositely directed and neutralize or cancel each other out.

In the above-mentioned first form of the invention, operating in accordance with the first mode of operation briefly defined above when the device is used as a pump requiring a driving mechanical input from an exterior source, either the housing means or the piston means (which is interchangeable with the expression "rotor means" in this case) or any means drivingly coupled thereto, may be power rotated from an external power-driven shaft, pulley belt, sprocket chain and sprocket, gearing, or any other external source of energy, or means for coupling same, adequate to power rotate said housing means and said piston or rotor means, considered as a combination system, substantially simultaneously around said supporting means centered on said axis of operation thereof, although said housing means will also rotate around said housing axis and said piston or rotor means will also rotate around said piston axis. Conversely, when said first form of the invention is used as a pressurized-fluid-actuated motor or as an engine, either the housing means or the piston or rotor means, or any means effectively driven thereby, may effectively comprise an output member, or power transmission member, adapted to be appropriately coupled to some external means or mechanism which is to be power rotated or power driven. In either aspect of the invention—that is, either as a driving device or a driven device—the input power transmission means or the output power transmission means may be broadly defined as power transmission or coupling means irrespective of which direction the power is being transmitted therethrough.

In the above-mentioned second form of the invention, which operates in accordance with the above briefly described second mode of operation of the invention, when used as a pump requiring a driving mechanical input coupled to the device by way of power transmission means from an exterior source, the portion of said pair of supporting means having said housing axis therein and relatively rotatively supporting said housing means may be directly, or indirectly, power rotated on said housing axis by means of a gear, pulley belt, sprocket chain and sprocket, offset crank or other power transmission means, power-driven from an external power-driven shaft, motor, or other external source of energy adequate to power rotate said supporting means portion. Conversely, when said second form of the invention is used as a pressurized-fluid-actuated motor or as an engine, the above-mentioned portion of the supporting means, or any means effectively driven thereby, may effectively comprise output power transmission means adapted to be appropriately coupled to some external means or mechanism which is to be power rotated or power driven.

In the third above-mentioned form of the invention, which operates in accordance with the third above-mentioned mode of operation, when used as a pump requiring a driving mechanical input coupled to the device by way of power transmission means for an exterior source of mechanical rotary power, the portion of said pair of supporting means having said piston axis and relatively rotatively supporting said piston means may be directly, or indirectly, power rotated on said piston axis by means of a gear, pulley belt, sprocket chain and sprocket, offset crank, or other power transmission means power driven from an external power-driven shaft, motor, or other external source of energy adequate to power rotate said supporting means portion. Conversely, when said third form of the invention is used as a pressurized-fluid-actuated motor or as an engine, the above-mentioned portion of the supporting means, or any means effectively coupled thereto or driven thereby, may effectively comprise an output power transmission means or member adapted to be appropriately coupled to some external means or mechanism which is to be power rotated or power driven by the motor or engine.

In the fourth above-mentioned form of the invention, which operates in accordance with the fourth above-mentioned mode of operation, when used as a pump requiring a driving mechanical input coupled to the device by way of power transmission means from an exterior source of mechanical rotary power, the supporting means may be, directly or indirectly, power rotated around said axis of operation by means of gearing, pulley belt means, sprocket chain and sprocket means, offset crank means, or other power transmission means power driven from an external power-driven shaft, motor, or other external source of energy adequate to power rotate said supporting means. Conversely, when said fourth form of the invention is used as a pressurized-fluid-actuated motor or as an engine, the supporting means, rotating around said intermediate axis of operation, or any means effectively coupled thereto or driven thereby, may effectively comprise an output power transmission means or member adapted to be appropriately coupled to some external means or mechanism which is to be power rotated or power driven by the motor or engine.

It should be noted that throughout this application specific reference is made to various different specific forms and/or aspects of the present broad generic and comprehensive invention, and to various different specific subportions thereof individually and in various different specific combinations, without specific reference in each instance to the substantial equivalency, replaceability, substitutibility, and/or interchangeability thereof, or of any portion thereof, by other specific, alternate, and/or broader aspects or forms of the invention, either as to major forms or portions thereof and/or as to lesser subcombination or subportion parts thereof, considered either individually or in any of numerous different possible combinations, and/or to the possibility of eliminating certain portions thereof in certain forms of the invention, with all such modifications being intended to be included and comprehended within the broad scope of this invention and application. Therefore, all such specific references are to be considered as exemplary only and nonspecifically limiting and are to be broadly read, construed, interpreted, and applied in the manner referred to in the foregoing statement with respect to broadness of definition, substantial equivalency, replaceability, substitutibility, interchangeability, and/or elimination of various different specifically referred to forms and/or portions of the complete, broad, inventive concept intended to be fully disclosed herein, and with respect to virtually all possible permutations and combinations of different subcombination portions thereof, which are also intended to be fully included within the scope hereof.

Taking into account the foregoing paragraph, I have elected, for exemplary purposes only, initially, in following pages of text, to primarily refer to that one of the many different included forms of the invention which operates in accordance with the hereinbefore generally described first mode of operation and which, therefore, may be said to comprise one version of the hereinbefore generically described first form of the invention, and which is illustrated and described largely in the driven aspect thereof (driven insofar as the working fluid is concerned) hereinbefore referred to as the second instance thereof where it comprises an engine (or motor) having a mechanical output member and is adapted to be operated by pressurized fluid, such as burned-fuel combustion gasses, for example. The foregoing statement is also substantially true of the brief figure description portion of this specification briefly describing and identifying the first **13** figures of the accompanying drawings (as well as being true of said FIGS. **1**—**13** inclusive themselves), and is true of the text set forth on the pages of this specification immediately following the end of the complete figure description portion of the specification and describing said FIGS. **1**—**13** inclusive in specific detail—all of which is to be considered as exemplary only and nonspecifically limiting and to be construed broadly in the light of the preceding paragraph.

In its broader aspects, the hereinbefore-mentioned first form, second instance of the invention provides a pressurized-fluid-operated device of the kind which is characterized by a housing (broadly speaking, housing means) defining an internal chamber, a rotor (broadly speaking, piston means) mounted within the chamber for turning on an axis eccentric to the chamber axis and with either the housing or the rotor having one or more angularly spaced movable vanes defining chamber spaces therebetween, and means for admitting a working fluid to and venting the working fluid from these chamber spaces in timed relation to rotation of the rotor. This basic structure of the present pressure fluid device will be recognized as that which is common to certain types of rotary pumps, rotary fluid pressure actuated motors, and rotary combustion engines. In this regard, it is significant to know at the outset that the improvement features of the invention may be utilized to great advantage in all three of the above-mentioned types of pressure fluid devices—i.e., pumps, motors, and engines. However, the hereinbefore-mentioned first form of the invention has great utility in and will be disclosed in connection with its application to rotary internal combustion engines, primarily for exemplary, although nonspecifically limiting, purposes.

In pressurized-fluid-operated devices of the kind under discussion, the volume of each chamber space alternately increases and decreases as the rotor turns due to the eccentricity of the rotor axis relative to the rotor chamber axis. This eccentric rotation of the rotor, of course, is permitted by the vanes by virtue of the fact that, in one exemplary and nonspecifically limiting form of the invention where they are carried by the rotor, these vanes are yieldably urged outwardly into fluid sealing relation to the wall of the rotor chamber, such that the vanes can move in and out of the rotor body to accommodate the continuous change in the radial spacing between any given point on the body and the chamber wall which occurs as the rotor turns. In a rotary pump of this kind, the valving is arranged to communicate each chamber space to a relatively low pressure fluid inlet during expansion of the respective chamber space and to a relatively high pressure fluid outlet during contraction of the chamber space, whereby the device exhibits a continuous pumping action. If the device is a fluid-pressure-actuated motor, the valving is arranged to communicate each chamber space to a relatively high pressure fluid inlet during expansion of the respective chamber space and to a relatively low pressure fluid outlet during contraction of the chamber space. In this case, action of the high pressure fluid within each chamber space on the unequal areas of the rotor vanes, and/or effectively eccentric portions of the rotor, bounding the space create a net torque in one direction on the rotor which drives the latter in rotation. The working fluid may be a liquid, a gas from an external pressurized gas source, or a gas generated by an external or internal combustion process. The operation of a rotary pressure fluid device, when used as an internal combustion engine, is essentially the same as in the case of the motor just discussed. In a rotary internal combustion engine, is essentially the same as in the case of the motor just discussed. In a rotary internal combustion engine, however, the high pressure working fluid in a gas (or gasses) generated directly within each chamber space by the burning of a combustible fuel in the space. As noted earlier while the present invention may be utilized to advantage in all of these types of rotary pressurized-fluid-operated devices, the hereinbefore-mentioned first form of the invention will be hereinafter initially disclosed primarily in connection with an internal combustion engine for exemplary, although nonspecifically limiting, purposes.

The existing rotary pressure fluid devices of the kind under discussion, while satisfactory in many ways, possess certain deficiencies which this invention seeks to cure. Many of these deficiencies have long been troublesome to those working in the art and have prevented large scale use of some kinds of rotary pressure fluid devices, particularly rotary internal combustion engines. This is true even though such engines are known to be superior, from many standpoints, to reciprocating piston engines.

Many of the deficiencies of the prior art rotary pressure fluid devices result from the fact that the rotor and housing of such devices undergo relative rotation—that is, rotation with respect to each other. Thus, in the majority, if not all, of the prior art devices, at least those of which I am aware, the housing is stationary and the eccentric rotor turns within and relative to the housing. This relative rotation of the rotor and housing has several disadvantages. For example, relative rotation of the rotor and housing results in sliding movement of the outer edges of the rotor vanes about or along the inner wall surfaces of the rotor chamber. Such sliding movement, of course, creates substantial wear and friction loss. Moreover, the rotor body and rotor chamber must be circular or generally circular in transverse cross section. In most of the prior art devices, both the rotor body and rotor chamber are circular in cross section, and expansion and contraction of the chamber spaces defined by the rotor vanes is accomplished by eccentric placement of the rotor in the chamber. In some cases, however, the rotor chambers are noncircular, such as generally elliptical. The prior art devices with such noncircular rotor chamber cross sections however, are costly to manufacture, give rise to excessive wear and friction loss between the rotor vanes and the wall surfaces of the rotor chamber, and are otherwise undesirable from the standpoint of manufacture, operation, and maintenance. It is obvious that the foregoing deficiencies of the prior art rotary pressure fluid devices are particularly serious in the case of rotary internal combustion engines.

One highly important aspect of the present invention is concerned with the fact that the housing as well as the rotor, of the hereinbefore-mentioned first form of the present improved pressure fluid device turns and, moreover, in unison with the rotor. This unified rotation of the rotor and housing occurs in such a way that the rotor and housing do not undergo relative rotation, at least any substantial relative rotation. As a consequence, the invention achieves a great reduction in wear and friction loss, particularly between the rotor vanes and the walls of the rotor chamber. Since the rotor vanes are not required to slide along the walls of the rotor chamber, machining of the present pressure fluid device is greatly simplified and reduced in cost. Moreover, the housing and rotor may have a wide variety of configurations or geometries in transverse cross section, including both circular and noncircular geometries. This permits much greater freedom in engine design or, for that matter, in pump or compressor design. In this regard, for example, another highly important aspect of the invention is concerned with certain unique housing and rotor shapes or geometries which maximize the ratio between the maximum and minimum volumes of each chamber space defined by the rotor vanes. Obviously, this aspect or feature of the invention is particularly important and advantageous in rotary engines for the reason that it permits a maximum compression ratio in the engine and maximum efficiency and power output. It is also largely true of pumps and/or compressors.

At this point, it is significant to note that in the hereinbefore-mentioned first form of the present pressure fluid device, each chamber space is bounded by walls which rotate in unison. In effect, then, each chamber space rotates with the rotor. Hence, the use of the descriptive phrase "rotary chamber" in connection with said first form of the present device.

Another disadvantage of many prior art rotary pressure fluid devices of the kind under discussion is their dynamic unbalance. Such unbalance is particularly serious in rotary engines, of course, because of their relatively high speeds of operation. An important feature of the present device is its dynamic balance which is achieved by the unique arrangement of the rotor and housing.

Yet a further deficiency of the prior rotary pressure fluid devices, particularly rotary engines, is concerned with the problem of sealing theretofore vanes to the wall of the rotor chamber. It is obvious, of course, that if an efficient seal is not provided between the rotor vanes and the walls of the rotor chamber, leakage of working fluid can occur from one chamber space to an adjacent chamber space. In the case of rotary fluid pumps and motors, such fluid leakage merely reduces the efficiency of the devices. Leakage of working fluid between adjacent chamber spaces in a rotary engine also reduces engine efficiency. More serious, however, is the fact that leakage of hot combustion gas from a chamber space under combustion or under exhaust to an adjacent chamber space undergoing the compression or the intake portion of its cycle may cause preignition of the fuel in the adjacent chamber space. Such preignition produces a resisting torque on the rotor in opposition to the normal driving torque on the rotor, causes rough engine operation, reduces engine power and efficiency, and frequently causes major damage to the engine to occur.

According to the exemplary, but nonspecifically limiting, first form, second instance of the present invention, leakage of working fluid between adjacent chamber spaces of the fluid pressure device is prevented in a new and unique way. First, the rotor body and vanes are provided with vane-actuating or vane-biasing means, which in one specific exemplary, but non specifically limiting, arrangement, take the form of having the rotor body and vanes equipped with interfitting plungers and chambers and with passages which communicate these vane chambers to the chamber spaces defined between the vanes. Accordingly, when each chamber space is pressurized, high pressure fluid from the space acts to urge the adjacent rotor vanes outwardly into more intimate fluid sealing relation with the wall of the rotor chamber. This may also be done without the use of the plungers by direct pressure on the vanes. This serves to maintain the vanes in intimate fluid sealing relation with the rotor chamber wall and, thereby, to minimize the entrance of working fluid between the outer edges of the vanes and the chamber wall. Secondly, the rotor vanes, in certain exemplary, but nonspecifically limiting forms, are equipped with vent passages which open centrally through the outer chamber wall-engaging edges of the vanes and communicate to a low pressure region, which, in some cases, may be ambient atmosphere. Accordingly, any working fluid which does enter between the outer edges of the vanes and the wall of the rotor chamber is effectively bled off to the low pressure region, or ambient atmosphere, and is thus prevented from entering the adjacent chamber space.

The improved device of the invention has certain other unique features and advantages which will become evident as the description proceeds. Some of these additional features, for example, are a unique cooling arrangement for use in a rotary chamber engine according to the invention a novel supercharging action for the engine, and unique valving which may be employed in any or all of the different forms of the present pressure fluid device.

Accordingly, it is a general object of the present invention to provide a novel rotary chamber fluid device of the character described.

A more specific object of the invention is to provide a rotary chamber pressure fluid device which may comprise a rotary pump for pressurizing a working fluid, a rotary motor to be actuated by a pressurized working fluid, or a rotary combustion engine wherein the working fluid comprises hot combustion gas which may be generated by a combustion process taking place externally of the engine or directly within the chamber spaces of the engine.

A highly important object of the invention is to provide a rotary pressure fluid device of the character described wherein the rotor and rotor housing rotate in unison in such a way as to eliminate relative rotation between the rotor and housing and, thereby, wear and friction loss.

Yet another object of the invention is to provide a rotary pressure fluid device of the character described wherein the rotor and rotor chamber may have a variety of different shapes or geometries, both circular and noncircular, in transverse cross section, thereby permitting substantially greater freedom in engine design.

A related object of the invention is to provide a rotary pressure fluid device according to the foregoing object wherein the rotor and rotor chamber have a unique noncircular cross section which results in a substantial increase in the ratio between the maximum and minimum volumes of the chamber spaces defined by the rotor vanes.

Another related object of the invention is to provide a rotary chamber engine according to the foregoing object which exhibits a maximum compression ratio hence maximum power output and efficiency.

A further object of the invention is to provide a rotary chamber pressure fluid device of the character described wherein leakage of working fluid between the adjacent chamber spaces, across the intervening rotor vane, is effectively eliminated.

A related object of the invention is to provide a rotary chamber engine according to the foregoing object wherein preignition, resulting from the leakage of hot combustion gas from a chamber space under combustion or under exhaust to an adjacent chamber space under compression or during intake, is avoided.

Still a further object of the invention is to provide a rotary chamber engine of the character described having a unique cooling system and an associated supercharging action.

Yet a further object of the invention is to provide a rotary chamber pressure fluid device of the character described having several unique valve arrangements for admitting working fluid to and venting or exhausting working fluid from the chamber spaces of the device.

Other objects of the invention are concerned with providing a rotary chamber pressure fluid device and engine of the character described which are relatively simple in construction, inexpensive to manufacture, reliable in operation, require minimum servicing, are relatively immune to malfunctioning, and are otherwise ideally suited to their intended purposes.

As previously pointed out, the foregoing objects pertain primarily to the previously described first form of the invention and to the first mode of operation thereof wherein the device actually has a rotary chamber by reason of the substantially simultaneous rotation of a hollow housing means and in an inner piston means (which actually comprises a rotor as referred to in the preceding objects). Also, the foregoing objects refer primarily to the driven aspect of the invention hereinbefore referred to as the second instance thereof where it comprises an engine or motor having a mechanical output member and is adapted to be operated by pressurized fluid, such as burned-fuel combustion gasses, for example. However, as previously pointed out, the invention is substantially broader than just the previously described first form of the invention operating in accordance with the previously described first mode of operation thereof and, therefore, the objects which follow more broadly refer to other forms and other modes of operation of the invention.

In its broadest conception, it is a general object of the present invention to provide a novel radial chamber, positive displacement, fluid power device of the character referred to herein which has any or all of the advantages referred to herein, including any or all of the features referred to herein, generically and/or specifically and individually or in combination, and which may actually comprise a device wherein the housing means and piston or rotor means actually physically rotate substantially in unison relative to the previously mentioned pair of eccentrically related supporting means so as to produce relative chamber space modifying movement of the piston or rotor means with respect to the housing means (or the reverse) during such substantially simultaneous rotation thereof in a manner which may be said to also effectively produce substantially simultaneous rotation of one or more rotary chamber spaces between the piston or rotor and the housing means, or which may actually comprise a device wherein the housing means and piston means do not actually physically rotate but wherein the previously mentioned pair of eccentrically related supporting means do actually physically rotate relative to the housing means and the piston means and thus produce chamber-space-modifying relative movement of the piston means and the housing means without effectively rotating the chamber space. In other words, in this second form of the invention operating in accordance with a second mode of operation, the one or more chamber spaces defined between the piston and the housing means are radially disposed or located relative to the center of the complete device but do not rotate therearound as in the first above-mentioned form of the invention operating in accordance with the first above-mentioned mode of operation thereof. The invention may also operate in a manner which may be said to be a combustion of the first and second modes of operation briefly described above—that is, where the housing means and piston or rotor means relatively rotate in substantial unison with respect to the eccentrically related pair of supporting means and wherein both said eccentrically related pair of supporting means and said housing means and piston means not only relatively rotate with respect to each other but also actually physically rotate. In other words, the invention contemplates and includes any arrangements wherein the housing means and piston means relatively rotate substantially in unison with respect to the pair of eccentrically related pair of supporting means and irrespective of whether or not either of same is fixed in an absolute sense or both are free to rotate (in differing manners, of course) in an absolute sense while yet producing relative rotation therebetween and in every case in a manner such that the relative and substantially unified rotation of the housing means and the piston means with respect to the eccentrically related pair of supporting means will be centered around an axis of operation which may be coincident with either one of a pair of eccentrically related axes of said supporting means coaxial with an effectively comprising a housing axis and a piston axis, or which may be positioned between said housing axis and said piston axis, while simultaneously effecting relative rotation of another one of said pair of eccentrically related axes of said supporting means (and, in some forms of the invention, both of same) around said axis of operation in the opposite direction in a manner such as to effect cyclic contraction and expansion of chamber spaces between the smaller diameter piston means and the corresponding inner wall portion of the larger diameter housing means.

It is another object of the present invention to provide a radial chamber, positive displacement, fluid power device of the character referred to above which may comprise an effective pump or compressor for moving and/or pressurizing a volume of working fluid in one or more stages or in a plurality of successive stages, or which may comprise a motor adapted to be actuated by a pressurized working fluid, or which may comprise a combustion engine wherein the working fluid comprises hot combustion gasses which may be generated by a combustion process taking place externally of the engine or internally of the engine. Incidentally, it should be noted that the word "pump," as used in this paragraph and as used elsewhere throughout this application, is not limited to the conventional meaning of a positive pump—that is, one which moves or pressurizes a volume of working fluid on the output side thereof—but is also intended to mean a negative pump which is sometimes referred to as a vacuum pump wherein the input side thereof is connected to working fluid in a region which is to have the pressure of said working fluid greatly reduced by evacuation of the working fluid from the region, and it should be noted that both of these meanings are intended to be included and comprehended in the broad scope of the present invention and application.

A further object of the present invention is to provide a radial chamber, positive displacement, fluid power device of the character referred to above wherein the piston means and housing means do not have any substantial relative angular or rotative displacement with respect to each other during operation of the device, whereby to eliminate relative wear and friction less such as normally occurs in most pumps and/or engines having a rotor and a rotor housing which relatively rotate with respect to each other.

It is a further object of the present invention to provide a radial chamber, positive displacement, fluid power device of the character described wherein the piston means and the chamber defined within the housing means may have a variety of different shapes or geometries, both circular and noncircular in transverse cross section or shaped in a great variety of other manners in transverse cross section, whereby to permit substantially greater freedom in engine and/or pump design.

It is a further object of the present invention to provide a novel radial chamber, positive displacement, fluid power device of the character described wherein the piston means and chamber defined within the housing means have a unique noncircular cross section which results in a substantial increase in the ratio between the maximum and minimum volumes of chamber spaces defined by and between the piston means, the adjacent inner wall of the housing means, and vanes effectively sealingly cooperating therewith.

It is a further object of the present invention to provide a radial chamber, positive displacement, fluid power device of the character described wherein the leakage of working fluid between adjacent chamber spaces across intervening portions of the piston means and the vane (or vanes) effectively sealingly interconnecting the piston means and the adjacent corresponding portions of the housing means is effectively eliminated.

It is a further object of the invention to provide a radial chamber, positive displacement, fluid power device of the character described taking the form of an engine and embodying the features set forth in the preceding object wherein preignition, which normally might result from the leakage of hot combustion gasses from a chamber space under combustion or under exhaust into an adjacent chamber space under compression or during intake, is substantially completely eliminated, avoided, and/or overcome.

It is a further object of the present invention to provide a radial chamber, positive displacement, fluid power device of the character described including any of a variety of different valving arrangements for admitting working fluid into and venting or exhausting working fluid from the chamber spaces of the device in proper sequence according to the desired mode of operation thereof as a pump or compressor, motor, or engine and according to whether it is to be operated as a two-cycle or four-cycle device or is otherwise operated.

It is a further object of the present invention to provide a novel radial chamber, positive displacement, fluid power device of the character described wherein the chamber defined within the housing means may have a rectangular shape or virtually any other desired shape and wherein the device is not limited to any specific number of chamber spaces but may have any number of chamber spaces ranging from two on upward and wherein the chamber spaces, if desired in certain forms of the invention, may have different volumes and also wherein said chamber spaces, if desired, may be appropriately ported in series for the purpose of providing a multistage device such as a multistage compressor, for example, although the invention is not specifically so limited.

It is a further object of the present invention to provide a novel radial chamber, positive displacement, fluid power device of the character described wherein the piston means and housing means may be effectively mechanically synchronized in any of a variety of different ways including positive gear coupling therebetween; holes carrying bolts, or bolts and spacers, or bolts and eccentric bushings effectively coupling the piston means and housing means for substantially unified relative rotation with respect to a pair of eccentrically related supporting means while allowing the relative chamber-space-modifying displacement thereof produced by reason of the eccentric mounting of the piston means with respect to the housing means. Also, crank pin means may be used for synchronizing the piston means and the housing means. Also, friction between the piston means and the housing means or between the vane means and the housing means may be employed as such effective synchronization means. Additionally, in certain forms of the invention where the piston means and the housing means have similar nonround configurations, these nonround configurations may be employed as effective mechanical synchronization means. In addition, a great variety of other types of synchronization means which will result in substantially unified relative rotation of the piston means and the housing means relative to the pair of eccentrically related supporting means may be employed, and all such are within the broad scope of the present invention.

It is a further object of the present invention to provide a novel radial chamber, positive displacement, fluid power device of the character described wherein the piston means is effectively flanged and cooperates with a simplified, one-sided form of housing means for the purpose of providing an extremely simple structure not requiring a completely enclosing housing means.

It is a further object of the present invention to provide a novel radial chamber, positive displacement, fluid power device of the character described wherein the chamber-defining surfaces of the housing means and the piston means are not limited to being parallel to their own individual longitudinal axes of rotation but may effectively converge or diverge along the length of said axes of rotation, respectively, in a manner which may be said to be longitudinally axially drafted or angled. In this form of the invention, a thrust bearing may be effectively intercoupled between the piston means and the housing means to compensate for the relative axial thrust produced by said axial drafting or angling, which may be of any desired contour along the length thereof as seen in a direction perpendicular to the length thereof, and, in certain forms of the invention where either the housing means or the piston means is firmly supported in an axially upstanding manner, the direction of said drafting or angling may be such that the axial thrust produced on the other one of said piston and housing means will effectively support same, or will provide at least a portion of said support for same, during operation of the device.

It is a further object of the present invention to provide a novel radial chamber, positive displacement, fluid power device of the character described which can be fabricated from virtually all common materials by common means. For example, the device may be made from injection-molded plastic in certain forms thereof. In other forms of the invention, it may be made of cast metal. Also in certain forms the vanes may be made of flexible rubberlike or elastomeric material or any substantial equivalent thereof. However, these are merely illustrative of the many different materials and/or fabrication or production processes which may be employed in manufacturing the device and are not to be construed as specifically limiting same.

It is a further object of the present invention to provide a novel radial chamber, positive displacement, fluid power device of the character described wherein chamber, or chamber space, displacement can be varied or made adjustable by the provision of eccentricity modifying means for effectively changing the distance between the two eccentrically related axes of the eccentrically supported piston means and housing means (usually by adjusting the physical spacing between the two eccentrically related axes of the supporting means).

It is a further object of the present invention to provide a novel radial chamber, positive displacement, fluid power device of the character described wherein synchronization may be achieved by effectively coupling the piston and/or the vane means with respect to the housing means in a manner permitting the relatively eccentric movement provided by reason of the supporting of the piston means and the housing means by said pair of eccentrically related supporting means while preventing any other substantial relative rotative angular movement therebetween. For example, said means may include, in addition to those previously referred to, the provision of slots coupling the vane means and/or the piston means relative to the housing means, or any other substantially functionally equivalent arrangement.

It is a further object of the present invention to provide a novel radial chamber, positive displacement, fluid power device of the character described wherein the valving means may comprise a central spindle or pintle valve adapted for operation by relatively rotatable, axial, or other timed relative movement with respect to the corresponding chamber spaces, spring-biased ball or check valves or any substantial equivalent (differential-pressure-operated, or otherwise operated, in the proper timed sequential relationship), cam-operated poppet valves, spool valves, mushroom valves, or the like, gear-operated, or otherwise operated rotary valves coupled to the rotating portion of the device, with any or all of said valving means being carried by portions of the piston means, portions of the housing means, or portions of both. Also, said valving means may include fluid port means communicating with the chamber spaces and passing through either the piston means, the housing means, or portions of both. Also, the invention is not limited to one fluid port of the valving means per chamber space but may include more than one.

It is a further object of the present invention to provide a novel radial chamber, positive displacement, fluid power device wherein the piston means is of smaller transverse cross-sectional area than the chamber defined within the housing means and wherein one or more vanes are provided and effectively sealingly cooperate with respect to corresponding portions of the piston means and the housing means whereby to divide the chamber into at least two chamber spaces.

It is a further object of the present invention to provide a novel radial chamber, positive displacement, fluid power device of the character referred to in the preceding object wherein the vanes are effectively controllably extendably and retractably carried by the piston means with outer ends thereof being adapted to sealingly engage corresponding inner wall portions of the housing means in any of a variety of different manners and having any of a variety of different shapes.

It is a further object of the present invention to provide a novel radial chamber, positive displacement, fluid power device of the character described in the second preceding object wherein the vanes are effectively carried by the inner wall of the housing means and effectively extend inwardly for relatively displaceable sealing cooperation with respect to the piston means.

It is a further object of the present invention to provide a novel radial chamber, positive displacement, fluid power device of the character described herein wherein one or more such vanes may be effectively biased into sealing relationship by any of a variety of effective vane-actuating or vane-biasing means which may take the form of fluid pressure means, spring means, centrifugal force provided during the operation of the device, magnetically caused force, or any other means for effectively biasing the vane means into sealing relationship at either or both ends relative to either the piston means, the housing means, both of same, or any other auxiliary sealing structures carried thereby. Such fluid pressure for actuating purposes can be provided from the chamber spaces of the device or from auxiliary pressure means, such as a separate pump, or from any other outside pressure source.

It is a further object of the present invention to provide a novel radial chamber, positive displacement, fluid power device of the character described above wherein the vanes may lie in relatively radial positions or relatively nonradial positions or any other positions extending between portions of the piston means and the housing means and effectively sealingly cooperable therewith for dividing the housing chamber into at least two chamber spaces.

It is a further object of the present invention to provide a novel radial chamber, positive displacement, fluid power device of the character described which may have the piston means and/or the vane means provided along edges thereof with appropriate groove means and seal means mounted therein for positively sealing the piston means and the vane means relative to corresponding interior wall surface portions of the housing means.

It is a further object of the present invention to provide a novel radial chamber, positive displacement, fluid power device of the character described wherein the synchronizing means may comprise through-bolts extending from one end of the housing to the other end thereof through corresponding holes in the piston means and there being provided with eccentric bushing means, and with said bolt means effectively providing structural strength to said end walls of the housing means for withstanding high interior chamber space pressures with the wall thickness of the housing means being at a minimum.

It is a further object of the present invention to provide a novel radial chamber, positive displacement, fluid power device of the character described wherein end walls of the housing may be axially loaded against interior chamber fluid pressures by venting chamber fluids behind or outwardly of inner chamber-defining surface portions of said end wall parts of the housing means or by providing other substantially equivalent pressure-neutralizing arrangements.

It is a further object of the present invention to provide a novel radial chamber, positive displacement, fluid power device of the character described and wherein the pair of eccentrically related supporting means supporting the piston means and the housing means is actually physically rotated relative to the nonphysically rotating housing means and piston means in a manner centered around an axis of operation coincident with one or the other of the two eccentrically related axes of the supporting means, or positioned therebetween by a direct axial drive centered on said axis of operation, an offset eccentric or crankshaft drive of the other of said axes (in certain forms of the invention, either one or both) around said axis of operation, or a relatively eccentric drive of said piston means with respect to said housing means (or the reverse) at one or more locations adjacent to, or displaced from, the axial center of the piston means and/or the housing means.

It is a further object of the present invention to provide a novel radial chamber, positive displacement, fluid power device of the character referred to herein which is of relatively simple, inexpensive construction adapted for manufacture with a relative minimum of tooling and, therefore, of capital costs and also adapted for production with a relative minimum of manufacturing operations and at a relatively low cost per unit such as to facilitate widespread and large scale manufacture, sale, and use of the invention for the purpose referred to herein or for any other substantially equivalent purposes.

Other objects, features and advantages of the present invention will become apparent to those versed in the art from a consideration of the following description, the appended claims, and the accompanying drawings, which are briefly described immediately hereinafter.

FIG. 1 is an axial section (except for an arcuately displaced section at the top of the outer casing) through a rotary chamber engine according to the invention , taken substantially as indicated by the arrows 1–1 of FIG. 3.

FIG. 2 is an enlarged section taken on line 2–2 of FIG. 1.

FIG. 3 is a section taken partially on line 3–3 of FIG. 1 along a plane containing two of the three vane-actuating means, partially along a plane axially displaced therefrom in order to show a typical one of three vane-end-venting means, and partially along a central plane to show the valve means.

FIG. 3*a* is a fragmentary section through the periphery of the rotor and housing of the rotary engine in FIG. 1 illustrating the manner in which these parts may be provided with cooling fins.

FIG. 4 is a section taken on line 4–4 of FIG. 1.

FIG. 5 is a section taken on line 5–5 of FIG. 1.

FIGS. 6*a* through 6*h* diagrammatically illustrate the operating cycle of the engine of FIG. 1.

FIG. 7 is an exploded perspective view of a rotary vane assembly embodied in the engine of FIG. 1.

FIG. 8 is an enlarged section taken on line 8–8 of FIG. 1 illustrating certain relationships of the intake and exhaust valving embodied in the engine.

FIG. 9 illustrates an alternative intake and exhaust valving arrangement which may be embodied in the engine.

FIG. 10 is a fragmentary axial section through a further modified rotary chamber engine according to the invention, illustrating an alternative placement of the engine spark plugs.

FIG. 11 is a transverse section through a modified rotary chamber engine according to the invention.

FIG. 12 is a transverse section through a modified rotary chamber engine according to the invention embodying a rotor and rotor chamber of unique geometry which results in a substantially increased compression ratio.

FIG. 13 is a section similar to FIG. 12 illustrating the rotor and housing of the engine in FIG. 12 in a subsequent position of operation.

FIG. 14 is a view similar in many respects to FIG. 12 but illustrates a slight modification thereof which comprises a pump or compressor adapted to be exteriorly driven by a driving belt (although not specifically so limited) and further having the central spindle or pintle valve arranged for two-cycle operation (although again not specifically so limited). This view is primarily a sectional view taken substantially on the plane and in the direction indicated by the arrows 14–14 of FIG. 15.

FIG. 15 is a view, largely in section, although the central spindle or pintle valve is shown in elevation, taken substantially along the plane and in the direction indicated by the arrows 15–15 of FIG. 14.

FIG. 16 is a fragmentary axial longitudinal sectional view of the spindle or pintle valve alone, with the rest of the device removed for reasons of drawing simplification and clarity, taken substantially along the plane and in the direction indicated by the arrows 16–16 of FIG. 15.

FIG. 17 is a view similar to FIG. 14 but comprises the second in a sequence of four sequential views (with FIG. 14 comprising the first of said sequential views) and shows the piston or rotor and the housing rotated 90° in a clockwise direction from the positions of said parts of the device as shown in FIG. 14.

FIG. 18 is another view similar to FIG. 14 but comprises the third in a sequence of four sequential views (with FIG. 14 comprising the first of said sequential views) and shows the piston or rotor and the housing rotated 180° in a clockwise direction from the positions of said parts of the device as shown in FIG. 14.

FIG. x9 is another view similar to FIG. 14 but comprises the fourth in a sequence of four sequential views (with FIG. 14 comprising the first of said sequential views) and shows the piston or rotor and the housing rotated 270° in a clockwise direction from the positions thereof as shown in FIG. 14.

FIG. 20 is a simplified and somewhat diagrammatic view similar in many respects to FIG. 14, but illustrates one exemplary of many possible differently shaped forms which the device may take both as to the shape of the exterior housing and the interior piston or rotor, each of which in this case is shown as being of rectangular form (although not specifically so limited).

FIG. 21 is another view of the rectangular form of the device shown in FIG. 20, which in this view has the piston or rotor and the housing rotated 90° in a clockwise direction from the positions thereof as shown in FIG. 20.

FIG. 22 is a view partly in top plan elevation and partly in section taken substantially along the plane and in the direction indicated by the arrows 22–22 of FIG. 21.

FIG. 23 is a view similar in many respects to FIG. 22 and is taken from the same vantage point, but illustrates a slight modification of the rectangular elevational form of the device shown in FIGS. 21 and 22 and which, in this modification in top plan view or top section, is substantially cylindrical rather than rectangular.

FIG. 24 is a view generally similar to FIG. 21 but illustrates a further modified form of the device which has only two vanes and two chamber spaces.

FIG. 25 is a view similar to FIG. 24 and shows another form of two-vane, two-chamber-space version of the device similar in many respects to the form shown in FIG. 24, but which, in this case, is of generally rectangular configuration as seen in end elevation or end section.

FIG. 26 is a view generally similar to FIG. 25 but illustrates a slight modification thereof having a single longitudinal vane rather than two vanes, with said single longitudinal vane passing completely through the split or apertured piston or rotor so as to allow the single longitudinal vane to relatively axially move with respect thereto.

FIG. 27 is a fragmentary and elevational or end sectional view generally similar in many respects to FIG. 14 as to aspect and position but illustrating a modified form of the device where the chamber defined by the housing and the piston or rotor are of what might be termed "scalloped" shaped in a manner such as to effectively minimize the length of the piston fluid ports comprising part of the valving system whereby to effectively maximize the compression ratio of the device.

FIG. 28 is a view generally similar to FIG. 15 but shows the piston or rotor and the housing immobilized, such as by being rigidly mounted, and conversely shows the first and second supporting means relatively rotatably mounting the housing on a housing axis and relatively rotatably mounting the piston or rotor (and the spindle valve) on a piston axis eccentric to the housing axis, with said supporting means being power rotated around the housing axis of the supporting means and the housing. This view shows the housing of the effectively rotatively unified and immobilized housing and piston as being the one fixedly attached with respect to a base support.

FIG. 29 is a view generally similar to FIG. 28 but in this case shows the piston or rotor as the one of the substantially rotatively unified piston and housing as being the one thereof fixedly attached with respect to a fixed mounting support.

FIG. 30 is a view also generally like FIG. 15 but shows the interior chamber defined by the inner surface of the housing and the corresponding exterior edge portions of the piston or rotor axially longitudinally drafted or angled and also shows a thrust bearing at the end thereof to compensate for the relative longitudinal displacement of the piston or rotor with respect to the housing, which would normally occur if said thrust bearing were not present, unless the entire device is vertically axially oriented in a direction such that the downward force of gravity acting on the piston (or on the housing) functions as a substitute for said thrust bearing.

FIG. 31 is a somewhat fragmentary diagrammatic end elevational view of a modified form of the invention taken substantially in the direction of the arrows 31–31 of FIG. 32 and illustrates in fragmentary form one exemplary one of many possible forms of a means for adjusting the extent of the eccentricity of the piston or rotor mounting relative to the housing mounting as carried by the two previously referred to eccentrically related supporting means.

FIG. 32 is a fragmentary sectional view taken substantially along the plane and in the direction indicated by the arrows 32–32 of FIG. 31 and further illustrates the novel exemplary but nonspecifically limiting eccentricity adjustment means illustrated in FIG. 31.

FIG. 33 is a fragmentary enlarged, somewhat diagrammatic and schematic view partially in end elevation and partly in end section taken substantially along a plane and in a direction such as is indicated by the arrows 33–33 of FIG. 34 and clearly illustrates one exemplary form of bolt, spacer, and hole type of synchronizing means for synchronizing relative rotation of said piston or rotor and said housing around the axis of said housing.

FIG. 34 is another fragmentary, somewhat enlarged side view partly in elevation and partly in section showing the bolt, symmetrical spacer, and hole type of synchronizing means of FIG. 33 substantially as viewed along the plane indicated by the arrows 34–34 of FIG. 33.

FIG. 35 is an enlarged fragmentary sectional view taken substantially along the plane and in the direction indicated by the arrows 35–35 of FIG. 36 and clearly shows a modified type of synchronizing means taking the form of a crank pin for effectively synchronizing the housing and piston or rotor while allowing chamber-space-modifying relative movement thereof only.

FIG. 36 is an enlarged fragmentary and elevational view taken substantially along the plane and in the direction indicated by the arrows 36–36 of FIG. 35 and illustrates the crank pin synchronization means as seen from the end rather than from the side.

FIG. 37 is a fragmentary somewhat diagrammatic and schematic view taken from a position generally similar to FIG. 15 but illustrates a modified form of the invention having a modified type of valving including oppositely directed intake and exhaust check valves and, in the case of the exhaust check valve, including a fluid exhaust port passage carried by the housing rather than by the central spindle or pintle valve in the manner of the FIG. 15 form of the invention.

FIG. 38 is a fragmentary, partially broken-away view of an aspect similar to FIG. 37 but illustrating a modification of the valving arrangement including intake and exhaust check valves so arranged as to be nonresponsive to centrifugal force.

FIG. 38*a* is a fragmentary, partially broken-away view similar to a top portion only of FIG. 38 but illustrating a further slight modification of the valving arrangement.

FIG. 39 is a fragmentary view of an aspect generally similar to FIG. 38 but illustrates a further modification of the valving arrangement wherein the valving arrangement comprises a spring-biased spool valve and an operating cam means adapted to cause appropriate operation of the spool valve in timed relationship to relative rotative operation of the device when functioning in a two-cycle mode of operation (although not specifically so limited).

FIG. 40 is a fragmentary cross-sectional view generally similar to the central portion only of FIG. 14 showing only the valve means and illustrating it in a modified form.

FIG. 41 is a fragmentary view of an aspect generally similar to FIG. 14 but illustrates another modified form of the invention having flexible vanes.

FIG. 42 is a somewhat diagrammatic view of another modification of the device of a type generally similar to that illustrated in FIGS. 14, 15, and 16 but shows the triangularly shaped piston or rotor alone and illustrates it, and the three vanes carried thereby, as being provided with a novel type of seal for sealingly engaging both opposite end walls of the housing means and sidewalls of the housing means.

FIG. 43 is a somewhat enlarged fragmentary sectional view taken substantially along the plane and in the direction indicated by the arrows 43–43 of FIG. 42.

FIG. 44 is a right side elevational view of the triangularly shaped piston or rotor illustrated in FIG. 42 but shows it with the vanes removed therefrom.

FIG. 45 is a fragmentary view of an aspect generally similar to FIG. 28 or FIG. 29, but shows a modified arrangement wherein the axis of operation lies between the housing axis and the piston axis and, thus, causes oppositely directed eccentric wobble of the pair of eccentrically related supporting means and of the housing and piston moved in a chamber-space-modifying manner thereby—said oppositely directed movement being such as to effectively cancel or neutralize any dynamic imbalance which might otherwise exist and doing so without requiring any auxiliary counterbalances.

FIG. 46 is a view illustrating a further modified form of the invention wherein the piston means is effectively flanged and cooperates with a simplified one-sided form of housing means for the purpose of providing an extremely simple structure not requiring a completely enclosing housing means.

The rotary chamber pressure fluid device or engine 10 which has been selected for illustration in FIGS. 1 through 8 of these drawings comprises a housing (broadly speaking, housing means) 12 defining an internal chamber 14 and having a central axis 16. Housing 12 is mounted on a support 18 (broadly speaking, one of a pair of eccentrically related supporting means) for rotation on its axis 16. Within the rotor chamber (broadly speaking, piston chamber) 14 is a rotor (broadly speaking, piston means) 20 including a body 22 having a central axis 24 disposed in spaced parallel relation to the housing axis 16. Rotor 20 is supported, by means 25, (broadly speaking, a portion of the other one of said pair of eccentrically related supporting means) for rotation on its axis 24. Slidably fitted in axially extending, radially opening slots in the rotor body 12 are a number of vanes 26. Within the rotor body are means 28 for yieldably urging these vanes outward (in the example illustrated, radially outward, although not specifically so limited) into fluid sealing relation with the wall of the rotor chamber 14. The adjacent rotor vanes 26 define therebetween chamber spaces 30. In a particular rotary chamber fluid pressure device or engine under consideration, the rotor vanes 26, and hence the chamber spaces 30, are three in number. The rotor vanes are uniformly circumferentially spaced 120° apart. Accordingly, the chamber spaces 30 are each 120° in circumferential extent. Operatively associated with the housing 12 and rotor 20 are one exemplary, but nonspecifically limiting form of means 32 for effecting rotation of the housing and rotor approximately in unison on their respective axes 16, 24, in such manner as to avoid any substantial relative angular movement between the housing and rotor.

Drivably coupled to the rotor 20 are one exemplary, but nonspecifically limiting, power transmission means 34 for transmitting rotary driving power between the engine and an external mechanism (not shown). In the engine under consideration, the engine drives the external mechanism through the transmission means 34. However, either the rotor 20 or the rotary housing 12 may either comprise or effectively drive virtually any type of mechanical output means. In the case of a rotary pump according to the invention, the pump rotor or housing would be driven from an external prime mover through the power transmission means 34 or any other suitable mechanical power input coupling means.

Within the engine are intake and exhaust passages 36, 38, respectively, for conveying a working fluid to and from the chamber spaces 30. In the illustrated engine, this working fluid is a combustible air fuel mixture. Valve means 40 are provided for communicating the intake passage 36 and the exhaust passage 38 to the chamber spaces 30 in timed relation to rotation of the housing 12 and rotor 20. Spark plugs 42 are provided for igniting the combustible mixture in each chamber space in timed relation to rotation of the rotor and housing in such a way as to effect driving of the rotor by the pressure of the hot combustion gas on the unbalanced areas of the vanes which bound each of the chamber spaces 30.

The operating cycle of the engine is illustrated in FIGS. *6a* through *6h*. This operating cycle will be explained in detail presently. Suffice it to say at this point that during unified rotation of the housing 12 and rotor 20, the chamber spaces 30 undergo progressive and alternate expansion and contraction. Briefly tracing the operating cycle of the chamber space *30a* in the latter figures, it will be observed that in FIG. *6b* the chamber space *30a* is undergoing expansion and is receiving a combustible air-fuel mixture (hereinafter referred to simply as fuel) from the intake passage 36. In FIGS. *6c* and *6d*, the chamber space *30a* is undergoing contraction with resultant compression of the fuel in the chamber space. In FIGS. *6e* and *6f*, the chamber space *30a* is again undergoing expansion and the fuel in the space is undergoing combustion for driving the rotor and housing in rotation. In FIGS. *6g* and *6h*, the chamber space *30a* is again undergoing contraction and the spent combustion gas in the chamber is being expelled into the exhaust passage 38.

Referring now in greater detail to the rotary chamber engine 10 illustrated in the drawings, the engine housing 12 will be observed to be generally cylindrical in transverse cross section. This housing includes a cylindrical wall 46 closed at its ends by circular platelike end walls 50. Each housing end wall 50 has an outwardly directed coaxial hub 52 surrounded by a number of circumferentially elongated openings 54. As shown best in FIG. 5, these openings are generally uniformly angularly spaced about the housing axis 16.

The housing support 18 includes upstanding mounting brackets 56 which straddle the housing 12 in its endwise direction. Mounting brackets 56 have inner coaxial journals 58 (another portion of said first-mentioned one of said pair of eccentrically related supporting means) which fit rotatably within the hubs 52 on the housing end wall 50. The mounting brackets 56 support the engine housing 12 for rotation on its axis 16.

The body 22 of rotor 20 is cylindrical in transverse cross section and has a diameter substantially less than the internal diameter of the cylindrical rotor chamber 14. Extending from the ends of the rotor body are integral coaxial shafts 60. These shafts extend rotatably through journal bores 62 in the housing mounting brackets 56 (another portion of said second-mentioned one of said pair of eccentrically related supporting means) and support the rotor for turning on its axis 24. The end faces of the rotor body 22 have seals 63 which engage the inner faces of the housing end walls 50. As shown best in FIG. 3, the rotor body 22 is a unitary structure having an outer relatively thin walled rim portion 64, a central hub portion 66, and a number of alternatively arranged and uniformly spaced spokes 68, 70 extending between the hub and rim. The spokes 68 are relatively narrow in the axial direction of the rotor body and are centered endwise between the ends of the body, as shown in FIG. 1. The width of the intervening spokes 70 is equal to the axial length of the rotor body 22. The spokes 68 and 70 are each three in number spaced 120° apart. The adjacent spokes 68, 70 are alternately arranged and thus spaced 60° apart.

The rotor vanes 26 are slidably fitted in corresponding radial slots 72 cut into the rotor body spokes 70. As shown best in FIG. 1, the vane slots 72 open through opposite ends of the rotor body 22. Each rotor vane 26 comprises a pair of plates 74 disposed in face-to-face contact and having confronting grooves defining vent passages 76. The outer ends of the vent passages in the vanes open to grooves 78 which extend along the outer edges of the vanes. The inner edges of the vent passages open through the inner edges of the vanes. Extending through the bottoms of the vane slots 72 are passages 80 in the rotor body 22 which communicate, in the manner hereinafter explained, to the engine exhaust 38. The outer vane grooves 78, therefore, communicate to the engine exhaust 38 through the vane passages 76 and the rotor body passages 80. As will appear presently, any working fluid, i.e., combustion gas, which tends to leak between adjacent chamber spaces 30 of the engine 10, past the outer edge of the intervening rotor vane 26, is bled to the engine exhaust 38 through the communicating passages just referred to. This aids in preventing preignition during operation of the engine.

The ends or end edges of the rotor vanes 26 are slotted to receive spring loaded metal seals 82. Seals 82 bear against the inner faces of the adjacent housing end walls 50. These seals, and the rotor body seals 63 referred to earlier, compensate for wear and prevent leakage of working fluid or combustion gas between adjacent chamber spaces 30 at the ends of the rotor body 22.

Within each rotor spoke 70, adjacent the ends of the corresponding rotor vane 26, are a pair of piston chambers or cylinders 84 which open outwardly through the bottom of the adjacent vane slot 72. The inner ends of these cylinders are closed. Slidable within the cylinders 84 are plungers 86 which seat against the inner edges of the adjacent rotor vanes 26. Springs 88 acting between the bottom walls of the cylinders 84 and the plungers 86 urge the latter outwardly against the rotor vanes 26 and, thereby, these vanes outwardly into fluid sealing relation with the wall of the rotor chamber 14. The inner end of each vane cylinder 84 communicates, through a passage 90 in the rotor body 22, to an adjacent chamber space 30. As will be explained presently, during operation of the engine 10, the high pressure combustion gas generated in each chamber space during combustion therein enters the adjacent vane cylinders 84 through the passages 90 and produces an outward force or thrust on the corresponding vane plungers 86 in addition to that exerted by the plunger springs 88 and centrifugal force. Accordingly, during operation of the gas engine 10, the rotor vanes 26 are subjected to outward spring, centrifugal, and combustion gas forces which urge the vanes outwardly against the wall of the rotor chamber 14.

It should be clearly noted that the type of vane-actuating or vane-biasing means illustrated in the first form of the invention and particularly described in the preceding paragraph is not to be construed as specifically limiting the invention to said specific exemplary version. In fact, the vane-actuating or vane-biasing means may assume a great number of different forms, all within the broad scope of the present invention. In this connection, and for exemplary purposes only, it should be noted that the plungers 86 referred to in the preceding paragraph may be eliminated entirely and fluid pressure acting through either the above-mentioned passages 90 in the rotor body 22 or otherwise supply to the inner ends of the vanes 26 may be directly employed for biasing the vanes 26 outwardly against the wall of the rotor chamber 14. Also, it should be noted that the source of fluid pressure for such a fluid-pressure type of vane-actuating or vane-biasing means may comprise the pressure in the rotor chamber 14 or in any of the particular chamber spaces 30 thereof which contain the working fluid under high pressure, or any other source of fluid under pressure may be employed for such outward actuation of the vanes 26. Indeed, even a separate or auxiliary high-pressure fluid pump may be employed for this purpose, if desired. Additionally, it should be noted that the vane-actuating or vane-biasing means need not combine fluid pressure and pressure of the plunger springs 88 together with the centrifugal force as mentioned in the preceding paragraph. Instead, in certain forms of the invention any of said vane-actuating or vane-biasing forces—that is, fluid pressure vane-actuating force, spring pressure vane-actuating force, or centrifugal vane-actuating force may be employed independently of each other for the purpose of outwardly biasing or actuating the vanes 26. Also, magnetic attraction and/or magnetic repulsion may be employed for vane-actuating purposes and will be referred to herein as magnetically caused vane-actuating force provided by magnetic vane-actuating means. Thus, it is possible for the springs 88 to be eliminated entirely and for the vanes 26 to be actuated outwardly substantially entirely by fluid pressure actuation. Conversely, it is possible for the fluid pressure actuation arrangement to be modified or eliminated entirely insofar as the vanes 26 are concerned, and to employ springs such as shown at 88 or any substantial equivalent for biasing or actuating the vanes outwardly. Also, it is possible to use neither fluid pressure actuation or plunger springs such as shown at 88 for outwardly actuating or biasing the vanes 26, but to rely substantially entirely on centrifugal force, which will tend to throw the vanes 26 outwardly when the rotor 20 and the housing 12 rotate in unison. Also, alternatively, magnetically caused vane-actuating force, alone, may be used. Also, it is possible to use any combination of these four different types of vane-actuating or vane-biasing means together or in combination, and all such arrangements are intended to be included and comprehended within the broad scope of the present invention.

Additionally, it should be noted that the invention is not limited to an arrangement of the type shown in the first form of the invention and best illustrated in FIG. 3 wherein each of the vanes 26 is radially carried by the rotor body 22 for slidable radial movement outwardly under the action of any of the above-mentioned types of vane-actuating or vane-biasing means into sealing relationship with the inner surface of that cylindrical portion of the housing wall 46 defining the rotor chamber 14. Actually, the vane means 26 may be nonradially positioned and/or may be carried by the wall 46 of the housing 12 rather than being carried by the rotor body 22. All that is necessary is that each such vane 26 effectively sealingly cooperates with both the rotor body 22 and the corresponding outwardly adjacent portion of the wall 46 of the housing 12 defining the rotor chamber 14, or with auxiliary sealing structure members carried thereby.

Furthermore, it is even possible in certain forms of the invention for the vanes to be of a flexible nature capable of allowing the relative chamber-space-modifying movement of the rotor 20 and the housing means 12 during rotative operation of the device to occur without the necessity of any actual sliding movement of each such vane occurring relative to either the rotor or the housing, and one such exemplary arrangement will be briefly described hereinafter in connection with FIG. 41. All such arrangements are intended to be included and comprehended within the broad scope of the present invention.

The above-described means for venting the outer edges of the rotor vanes 26 and for urging the vanes outwardly against the wall of the rotor chamber 14 cooperate to maintain the vanes in highly efficient fluid sealing relation with the chamber wall and, thereby, to prevent leakage of working fluid or combustion gas between adjacent chamber spaces 30. Preignition in the chamber spaces during operation of the engine is thus avoided.

It will be recalled that the rotary chamber engine 10 includes transmission means 32 which drivably couple the engine housing 12 and rotor 20 for turning thereof in unison and power transfer means 34 through which driving torque is transmitted from the engine to an external mechanism (not shown) to be driven. As shown best in FIGS. 2 and 4, the power transfer means 34 comprises a power output shaft 97 which is rotatably supported in one of the housing mounting brackets 56 for turning on an axis parallel to but offset slightly below the rotor axis 24. Rigid on the output shaft are a pair of gears 92 and 94. Gear 92 meshes with a gear 96 rigid on the outer end of the adjacent rotor shaft 60. Output shaft gear 94 meshes with a gear 98 coaxially fixed to the adjacent end of the housing 12. It is now evident, therefore, that turning of the engine rotor 20 is effective to drive both the engine housing 12 and the output shaft 97 in rotation. The output shaft gears 92, 94 have approximately the same diameter and the same number of teeth, as do the rotor and housing gears 96, 98. Accordingly, the housing 12 and rotor 20 turn in the same direction and at the same or approximately the same angular velocity.

The exemplary, but nonspecifically limiting valve means 40 for communicating the engine chamber spaces 30 to the engine intake 36 and exhaust 38 comprise a rotary valve sleeve, tube, or pipe 100. This valve sleeve extends through the body 22 of the engine rotor 20 on the rotor axis 24 and is rotatable relative to the rotor body 22. Suitable rotary seals (not shown) may be provided for sealing the valve sleeve with respect to the rotor body 22. The ends of the valve sleeve 100 are open and extend coaxially through and beyond the rotor shafts 60. Fixed on the end of the valve sleeve 100 adjacent the output shaft 97 is a gear 102 which meshes with a gear 104 rigid on the output shaft 97. Accordingly, during operation of the engine 10, the valve sleeve 100 is driven in rotation in the same direction as the housing 12 and rotor 20. However, the valve sleeve gear 102 is smaller than the rotor and housing gears 96, 98 and the output shaft gear 104 is larger than the output shaft gears 92, 94. As a consequence, the angular speed of the valve sleeve exceeds the angular speed of the engine housing 12 and rotor 20. In a typical engine according to the invention, for example, the valve sleeve turns at one end one-half times the speed of the rotor and housing (in certain forms, multiplied by one half or other fraction having two as a denominator and an odd number as a numerator). Thus, during operation of the engine 10, the rotor 20 and valve sleeve 100 undergo relative rotation. This of course occurs during four-cycle operation. For two-cycle operation, the valve sleeve 100 need not turn at all, or at a rate which is an even multiple of the unified rate of rotation of the rotor and housing.

Extending across the interior of the valve sleeve 100 at its center is a wall 106, the central portion of which is disposed in a plane containing the axis of the valve sleeve. The central valve sleeve passage at the right-hand side of this wall in FIG. 1 forms an intake passage 108 which communicates to the engine intake 36. The central valve sleeve passage at the left-hand side of the valve sleeve wall 106 forms an exhaust passage 110 which communicates with the engine exhaust 38. Opening through the cylindrical wall of the valve sleeve at opposite sides of its internal wall 106 are intake port 112 and an exhaust port 114. The intake port 112 communicates with the valve sleeve intake passage 108. The exhaust port 114 communicates with the valve sleeve exhaust passage 110.

It will be recalled that during operation of the engine 10, the rotor 20 and the valve sleeve 100 undergo relative rotation. During this relative rotation of the rotor and valve sleeve, the valve sleeve intake and exhaust ports 112 and 114 are successively aligned with combined intake and exhaust passages 116 in the rotor body 22. As shown best in FIGS. 1 and 3, the rotor passages 116 extend through the narrow rotor spokes 68 and open at their outer ends to the adjacent chamber spaces 30. The inner ends of the passages 116 open to the central bore through the rotor body 22 which receives the valve sleeve 100. It is evident at this point, therefore, that during operation of the engine 10, relative rotation of the rotor 20 and valve sleeve 100 is effective to alternately communicate the engine chamber spaces 30 to the engine intake 36 and the engine exhaust 38.

As shown best in FIG. 1, the wall of the valve sleeve 100 has a number of ports 118 at the exhaust side of its central internal wall 106. These ports are circumferentially spaced about the valve sleeve 100 in a plane containing the rotor vane vent passages 80 in the rotor body 22 and open to an external groove 119 in the sleeve. It is apparent that during operation of the engine, the rotor passages 80 and valve sleeve ports 118 continuously communicate the outer vane groove 78 to the engine exhaust 38, for the reasons stated earlier.

In the particular rotary chamber engine 10 illustrated in the drawings, the engine intake 36 communicates with the central passage through a conduit 120 for conveying a combustible air fuel mixture from a carburetor 122 to the engine 10. The downstream end of the conduit 120 is open and is disposed in coaxial fluid sealing relation to the intake end of the valve sleeve 100, thus to permit flow of the fuel, i.e., the combustible air fuel mixture, into the valve sleeve intake passage 108. The engine exhaust 38 communicates with a central passage through an engine exhaust conduit or pipe 124. This exhaust pipe has an open end communicating with the exhaust end of the engine valve sleeve 100, thus to permit exhaust gas flow from the valve sleeve to the exhaust pipe. Any conventional rotary fluidtight joints may be provided between the engine valve sleeve 100, the fuel supply conduit 120, and the exhaust conduit or pipe 124. In the drawings, for example, these parts are provided with simple beveled interfitting ends which are effective to permit rotation of the valve sleeve 100 while preventing fuel leakage at the intake end of the valve sleeve and exhaust gas leakage at the exhaust end of the valve sleeve. However, it should be understood that any other suitable type of rotary seals may be used in lieu thereof.

The housing support 18 of the illustrated rotary chamber engine 10 comprises, in addition to the housing mounting brackets 56, a casing 126 which encloses the engine 10. At one end of this casing is an air inlet 128. Extending from the opposite end of the casing 126 is an air return pipe 130 for conveying air from the interior of the casing to the carburetor 122 for mixing the combustible air fuel mixture entering the engine 10 through the intake 36. As will appear presently, during operation of the rotary chamber engine 10, airflow occurs through the casing 126 to cool the engine 10. Ignition of the combustible air fuel mixture entering the engine is accomplished by spark plugs 42. These spark plugs are uniformly angularly spaced about and are threaded in the cylindrical wall 46 of the outer motor housing 12. The points of the spark plugs are exposed within the chamber spaces 30, respectively, defined by the rotor vanes 26.

It is apparent at this point that if we assume, for the moment, the rotor 20 is driven in rotation by the combustion, within the chamber spaces 30, of the air fuel mixture entering the engine through the engine intake 36, the rotor turns on its axis 24, the housing 12 is driven in rotation, on its axis 16, by and in unison with the rotor through the transmission means 32, although various other effective synchronizing means may be employed in lieu thereof including crankpin means, coupling transverse bolts (or bolts and spacers, bolts and eccentric bushings), and corresponding oversize holes carried, respectively, by the end plates 50 of the housing 12 and the rotor 20, or vice versa, with crankpin and/or holes (and eccentric bushings, where used) providing for the requisite relative chamber-space-modifying relative movement of the rotor and housing. Also, effective rotative vane-to-housing and/or rotor-to-housing frictional coupling, or other type of "lost motion" coupling may be employed for such synchronizing purposes. This also includes nonround rotor and housing configurations, etc. The valve sleeve is driven in rotation on the rotor axis, in time relation, in the same direction as, but at a faster angular velocity than the rotor through the gear train 102, 104. The resultant relative rotation of the rotor and valve sleeve is effective to alternately communicate the valve sleeve intake and exhaust ports 112, 114 with the engine chamber spaces 30 in timed relation to rotation of the rotor 20, in the manner illustrated in FIGS. *6a* to *6h*. As a consequence, these chamber spaces are placed in alternate communication with the engine intake 36 and exhaust 38 in timed relation to rotation of the rotor, also as illustrated in FIGS. *6a* through *6h*.

As noted earlier and is now obvious, the chamber spaces 30 in the present rotary chamber engine 10, rotate with the engine housing 12 and rotor 20. During this rotation of the chamber spaces, the latter undergo alternate expansion and contraction. Thus, each chamber space undergoes expansion during one-half of each revolution of the rotor and housing and contraction during the remaining half of each revolution. During this eccentric rotation of the rotor and housing, the rotor vanes 26 slide in and out relative to the rotor body 22 to accommodate this expansion and contraction of the chamber spaces. However, as noted earlier and is now obvious, little if any relative sliding movement occurs between the rotor vanes 26 and the rotor housing 12 owing to the fact that the rotor and housing turn in unison.

The operation of the rotary chamber engine 10 will now be described by reference to FIG. *6a* through *6h*. In the following description of the engine operation, the operating cycle of only one engine chamber space, i.e., chamber space *30a* in the latter figures, will be explained in detail since its operating cycle is typical of all of the chamber spaces. In FIGS. *6a* through *6h*, the successive figures represent successive 90° angles of rotation of the housing 12 and rotor 20 and successive 135° angles of rotation of the housing 12 and rotor 20 and successive 135° angles of rotation of the valve sleeve 100 and valve 40. Thus, FIG. *6b* illustrates the rotor and housing after rotation through 90° from the position of FIG. *6a*. FIG. *6c* illustrates the rotor and housing after rotation through 90° from the position of FIG. *6b*, and so on. In the initial rotor and housing position illustrated in FIG. *6a*, the chamber space *30a* is contracted to its minimum volume and the valve sleeve 100 blocks all of the rotor intake-exhaust passages 116. During the first 90° of rotation of the rotor and housing to the position of FIG. *6b*, the chamber space *30a* undergoes expansion and the valve sleeve 100 rotates forwardly relative to the rotor 20, that is forwardly in the direction of rotation of the rotor, to place the valve sleeve intake port 112 in communication with the rotor passage *116a* leading to the chamber space *30a*. Accordingly, during rotation of the rotor and housing from the position of FIG. *6a* to the position of FIG. *6b*, combustible mixture from the carburetor 122 enters the expanding chamber space *30a*.

During the next 90° of rotation of the housing 12 and rotor 20 from the position of FIG. *6b* to the position of FIG. *6c*, the chamber space *30a* undergoes continued expansion to its maximum volume condition of FIG. *6c*. The chamber space continues to receive combustible mixture from the carburetor 122 until forward rotation of the valve sleeve 100 relative to the rotor 20 results in reclosing of the rotor passage *116a* leading to the chamber space *30a*, as in FIG. *6c*.

During the next 180° of rotation of the rotor housing **12** and rotor **20** from the position of FIG. 6*c*, through the position of FIG. 6*d*, to the position of FIG. 6*e*, the chamber space **30***a* undergoes contraction to its minimum volume condition of FIG. 6*e*. The rotor passage **116***a* leading to the chamber space **30***a* continues to be blocked by the valve sleeve **100**. Accordingly, the combustible mixture within the chamber space is compressed.

At or slightly beyond the position of FIG. 6*e*, at which the combustible mixture in the chamber space **30***a* has been compressed to its minimum volume, the spark plug **42** associated with the chamber space is energized to ignite the mixture. The manner in which the spark plugs are energized or fired in timed relation to rotation of the rotor and housing will be explained presently. Ignition and resultant combustion of the compressed combustible mixture in the currently contracted chamber space **30***a* generates high pressure combustion gas in this space. Such ignition and combustion is initiated when the leading vane bounding the chamber space **30***a* has greater exposed surface area than the trailing vane. The reaction of the high pressure combustion gas against the unbalanced areas of the rotor vanes bounding the chamber space **30***a*, therefore, produce a resultant or net torque on the rotor **20** for driving the latter in the direction of rotation indicated in FIGS. 6*a* through 6*h*. This driving torque continues to be exerted on the rotor from the position of FIG. 6*e* at which ignition occurs, through the position of FIG. 6*f*, to the position of FIG. 6*g*. During rotation of the housing **12** and rotor from the position of FIG. 6*e* to the position of FIG. 6*g*, the chamber space **30***a* undergoes reexpansion from its minimum volume condition to its maximum volume condition. It will be observed that the valve sleeve **100** continues to block the rotor passage **116***a* leading to the chamber space **30***a*, whereby the combustion gas remains trapped in the chamber space and, therefore, continues to react on the rotor vanes **26** for producing a continued driving torque on the rotor, as just stated.

During the next 180° of rotation of the housing **12** and rotor **20** from the position of FIG. 6*g*, through the position of FIG. 6*h*, to the initial position of FIG. 6*a*, the chamber space **30***a* again undergoes contraction from its maximum volume condition to its minimum volume condition. The forward relative rotation of the valve sleeve **100** with respect to the rotor **20** aligns the exhaust port **114** in the valve sleeve with the rotor passage **116***a* leading to the chamber **30***a*. Accordingly, contraction of the chamber space **30***a* occasioned by rotation of the housing and rotor from the position of FIG. 6*g* to the position of FIG. 6*a* expels the spent combustion gas from the chamber space, through the exhaust port **114**, to the engine exhaust **38** to complete one operating cycle of the chamber space **30***a*. The chamber space **30***a* undergoes the same operating cycle during each two successive revolutions of the housing **12** and rotor **20**. As noted earlier, the operating cycle described above is typical of all of the chamber spaces of the rotary chamber engine **10**, except, of course, that they occur sequentially according to the firing order of the engine. Assuming the engine spark plugs **42** are successively numbered 1, 2 and 3 counterclockwise direction and assuming clockwise rotation of the housing **12** and rotor **20**, the preferred firing order of the engine, i.e., of the spark plugs, is 1, 3, 2, 1, 3, 2....

FIG. 8 illustrates in enlarged detail, the arrangement of the intake and exhaust valving of the engine for attaining the engine operation described above. In this figure, it will be observed that each of the intake and exhaust ports **112**, **114** in the valve sleeve have an angular extent of 45° circumferentially of the valve sleeve.

The centers of the ports are spaced 90° apart. Accordingly the land between the ports has an angular extent, circumferentially of the valve sleeve, 45°. The cross-sectional dimension of each of the rotor intake-exhaust passages **116**, measured in a circumferential direction of the valve sleeve, is equal to the corresponding circumferential dimension of the valve sleeve ports **112**, **114** and the intervening land. As noted earlier, in the exemplary, by nonspecifically limiting form of the invention illustrated, the valve sleeve is driven at one and one-half times the velocity of the engine housing **12** and rotor **20**. Accordingly, during the operating cycle described above, the valve sleeve undergoes three revolutions in moving through the positions shown in FIGS. 6*a* through 6*h* and back to 6*a*. It is apparent that the above dimensional and velocity relationships between the rotor **20** and valve sleeve **100** enable the present engine to accomplish the described operating cycle for each of its chamber spaces **30**.

It is significant to note a this point that the illustrated rotary chamber engine **10** is a four-cycle engine wherein the operating cycle of each of the chamber spaces **30** include four successively occurring cycle phases, to wit, an intake phase, a compression phase, a power phase, and an exhaust phase. These operating phases of the several chamber spaces are timed in such a way as to produce, on the rotor **20**, a relatively smooth and continuous unidirectional driving torque.

It will be recalled that the chamber spaces **30** communicate, via the passages **90** in the rotor body **22**, to the inner ends of the chambers or cylinders **84** in the rotor body **22** which contain the rotor vane biasing plungers **86** and plunger springs **88** or any of the simpler types of vane-actuating means previously referred to. When combustion occurs in each of the engine chamber spaces **30**, the high pressure combustion gas generated in the chamber reacts outwardly on the adjacent rotor vanes **26**, thereby urging the vanes upwardly into fluid sealing relation with the wall of the rotor chamber **14**. It will be further recalled that the grooves **78** in the outer edges of the rotor vanes communicate, via the passages **80** in the rotor body **22** and the valve sleeve ports **118**, to the engine exhaust **38**. The combined spring, centrifugal and gas forces active on the rotor vanes **26** during operation of the engine **10** is effective to urge the outer edges of the vanes into highly efficient fluid sealing relation with the surrounding wall of the rotor chamber **14**, thereby to minimize leakage of combustion gas across the vanes between a chamber space **30** under combustion and an adjacent chamber space containing combustible mixture under pressure. Any combustion gas which does tend to thus leak across a rotor vane is immediately vented to the engine exhaust. Accordingly, it is virtually impossible for leakage of combustion gas to occur between two adjacent chamber spaces **30**, whereby the possibility of preignition of the compressed combustible mixture in one chamber space by hot combustion gas from an adjacent chamber space under combustion is virtually eliminated. This prevention of preignition in the present rotary chamber engine constitutes a highly important feature of the invention. The lack of sliding contact between the rotor vanes and the wall of the rotor chamber **14** constitutes a second highly important feature of the invention which, obviously, results in a substantial reduction in wear and friction loss in the engine.

In the present rotary chamber engine **10**, the spaces between the adjacent rotor spokes **68**, **70** communicate with the openings **54** in the housing end walls or plates **50** to define axial passages through the engine which a coolant, such as air, may be circulated for cooling the engine. In FIG. 1, for example, communication of the interior of the engine casing **126** to the engine intake, via the conduit **130**, induces a continuous flow of air into the casing through its inlet **128**. The incoming air flows through the engine cooling passages and then through the conduit **130** and the carburetor **122** to the engine intake **36**. During its passage through the engine, the air cools the engine and, in turn, is heated. If improved air-cooling of the engine is required, the engine housing and rotor may be equipped with cooling fins **134**, as illustrated in FIG. 3*a*. If desired, the cooling fins may be angled or pitched, as shown, to induce high velocity airflow through the engine and casing **126** into the engine intake, thus to produce an effective supercharging action.

FIG. 9 illustrates alternative intake and exhaust valve means which may be employed in the engine in lieu of the valve sleeve **100** of the engine described above. The engine shown in FIG. 9 is identical in most respects to the engine described earlier and, for this reason, only the difference in the engine of

FIG. 9 will be described. Also similar reference, numerals followed by the letter "A," however, designate similar parts. With this in mind, the rotor 20A comprises a body 22A which is identical to the engine rotor described earlier except that the common radial intake-exhaust passages 116 of the latter rotor are replaced, in the rotor 20A, by separate radial intake passages 116A and exhaust passages 116A'. A wall 208 extends across the central opening through the rotor body between the intake passages 116A and the exhaust passages 116A' to divide the central opening into a central intake passage 108A and a central exhaust passage 110A. The radial intake passages 116A open, at their inner ends, to the central intake passage 108A and at their outer ends through the outer circumference of the rotor 20A. The radial exhaust passages 116A' open, at their inner ends, to the central exhaust passage 110A and at their outer ends through the circumference of the rotor 20A. Extending axially through the rotor body 22A, in intersecting relation to the pairs of radial intake and exhaust ports 116A, 116A', respectively, are rotary valves 40A. Each rotary valve has an intake port 112A and an exhaust port 114A and is rotatable to align its intake port 112A with the corresponding radial intake passage 116A and its exhaust port 114A with the corresponding radial exhaust passage 116A'. The ports in each valve are disposed at right angles to one another so that the radial intake an d exhaust passages 116A, 116A' in the rotor 20A are alternately opened and closed by rotation of the valves 40A.

The valves extend axially beyond one end of the rotor and through the openings 140 in the adjacent end of the engine housing 12A. Fixed to the extending end of each valve 40A is a gear 142. The valve gears 142 mesh with a central gear 144 which is fixed to the adjacent rotor housing mounting bracket 146. The engine of FIG. 9 is otherwise identical to the engine described earlier.

It is obvious from the foregoing description that during operation of the rotary chamber engine of FIG. 9, the valves 40A rotate in time relation to rotation of the rotor 20A and its housing 12A. During this rotation of the valves, the latter alternately communicate the engine chamber spaces to the engine chamber spaces to the engine intake and exhaust, thus to admit combustible mixture to and vent spent combustion gas from the chamber spaces. The rotary valves are relatively oriented and timed in such a way as to provide their respective chamber spaces with the same operating cycle as described earlier in connection with FIGS. 1 through 8.

FIG. 10 illustrates a modified spark plug placement which may be utilized in the rotary chamber engine of FIGS. 1 through 8. Similar reference numerals followed by the letter "B," however, designate similar parts. In this case, the spark plug 42B for each chamber space is threaded into the rotor spoke 68B which contains the combined intake-exhaust passage 116B leading to the respective chamber space. The points of the spark plugs are exposed to the interior of the passages. The spark plug leads extend through the adjacent rotor shaft 60B to the exterior of the rotor housing 12B for connection to a distributor (not shown).

It is apparent that since the rotor and rotor housing of the present rotary chamber engine do not undergo relative rotation, it is unnecessary for the rotor and/or the rotor chamber to be circular in transverse cross section, as they must in convention rotary engines. FIG. 11, for example, illustrates one possible noncircular rotor chamber configuration which may be employed in the present rotary chamber engine. Similar reference numerals followed by the letter "C," however, designate similar parts. In this case, the inner surface of the rotor housing 12C, which defines the outer wall of the rotor chamber 14C, has a number of arcuate, axially extending recesses or scallops 148 uniformly circumferentially spaced thereabout. These scallops have equal radii of curvature which is the same as the external radius of the body 22C of the engine rotor 20C. The rotor housing scallops 148 are equal in number to the chamber spaces 30C defined by the rotor vanes 26C and are located between the vanes so as to form the outer walls of these chamber spaces.

As illustrated in the upper portion of FIG. 11, in the minimum volume condition of each chamber space 30C, the body 22C of the rotor 20C seats within the corresponding scallop 148 in the rotor housing 12C, thus to provide the respective chamber space with substantially zero, or at least absolutely minimal, volume. This is in contrast to the rotary chamber engine illustrated in FIGS. 1 through 8, for example, wherein it will be observed that in its minimum volume condition, each chamber space 30 has an appreciable volume, owing to the difference between the internal radius of the rotor housing 12 and the external radius of the rotor body 20. The engine configuration of FIGS. 1 through 8, therefore, is inferior to that illustrated in FIG. 11 for the reason that the latter engine configuration permits a substantially higher compression ratio and, therefore, substantially greater power output and higher engine efficiency.

FIGS. 12 and 13 illustrate an alternative noncircular rotor and rotor housing configuration according to the invention. Similar reference numerals followed by the letter "D," however, designate similar parts. In this case, the body 22D of the engine rotor 20D and the rotor housing 12D are generally triangular in transverse cross section. Here again, this noncircular or triangular configuration of the rotor and rotor housing do not undergo relative rotation. However, to permit some degree of freedom of relative rotation between the rotor and housing, and thus avoid excess strain in the engine parts, the rotor housing 12D may be provided with cylindrically curved seating surfaces 150 within its apices for seating engagement by the rotor vanes 26D. The circumferential dimensions of the seating surfaces 150 is somewhat greater than the thickness of the rotor vanes 26D to provide limited freedom of relative angular movement between the rotor and rotor housing. Thus, the vanes will slide back and forth along the seating surfaces once per revolution and through a distance equal to the spacing between the rotor and housing axes.

As shown in the upper portion of FIG. 12, this triangular rotor and rotor housing configuration permits each side of the rotor body 22D to seat flat against the opposing side of the rotor housing 12D, in the minimum volume condition of the corresponding chamber space 30D of the engine, thus to provide each chamber space with substantially zero volume in its minimum volume condition. Accordingly, the engine configuration of FIGS. 12 and 13 achieves the same desirable high compression ratio as the engine configuration of FIG. 11. Obviously, other noncircular engine configurations are possible. It is evident, of course, that the exact shape of any noncircular engine configuration is dictated, in part, by the number of rotor vanes, and chamber spaces, in the engine. For example, if minimum vane extension and retraction is desired, the triangular engine configuration of FIGS. 12 and 13 is preferably arranged to have a rotor with three vanes, although the invention is clearly not so limited. The scalloped engine configuration of FIG. 11 may be employed in engines having rotors with various numbers of rotor vanes, defining a corresponding number of chamber spaces. Engines with more than (or, in certain cases, less than) three chambers may have flat walled chambers similar in certain respects to those shown in FIGS. 12 and 13.

In this latter regard, attention is directed to the fact that the rotor 20C of the rotary chamber engine illustrated in FIG. 11 has five vanes 26C defining five chamber spaces 30C, in contrast to the three vanes and three chamber spaces of the rotary chamber engine illustrated in FIGS. 1 through 8 and FIGS. 12, 13. The engine of FIG. 11, of course, would be provided with an equal number of spark plugs (not shown) for igniting the combustible mixtures within the chamber spaces 30C during the power portions or strokes of their respective operating cycles. Increasing the number of chamber spaces, obviously, increases the number of power or torque impulses which are exerted on the rotor during each revolution and, as a result, the smoothness of the engine operation. Accordingly, the maximum number of chamber spaces is desirable in most cases in the interest of optimum engine operation. In the case of the engine of FIG. 11, the preferred firing order of the engine spark plugs is 1, 3, 5, 2, 4, assuming that these plugs are consecutively numbered in the counterclockwise direction and clockwise rotation of the rotor and rotor housing.

The rotary chamber engine of FIG. 11, obviously, may embody the intake-exhaust valving illustrated either in FIGS. 1 through 8 or in FIG. 9, or any of the other valving arrangements disclosed elsewhere herein. However, the engine illustrated in FIG. 11 has been shown to comprise the separate rotary valve arrangement of FIG. 9.

The spark plugs of the present rotary chamber engine may be energized or fired by various distributor means. When the plugs are mounted on the housing, as in the engine of FIGS. 1 through 8, for example, a contact 136 may be mounted on the outer engine casing in a position to engage a mating contact 138 on each plug at the proper point in the cycle of the corresponding chamber space, thus to fire the plug. In this case, each spark plug will fire once during the power phase and once again during the exhaust phase of its respective chamber space and in the preferred firing order, and modified or additional means to facilitate this are all intended to be included and comprehended within the broad scope of the present invention. This may be desirable to ignite any unburned fuel and thereby purify the exhaust gas. Alternatively, if the spark plugs are mounted on the rotor, as in FIG. 10, an external distributor is required to fire the plugs, as stated earlier.

It is now apparent that the invention disclosed herein achieves all of the objects and advantages set forth earlier, to wit, absence of, or at least minimal, relative rotation between the rotor and housing, minimal friction loss and wear, minimal dynamic unbalance, maximum compression ratio, simplicity of construction, economy of manufacture, and reliability of operation. As noted earlier, while the invention has been disclosed in connection with a rotary, or more particularly a rotary chamber, internal combustion engine, the features of the invention obviously may be embodied in other rotary pressure fluid devices including pumps and fluid pressure operated motors. In this connection, attention is directed to the fact that the disclosed rotary chamber engine of the invention may be powered by high pressure combustion gas generated in a combustion process occurring in combustion chamber external to the engine.

FIGS. 14 through 19 illustrate a further modified form of the invention which in the form illustrated is shown as comprising a two-cycle pump or compressor for a working fluid which may be a liquid, a gas, a vapor, a plasma, a semiliquid slurry, a finely divided particulate material, or any other material not characterized by rigidity and, therefore, capable of being pumped, moved, or compressed. In this connection, it should be noted that normally the term "compressor" is applied to a device of the character just briefly referred to which operates on a working fluid which is of a compressible type such as gases, vapors, or plasmas, although there are a few liquids which are slightly compressible. In general, the term "-pump" is reserved for a similar or identical device operating on a working medium of a relatively noncompressible or incompressible type. However, apart from this distinction as to working medium, a pump and a compressor are similar or otherwise substantially identical in many respects and the terms will be somewhat loosely and interchangeably used throughout this description without any intent to limit the invention in any manner by the use of either of said terms in any particular instance.

Because this form of the invention is a modification of, and is similar in many respects to, the previously described forms of the invention, parts which are functionally or structurally substantially similar or equivalent to those of previously described forms of the invention are designated by similar reference numerals, followed by the letter "E," however.

Generally speaking, it may be said that the illustrative pump or compressor illustrated in FIGS. 14 through 19, inclusive, comprises a radial chamber, positive displacement, fluid power device having a hollow housing means, such as is generally designated by the reference numeral 12E, which defines an internal piston chamber generally designated by the reference numeral 14E. The housing means 12E has a central or transversely directed axis 16E coaxial with and common to a corresponding axis (also indicated by the reference numeral 16E) of one of a pair of supporting means, indicated at 58E, which relatively rotatively supports the entire housing means 12E with respect thereto. The device also includes a piston or rotor means, indicated generally at 20E, positioned within the chamber 14E and having a smaller cross-sectional area than the cross-sectional area of the chamber 14E in a plane perpendicular to the transversely directed housing axis 16E. Piston or rotor means 20E has a transversely directed piston axis 24E which is parallel to and is displaced from the previously mentioned housing axis 16E by a predetermined spacing which will be referred to hereinafter as the accentricity of said piston axis 24E with respect to the housing axis 16E and which is coaxial with and common to a corresponding axis (also indicated by the reference numeral 24E) of a second one of said previously mentioned pair of supporting means, such as is indicated at 25E.

It should be clearly noted that the pair of above-mentioned relatively eccentrically related supporting means 58E and 25E may be said to, in effect, have the two previously mentioned eccentrically related axes 16E and 24E aligned coaxial and common respectively with said previously mentioned housing axis (also indicated by the reference number 16E) and the previously referred to piston axis (also designated by the reference numeral 24E) and that together they function for relatively rotatively supporting the entire housing means 12E around said housing axis 16E and for relatively rotatively supporting the entire piston or rotor means 20E around said piston axis 24E, and this is true irrespective of whether the housing means 12E and piston means 20E actually physically rotate around said two supporting means 58E and 25E or whether said housing means 12E and said piston means 20E do not actually physically rotate but only relatively rotate with respect to the supporting means 58E and 25E, respectively, which do actually physically rotate. The first arrangement is the form illustrated in FIGS. 14—19 although it should be clearly understood that the second-mentioned arrangement is also possible and will be described hereinafter.

In the exemplary form illustrated in FIGS. 14—19, both of said pair of eccentrically related supporting means 58E and 25E are, in effect, carried by the base part 18E of the complete support for both the housing 12E and the rotor 20E.

In the exemplary form of the invention illustrated in FIGS. 14—19, the device is provided with three movable vanes 26E sealingly cooperating with the piston means 20E and a corresponding outwardly spaced inner wall surface portion 46E of the housing means 12E at each of three equiangularly spaced locations so as to divide the chamber 14E into three angularly adjacent chamber spaces 30E. In this connection, it should be clearly noted that the three-vane, three-chamber-space form of the invention illustrated in FIGS. 14—19 inclusive is exemplary only and is not intended to specifically limit the invention to any particular number of vanes or to any particular number of chamber spaces. Actually, the invention may employ one vane or any number of vanes in excess of one and may have two chamber spaces or any number of chamber spaces in excess of two. In the case where only one vane is used, it is possible to so place the piston 20E with respect to the housing 12E as to cause same to be in virtual abutment at one location so as to function as a second divider for the chamber 14E which, which, with such a single additional vane, would, in effect, divide the chamber 14E into at least two chamber spaces 30E. Additionally, it should be noted that more than one vane may be employed for each chamber space.

In the exemplary arrangement illustrated in FIGS. 14—19, the relatively eccentric positioning of the piston means 20E and the one (25E) of said pair of supporting means relatively rotatably supporting the piston means 20E with respect to the chamber 14E, and the relative cross-sectional shape of the piston means 20E with respect to the larger cross-sectional shape of the chamber 14E are so related as to provide and define the previously mentioned three radially varying chamber spaces 30E at different relatively angularly spaced locations between the piston means 20E and the inner wall surface 46E of the housing means 12E defining the chamber 14E, with each such chamber space radially varying in extent as a function of relative rotative angular location of the relatively rotated housing means 12E and piston means 20E with respect to their respective axes and respective portions of said pair of eccentrically related supporting means, and with each of said chamber spaces 30E lying between the corresponding radially spaced portions of the piston means 20E and the housing means 12E.

The exemplary form of the invention illustrated in FIGS. 14—19, inclusive, also may, in effect, be said to include means for causing substantially simultaneous relative rotation of the housing means 12E and the piston means 20E to occur around an axis of operation coincident with one or the other of the axes 16E or 24E of the supporting means 58E or 25E, respectively, (or lying between the axes 16E and 24E) while simultaneously effecting relative rotation of the other of said axes (in certain forms of the invention, both of said axes) 16E and 24E of said supporting means around said axis of operation of said supporting means in the opposite direction in a manner such as to effect cyclic contraction and expansion of each chamber space 30E without any substantial relative angular movement between the piston means 20E and the housing means 12E occurring. In other words, the above-mentioned cyclic contraction and expansion of the chamber spaces 30E occurs while substantially unified relative rotation of the housing means 12E and piston means 20E occur relative to their corresponding supporting means portions 58E and 25E, respectively.

In the example illustrated, the above-mentioned means for effecting substantially simultaneous relative rotation of the housing means 12E and the piston means 20E comprise what might be termed a particular type of rotary synchronizing effective power transmission and coupling means effectively coupled therebetween for substantially preventing relative angular displacement between said housing means 12E and said piston means 20E from occurring while freely allowing only said substantially simultaneous relative rotation of said housing means 12E and said piston means 20E around said axis of operation (usually coincident with one of said axes 16E or 24E) of said supporting means and said simultaneous relative rotation of the other of said axes 24E or 16E (in certain cases, both of same) of said supporting means around said axis of operation of said supporting means in the opposite direction in said manner such as to effect said cyclic expansion and contraction of the chamber spaces 30E to occur

In the exemplary form of the invention illustrated in FIGS. 14—19, inclusive, the above-mentioned rotary synchronizing effective power transmission and coupling means is generally designated by the reference numeral 32E and takes the form of three through-bolts or pins 152 carrying eccentric bushings 154, each of which is rotatably mounted in a corresponding hole 156 extending in a direction parallel to the piston axis 24E through the piston means 20E. Each of the three bolts or pins 152 is fastened to corresponding end-positioned chamber plates or end walls 50E of the housing means 12E and thus provides firm support and rigidity to said end walls 50E of the housing means 12E and renders the complete housing means 12E capable of withstanding a much greater internal pressure than would otherwise be possible. It will be understood that each of the eccentric bushings 154 will effectively rotate within the corresponding clearance hole 156 as the housing means 12E and piston means 20E rotate in unison around the housing axis 16E (which, in this specific example, is coincident with and effectively comprises the axis of operation), and while the piston means 20E individually rotates around the piston axis 24E, thus causing any particular point on the surface of the piston means 20E to move along a circular path such as is indicated in broken lines at 158 in FIG. 14. It will be noted that the diameter of the circular path of movement of any particular point on the surface of the piston or rotor 20E has a diameter of twice the spacing or eccentricity existing between the housing axis 16E and the piston axis 24E and that, correspondingly, this determines the diameter of each of the clearance holes 156 which will in each case equal the diameter of the bolt or pin 152 plus twice the eccentricity or spacing between the housing axis 16E and the piston axis 24E.

The above-mentioned type of rotary synchronizing means comprising through-bolts 152 mounting eccentric bushings 154 in clearance holes 156 merely comprises one exemplary form of such rotary synchronization means and it should be clearly understood that the invention is not specifically limited thereto. Actually, the eccentric bushings 154 may be eliminated and the bolts 152, or such bolts with symmetrical spacers or sleeves carried thereon, may be positioned in the larger-diameter clearance holes 156 with the same dimensional relationships as defined hereinbefore, and this modification will still function as a very effective rotary synchronization means. Also, it should be noted that synchronization means of the type previously described in connection with the first form of the invention and designated by the reference numeral 32, or any other type of positive gear-coupling means, or functional equivalent, may be employed for this purpose, a crankpin type of rotary synchronization means having the desired eccentricity and coupling the piston or rotor 20E with respect to the chamber plate or housing end walls 50E may be employed, or any other type of coupling between end surfaces of the piston or rotor 20E and the corresponding housing portions 12E or between corresponding parts of the vanes 26E and the inner surface of the housing means 12E, either of a mechanical lost-motion type allowing the desired eccentric movement shown at 158 in FIG. 14 to occur or of a frictional type, may be employed as alternate forms of such rotary synchronization means. Also, it should be noted that synchronization means of the various types referred to above are only required when the piston or rotor means 20E and the chamber 14E defined within the housing means 12E are of substantially circular shape. When they are not of such substantially circular shape, the rotary synchronization means may take another form, if desired, and, indeed, in the form of the invention illustrated in FIGS. 14—19 inclusive, the synchronization means may take such a modified form by eliminating all of the through-bolts or pins 152, eccentric bushings 154, and clearance holes 156 and by using an arrangement as described immediately hereinafter.

In such a further modified form of the rotary synchronization means 32E, particularly as applicable to the exemplary form of the invention illustrated in FIGS. 14—19 inclusive, said rotary synchronizing, effective power transmission and coupling means may be said to, in effect, comprise the noncircular transverse cross-sectional shape of the rotor 20E and having the confronting walls 160 and 162. It will be understood that the irregular or nonround shape of the piston means 20E and the housing means 12E effectively synchronizes the two for substantially simultaneous or unified relative rotation and, therefore, said rotary effective synchronization means is also generally designated by the reference numeral 32E, which in this case is shown in broken lines because this is an alternate version of said rotary synchronization means.

Also, the exemplary form of the invention illustrated in FIGS. 14—19 inclusive includes means for admitting working fluid into and for venting a working fluid from the chamber spaces 30E, respectively, in time relation to chamber-space-modifying relative movement of the piston means 20E and the housing means 12E in the manner shown by the point-excursion broken line 158 in FIG. 14 in response to substantially simultaneous relative rotation of the housing means 12E and the piston means 20E around said axis of operation (usually one of said axes 16E or 24E) of the supporting means 58E and 25E and said relative rotation of the other of said axes (24E or

16E) of said supporting means around said axis of operation of said supporting means in the opposite direction. In the exemplary form of the invention illustrated, said means for admitting working fluid into and for venting working fluid from the chamber spaces 30E is generally designated by the reference numeral 164 and comprises valve means 40E and, in the example illustrated, three piston ports or fluid ports 116E extending outwardly from the valve means 40E to the corresponding three chamber spaces 30E for communicating same in repetitive timed relationship during the operating cycle of the device.

In the exemplary form of the invention illustrated in FIGS. 14—19, the valve means 40E comprises a longitudinal axially directed sleeve valve pipe 100E including both an intake portion, indicated generally by the reference numeral 36E, and an exhaust portion, indicated generally by the reference numeral 38E. The intake portion 36E includes an inner intake passage 108E, while the exhaust portion 38E of the valve means 40E includes an inner exhaust passage 110E. It will be noted that the inner intake passage 108E and the inner exhaust passage 110E are separated from each other by a central dividing wall 106E and that the inner intake passage 108E is connected to a circumferentially positioned intake port 112E and that the inner exhaust passage 110E is connected to an oppositely circumferentially positioned exhaust port 114E. The entire sleeve 100E is fixedly and nonrotatably fastened by key means 166 to the bearing 168 which in turn is nonrotatively fastened by key means 170 to the fixed base support portion 18E thus, mounting the complete sleeve valve pipe 100E and the complete valve 40E in a nonrotative manner and with the central dividing wall 106E substantially vertically directed when the apparatus is in the position shown in FIGS. 14 through 19 inclusive. It will be noted that the exterior surface of the sleeve valve pipe 100E actually comprises the previously mentioned one (25E) of the pair of eccentrically related supporting means which relatively rotatively mounts the complete piston or rotor means 20E, which thus is free to actually physically rotate around the piston axis 24E and around the fixed sleeve valve 40E. It should also be noted that the housing means 12E is rotatably mounted by the second one (58E) of said previously mentioned pair of eccentrically related supporting means for rotation around the housing axis 16E and that since the bearing 168 is fixed by the key means 170 to the fixed base support means 18E, this means that the housing means 12E actually physically rotates around the housing axis 16E rather than merely relatively therearound.

Incidentally, it should be noted that in the FIGS. 14—19 form of the invention, the piston means 20E actually physically rotates around the piston axis 24E in a clockwise direction as viewed in FIG. 14, and the housing means 12E actually physically rotates around the housing axis 16E in a clockwise direction as viewed in FIG. 14, and both the piston means 20E and the housing means 12E rotate, as a system, in a clockwise direction as viewed in FIG. 14, around the axis of operation which is coincident with the housing axis 16E in this exemplary form of the invention. This is because the hereinafter referred to drive belt 178 of the hereinafter referred to power transmission means 34E moves in the direction indicated by the arrows in FIG. 14 such as to cause such clockwise rotation. However, it should be clearly understood that the entire device may be driven in a reverse direction and the valve means 40E can be effectively reversed or effectively operated in reverse so that the entire system will operate substantially as described hereinabove when operated as a pump. However, it should also be understood that when the device is operated as a pressurized-fluid-actuated motor or engine having mechanical power output transmission means, the above-mentioned belt 178 may effectively comprise one form of a power transmission mechanical output means which may be coupled to any other device which is to be driven thereby. This may also be considered to be another aspect of the reversible feature referred to above. Incidentally, this reversible feature is true of all forms of the invention referred to herein and is to be specifically so understood in connection with all forms of the invention referred to herein even though this reversible features is not specifically referred to in connection with each form of the invention specifically described or referred to herein.

Thus, since the piston means 20E rotates around the piston axis 24E in a symmetrical and fully balanced manner and the housing means 12E rotates around the displaced housing axis 16E in a symmetrical and thus fully balanced manner, it will be noted that no dynamic unbalance exists and that it may be said that both the piston means 20E and the housing means 12E rotate together in substantial unison around the housing axis 16E (which is the axis of operation in this example) in one direction while the piston axis 24E appears to relatively rotate around the housing axis 16E in the opposite direction with respect to the unified rotation of the housing means 12E and the piston means 20E therearound. This produces the previously mentioned cyclic contraction and expansion of each of the three chamber spaces 30E without requiring any substantial relative angular movement between the piston means 20E and the housing means 12E and, indeed, without requiring any type of relative movement therebetween except the type of eccentric movement indicated in broken lines at 158 in FIG. 14.

Since the intake and exhaust ports 112E and 114E remain fixed while the piston or fluid ports 116E rotate therearound, it will be found that the structure illustrated in the form of the invention shown in FIGS. 14—19, inclusive, operates as a compressor or pump in a manner which is generally known as two-cycle operation and wherein the expanding one of the chamber spaces is normally connected through a corresponding one of the piston or fluid ports 116E to the corresponding intake port 112E and thus aspirates or draws the working fluid into the expanding chamber space 30E. This occurs during very nearly one-half of a complete rotation of the device and corresponds to the arcuate extent of the intake port 112E. Subsequently, as the particular chamber space 30E referred to in the preceding sentence begins to contract, it is connected by the corresponding piston port or fluid port 116E to the exhaust port 114E and forcibly pumps out the working fluid. This occurs during very nearly one-half of a complete rotation of the device. This cycle of expansion and intake of the working fluid and contraction, compression, and output pumping of the working fluid occurs once during each complete rotation of the device for each of the three chamber spaces 30E. The above-mentioned type of operation is permitted by reason of the facts that the vanes 26E are slidably positioned within the vane slots and may be effectively biased outwardly in any of the manners referred to hereinbefore in connection with previously described forms of the invention and previously described forms of vane-actuating or vane-biasing means.

It should be noted that in the particular form of the invention illustrated, the housing means 12E is made up of the two end plates or chamber plates 50E and the intervening chamber block 172, which are effectively joined together by the previously mentioned through-bolts 152 comprising part of the rotary synchronization means 32E, although other exterior fastening bolts 174 and through-holes 176 are also employed for this purpose.

It should be noted that any type of antifriction bearing means may be employed at the two supporting means locations indicated by the reference numeral 25E and 58E, which antifriction means are not shown in detail since such structures are well known in the art and do not touch upon the real inventive concept of the present invention.

It should of course be noted that while the housing supporting means 58E and the piston or rotor supporting means 25E are both shown as being effectively fixedly carried by the base support portion 18E so that the actual rotation which occurs when the device operates is rotation of the housing means 12E and the piston means 20E around each of said supporting means, respectively. However, this arrangement may be reversed with respect to the fixed portions of the device and the actually physically rotatable portions of the device, so that the housing means 12E and the piston or rotor means 20E may be relatively rotatively immovably mounted and the two supporting means 58E and 25E may be mounted for rotation in any of at least three manners, a first one of which comprises actual physical rotation around the housing axis 16E, the second of which comprises actual physical rotation around the piston axis 24E and a third one of which comprises actual physical rotation around an operation axis between the axes 16E and 24E. In the first case, it will be found that the piston axis 24E will revolve around housing axis 16E and will eccentrically displace the piston means 20E relative to the housing means 12E. In the second case, it will be found that the housing axis 16E will revolve around the piston axis 24E and will eccentrically displace the housing means 12E with respect to the piston means 20E. In the third case, both the housing axis 16E and the piston axis 24E will revolve around the intervening operation axis and both the housing means 12E and the piston means 20E will be eccentrically and oppositely displaced with respect to the operation axis. All such arrangements are intended to be included and comprehended within the broad scope of the present invention.

In the exemplary form of the invention illustrated in FIGS. 14—19 inclusive, the above-mentioned actual physical rotation of the housing means 12E and the piston means 20E in unison around their respective housing and piston axes 16E and 24E is accomplished by effective power transmission means, indicated generally at 34E, coupled with respect to the actually physically rotatable housing means 12E, although not specifically so limited. In the exemplary arrangement illustrated in FIGS. 14—19, said effective power transmission means comprises a peripheral or circumferential drive belt groove 178 carried around the exterior circumference of the chamber block 172 of the housing means 12E, which is adapted to receive therein a drive belt, such as is fragmentarily shown in phantom at 180, which may be coupled to an external driving mechanism of any desired type for positively applying torque to the housing means 12E, which will of course also apply torque to the piston means 20E by reason of the effective unified coupling of said housing means 12E and piston means 20E provided by the rotary synchronization means 32E, one exemplary and nonspecifically limiting form of which has been previously described in detail. This provides a convenient driving arrangement for the device when it comprises a two-cycle air compressor, hydraulic pump, or the like, and, indeed, it will be found that the entire pump illustrated in FIGS. 14—19 inclusive can be of substantially the same size as, and is readily substitutable for, the combination belt drive wheel and/or flywheel of a conventional piston-type compressor (and exclusive of such a piston-type compressor), thus clearly indicating one major advantage of the exemplary form of the present invention illustrated in FIGS. 14—19 for operation as a two-cycle compressor or pump as compared to the very much larger and much heavier piston-type compressor and pump having generally comparable compressing and/or pumping characteristics.

However, it should be clearly noted that the power transmission means, indicated as comprising the belt drive groove 178 and the belt 180, is not to be construed as limiting the invention to any such specific structure. Actually, the power transmission means 34E may be of any convenient well-known type, or any other type, capable of coupling an external source of power to either the housing means 12E or the piston means 20E, in the exemplary form illustrated where they are the actually physically rotating portions of the device, and the piston means 20E may be provided with an externally accessible actually physically rotating sleeve similar to that shown at 60 illustrating the first form of the invention, or may be provided with any other means for coupling the interior actually physically rotating piston 20E with respect to an external source of power for driving same. Also, as previously pointed out, in that form of the invention where the housing means 12E and the piston means 20E do not actually physically rotate, but instead the supporting means 58E and 25E actually physically rotate, usually around the housing axis 16E, although in one form they may rotate around the piston axis 24E (or an operation axis between the axes 16E and 24E), the above-mentioned power transmission means 34E may be effectively coupled with respect to said supporting means 58E and 25E for effectively actually physically rotating same around any of said axes relative to the nonphysically rotating housing means 12E and piston means 26E. Additionally, it is also possible to provide power transmission means relatively coupled in a differential manner with respect to said supporting means 58E and 25E and with respect to the rotatively effectively substantially unified housing means 12E and piston means 20E for actual physical rotation in different ways of each of same so that relative differential rotation occurs therebetween, and all such arrangements are intended to be included and comprehended within the broad scope of the present invention.

It is also possible for the above-mentioned power transmission means 34E (which will be an input power transmission means in the case of a pump or compressor or an output power transmission means in the case of a fluid-pressure-actuated motor or engine) to comprise any one or all of the previously mentioned eccentric bushings 154 and the offcenter bolts, shafts, or pins 152 rotatively mounting same with respect to the piston means 20E. All that is necessary to do is to provide an external connection thereto for either eccentrically driving same or for being driven thereby and, if desired, one or more of said eccentric bushings 154 may be coupled together for simultaneous driving or driven operation in this manner whereby to provide a somewhat different type of power transmission means for either driving the entire device when it operates as a pump or compressor or for being rotatively driven by the entire device when it operates as a motor or engine. Also, any other noncentrally located eccentric bushing, crankpin, or other functionally equivalent driving or driven power transmission means may be employed for a similar purpose.

It should also be noted that the form of the invention illustrated in FIGS. 14—19 inclusive is not limited to operation as a pump or compressor, but may also function in an effectively reversed manner as either a fluid-pressure-operated motor, where a working fluid is supplied thereto under pressure produced externally or internally in any desired manner, or as an engine of either an external or internal combustion type, where a fuel is burned and produces pressurized expanding burned-fuel gases which effectively cause operation of the device as an engine having a rotating output power transmission means or portion capable of being coupled to an external mechanism for positively driving same. Said output power transmission means or portion might comprise any of the input power transmission means or portions just described above or any substantial equivalent thereof, such as the geared output power transmission shaft indicated at 97 in FIGS. 2 and 4 of the previously described first form of the invention, although not specifically so limited. All that is necessary in converting the pump or compressor form of the invention illustrated in FIGS. 14—19, inclusive, into such a fluid motor is to connect a source of fluid under pressure to the engine intake 36E and to connect the exhaust 38E of the device to a region of lower pressure in an open-cycle system or, in a closed-cycle system, to a low-pressure portion or side of a fluid circuit prior to repressurization and return to the intake 36E of the device. This mode of operation would also be applicable with respect to an external combustion engine where the external combustion means would merely comprise the means for pressurizing or repressurizing the working fluid.

In the case where the device is to be operated as an internal combustion engine, it is only necessary to provide appropriately spaced spark plugs, or other ignition means, in a manner similar to that previously described and illustrated in connection with the first form of the invention shown in FIGS. 1 through 8 inclusive and illustrated in a four-cycle mode of operation in FIGS. 6*a* through 6*h*, with the understanding that of course the valve ports 112E and 114E would have to be correspondingly changed and the entire valve sleeve 100E would have to be relatively rotated at either one-half the unified rate of rotation of the piston means 20E and the housing means 12E or one and one-half times said rate, or the like, so that the valve will follow the sequence of angular-incremental-positions and the mode of operation illustrated in said FIGS. 6*a* through 6*h*. However, it is also possible to operate the form of the invention illustrated in FIGS. 14 through 19, inclusive, as a two-cycle internal combustion engine, in which case the valve means 40E is of the type shown in said figures and remains stationary and all that is necessary is to provide the appropriate spark plugs or other ignition means and means for electrically energizing them in the proper timed substantial relationship in a manner generally similar to that which has been described hereinbefore in connection with the four-cycle mode of operation of the engine of the first form of the invention illustrated in FIGS. 6*a* through 6*h*.

It should also be noted that the exemplary valve means illustrated at 40E in the form of the invention illustrated in FIGS. 14 through 19 is exemplary and is not to be construed as specifically limiting the invention thereto. Actually, a great variety of different types of valve means and/or fluid ports may be employed and may be centrally positioned as illustrated in said figures or may be otherwise located and may be mounted all or in part in the housing means 12E rather than being completely mounted in the central valve sleeve 100E and in the piston means 20E and may comprise correlated reciprocatably or rotatively driven valving means, biased (usually spring-biased) ball or check valves, poppet valves, spool valves, mushroom valves, and they may be arranged to be pressure-actuated by differential pressure existing thereacross at certain time periods during a complete cycle of operation thereof so as to provide proper opening and closing of said valve means or may be arranged to be mechanically actuated by cam means, cam follower means, and/or other means arranged to provide valve actuation in response to relative rotation of the unified housing means 12E and rotor means 20E with respect to the supporting means 58E and 25E at proper time periods during the complete rotative cycle of operation thereof, whereby to bring about either a two-cycle operation thereof, a four-cycle operation thereof, or any other mode of operation thereof when the device is operated as either a fluid-moving compressor or pump or as a fluid-pressure-driven motor or engine as referred to hereinbefore for exemplary purposes and when operated in any other substantially functionally equivalent manner.

It should also be noted that the vanes 26E can be hydraulically radially outwardly biased in a manner similar to that previously described in connection with the first form of the invention or in any substantially functionally equivalent manner, that said vanes may be resiliently biased outwardly by biasing spring means in a manner similar to that described hereinbefore, that said vane means may be merely outwardly biased as a result of centrifugal force produced in response to unified rotation of the piston means 20E and the housing means 12E, or that the vanes 26E may be magnetically biased outwardly by the provision of appropriately located magnet means.

It should also be noted that the vane means 26E may have substantially T-shaped outer ends, split ends, substantially flat outer ends, curved outer ends, or otherwise-shaped outer ends of different surface area extents and/or may have the vane end vented to a low-pressure region in accordance with the general teachings of the first form of the invention previously described, although not limited to the specific form thereof described and illustrated in connection with the first form of the invention, so that high pressure in one vane space 30E is virtually completely prevented from passing a vane end into the next adjacent chamber space 30E. All of these and other individual features disclosed in various other forms of the invention throughout this application may be employed in this modification of the invention, if desired, and all such arrangements are intended to be included and comprehended within the broad scope thereof. This is also true of the other modifications of the invention described hereinafter.

FIG. 20 illustrates a slight modification of the FIGS. 14—19 form of the invention and parts which are structurally or functionally similar or substantially equivalent to previously described forms of the invention are designated by similar reference numerals, followed by the letter "F," however. In this modification, the housing means, generally designated by the reference numeral 12F, is of rectangular configuration and the chamber generally designated by the reference numeral 14F has four different chamber spaced 30F defined by four non radially arranged vanes 26F slidably carried in corresponding vane slots in the piston means 20F. The sleeve valve indicated generally at 40F is substantially the same as that illustrated in the FIGS. 14—19 form of the invention as are the two fluid ports 116F connecting with the two larger chamber spaces at each side of the device as shown in FIG. 20. However, it will be noted that in the FIG. 20 modification there are no fluid ports connecting to the two smaller chamber spaces 30F, although optionally there may be two such fluid ports as shown in broken lines at 116F. In other words, as shown in solid lines in FIGS. 20—22 the only two chamber spaces 30F which are actually functional are the two larger chamber spaces, while the two smaller chamber spaces 30F do not function for pumping purposes and may be considered to be either wasted space or employed as bleedoff chamber spaces or neutral chamber spaces.

However, as indicated by the broken-line ports 116F, said two smaller chamber spaces 30F may be ported and may merely be used as smaller working chamber spaces than the two larger chamber spaces 30F or the porting may be modified to provide a two-stage compression or supercharging action so that first the two larger chamber spaces 30F may be employed for compressing a gas to a first increased pressure which may then be fed to the two smaller chamber spaces 30F and subsequently compressed again to a second further-elevated pressure, or a reversed two-stage or multiple-stage arrangement may be provided by appropriate porting. This may also be done with more than two units.

For two-cycle pumping or compressing action, the valve means 40F remains stationary and the operation of the entire device is similar to that described in connection with the FIGS. 14—19 form of the invention when employed as a compressor or pump although the means for positively driving the device may be modified somewhat from the drive belt groove 178 and drive belt 180 of the FIGS. 14—19 form of the invention because of the nonround exterior shape of the housing means 12F. The shape of the housing means 12F may be rectangular as seen in the direction of the arrows 22–22 of FIG. 21 and such as is clearly shown in FIG. 22 or may be some other plan view cross-sectional configuration such as the substantially cylindrical configuration of the housing means as shown in FIG. 23 wherein it is generally designated by the reference numeral 12F′. The piston means 20F′ of FIG. 23 is also similarly modified as to shape. Otherwise, the FIG. 23 variation of the device having a differently shaped top configuration is substantially the same as that illustrated in FIGS. 20—22 and employs the same reference numerals except for the housing means 12F′ and the piston means 20F′ having said modified shapes.

It should be noted that the modified from of the invention shown in FIGS. 20 through 23, while shown as being rectangular as seen in end elevation or section, may have the rectangle modified into square form, in which case each of the chamber spaces 30F may be of equal size, or may have the shape of both the housing means and the piston means modified in a number of other ways, all within the broad scope of the present invention.

The rotary synchronization means indicated generally at 32F is of the type referred to hereinbefore wherein the nonround or irregular shape of both the piston means 20F and the housing means 12F effectively couples them together for substantially unified rotation except for relatively eccentric movement thereof around their respective piston axis 24F and housing axis 16F, respectively, which are appropriately supported by supporting means functionally equivalent to those indicated at 58E and 25E in the FIGS. 14—19 form of the invention, although not specifically so limited as to actual structure. However, any of the other types of synchronization means referred to herein may be employed in lieu thereof.

FIG. 24 is a view similar in many respects to FIG. 21 and, therefore, parts which are substantially similar structurally or functionally to earlier forms of the invention are designated by similar reference numerals, followed by the letter "G," however. In this modification, the major difference of the device from the form illustrated in FIG. 21 is the fact that the piston means 20G is provided with only two vanes 26G rather than four vanes and, thus, defines only two chamber spaces 30G rather than four chamber spaces as in the FIG. 21 form of the invention. Otherwise the FIG. 24 modification is substantially identical to the FIG. 21 form and no further detailed description thereof is thought necessary in the light of the foregoing description of the FIG. 21 form of the invention.

FIG. 25 is a view generally similar to FIG. 24 and shows a two-vane, two-chamber-space form of the device functionally substantially equivalent to the form illustrated in FIG. 24 and, therefore, having parts which are substantially similar, structurally or functionally, designated by similar reference numerals, followed by the letter "H," however. In this modification, it is assumed that a different type of valving carried in the housing means 12H or in an end casing, or the like, and not shown since substantially equivalent arrangements have already been referred to or are otherwise described herein, is employed in lieu of the central valving shown in FIG. 24, although central valving of substantially the same type as shown in FIG. 24, or any other substantial functional equivalent thereof, may be employed in lieu of such an arrangement as that just referred to. The major difference of the FIG. 25 form of the invention from that illustrated in FIG. 24 is the changed configuration of the housing means 12H and the piston means 20H. Otherwise, this modification is substantially functionally equivalent to that illustrated in in the FIG. 24 form of the invention and, thus, no further detailed description therefore is thought necessary or desirable.

FIG. 26 is another view quite similar to FIG. 25 and, therefore, parts which are substantially similar, structurally or functionally, are designated by similar reference numerals, followed by the letter "J," however. In this modification, it will be noted that the piston means 20J actually has a single double-ended vane means 26J slidably extending completely therethrough so that the one double-ended vane 26J functions in a manner similar to the two vanes 26G of the FIG. 24 form of the invention or 26H of the FIG. 25 form of the invention by merely sliding back and forth in the through hole carried by the piston means 20J. Otherwise, this modification of the invention is very similar to that described above in connection with FIG. 24 and may have valve means of substantially the same type, or any of the other valving arrangements disclosed or referred to herein may be employed in lieu thereof. Otherwise, the FIG. 26 form of the invention is substantially the same as the FIG. 24 form of the invention and, thus, no further detailed description thereof is thought necessary or desirable.

FIG. 27 is a view generally similar to FIG. 14 but illustrates a modified form of the invention modified primarily as to number of chamber spaces, number of vanes, and; more importantly, as to the shape of the housing means and the piston means. In this modification, parts which are substantially similar to those of previously described forms of the invention are designated by similar reference numerals, followed by the letter "K," however, and it will be noted that the housing means 12K has inside surface or wall portions 4K which are of inwardly convex configuration and that the inwardly adjacent outer surfaces 160K of the piston means 20K are inwardly convex or outwardly concave and inwardly spaced from the corresponding inwardly convex wall surface 46K of the housing means 12K. Thus, it may be said that the housing means 12K defines a scalloped chamber, indicated generally at 14K, and that the piston means 20K is correspondingly scalloped in lateral transverse cross-sectional or end-elevational shape which has the important effect of greatly shortening the length of each of the fluid ports 116K which, thus, increases the effective compression ratio of the device. The centrally positioned valve means 40K is illustrated as being of the same general type as the shown in the FIGS. 14—19 form of the invention, although it may assume any of the other valving forms disclosed in any of the various versions of this application or any substantial functional equivalent thereof, and this is also true with respect to the synchronization means (comprising the irregular or nonround housing means shape and piston means shape as generally designated by the reference numeral 32K), and with respect to the structure and mounting of the vane means 26K. This is also true of the two supporting means mounting the device for rotation around the two different axes 16K and 24K in a manner similar to that described hereinbefore in connection with other illustrated forms of the invention and is additionally true of any of the various disclosed types of vane-actuating or vane-biasing means, any of which may be employed for biasing the vane means 26K. Otherwise the modified form of the invention illustrated in FIG. 27 is substantially similar to that illustrated in the FIGS. 14—19 form of the invention and, thus, no further detailed description thereof is thought necessary or desirable.

FIG. 28 is a view generally similar to FIG. 15 but illustrated the FIGS. 14—19 form of the invention very slightly modified so as to operate in accordance wit the previously mentioned second mode of operation. Therefore, because it is a modification, reference numerals similar to those of the FIGS. 14—19 form of the invention, followed by the letter "L," however, are employed to designate structurally or functionally similar portions of the device. In this modification, operation in accordance with the previously described second mode of operation, the supporting means 58L and 25L actually physically rotate around an axis of operation coincident with the housing axis 16L, while the housing means 12L and the piston means 20L are rotatively immobilized. In the FIG. 28 form of the invention, this is accomplished by providing a modified base support, indicated generally at 18L, attached to and underlying a bottom peripheral portion of the housing means 12L, although any other type of attachment or support means for immobilizing the housing means 12L may be employed in lieu thereof.

It will be understood that the rotative immobilization of the housing means 12L also correspondingly rotatively immobilizes the piston means 20L by reason of synchronization means substantially identical to the synchronization means shown at 32E in the FIGS. 14—19 form of the invention, or by reason of the provision of any of the other types of synchronization means referred to herein which are not again shown in detail in FIG. 28.

In this particular form of the invention, the power transmission means is generally designated by the reference numeral 34L and is similar to the power transmission means generally designated by the reference numeral 34E in the FIGS. 14—19 form of the invention except that, in FIG. 28 form of the invention, the drive belt groove 178L and the corresponding drive belt 180L are circumferentially or peripherally carried by the bearing member 168L in a manner centered around the axis of operation which is coincident with the housing axis 16L so that when the drive belt 180L power rotates the bearing member 168L, both of the supporting means 58L and 25L are actually physically rotated around the combination housing axis and axis of operation 16L, which causes the piston means 20L to move in a chamber-space-modifying manner with respect to each of the three chamber spaces, such as those shown at 30E in the FIGS. 14—19 form of the invention, while maintaining substantial rotative immobility in unison with the rotative immobility of the housing means 12L provided by the rigid base support mounting 18L thereof.

Because of the eccentricity of the actually physically rotating bearing 168L, and pair of supporting means 58L and 25L, around the composite axis of operation and housing axis 16L, a small degree of rotative imbalance might be produced in the complete device when operated at high rotative speeds. Therefore, if desired, this may be neutralized by causing the mass of the bearing 168L on the opposite side of the combination axis of operation and housing axis 16L from the piston axis 24L to be of a larger mass or to be extended so as to be displaced on appropriate distance from the combination axis of operation and housing axis 16L to a degree such as to effectively comprise a counterbalance and to function in a neutralizing counterbalancing manner offsetting any such unbalanced forces produced by the eccentricity of the portion of the supporting means positioned on the eccentric piston axis side thereof.

It should be noted that in the FIG. 28 modification of the invention when the bearing means 168L and the two supporting means 58L and 25L are actually physically rotated around the combination axis of operation and housing axis 16L in a power-driven direction such as is imparted thereto by the drive belt 180L, this may be said to effectively comprise relative rotation in the opposite direction, which will hereinafter be referred to as a first direction of relative rotation, of the housing means 12L and the piston means 20L with respect to said supporting means 58L and 25L and that simultaneously said piston axis 24L may also be said to be rotating around the combination axis of operation and housing axis 16L in a second direction opposite to said first direction such as to effect the previously mentioned cyclic contraction and expansion of the three chamber spaces of the device which are similar to those best shown at 30E in FIG. 14 of the FIGS. 14—19 form of the invention.

FIG. 29 is another view also generally similar to both FIG. 15 and FIG. 28 and shows the device modified in a manner such as to also have the housing means and piston means rotatively immobilized while the supporting means are actually physically rotated and, thus, is a view very similar to FIG. 28. Because it is a modification, parts which are structurally or functionally similar to those of the previously described forms of the invention as shown in FIG. 15 and FIG. 28 are designated in FIG. 29 by similar reference numerals, followed by the letter "M," however. In the FIG. 29 modification, it will be noted that the base support member 18M is now effectively attached to the piston means 20M and fixedly supports same in a rotatively immobile manner. This is accomplished in the FIG. 29 modification of the invention by causing the piston means 20M to have an axially extended hollow sleeve portion 60M extending axially outwardly from one end of the device, which sleeve is fixedly attached to the modified base supporting member or means 18M.

It is quite obvious with the arrangement illustrated in FIG. 29 that the housing means 12M is also rotatively immobilized by reason of the provision of synchronization means similar to that shown at 32E in the FIGS. 14—19 form of the invention, although any other type of synchronization means referred to herein may be employed in lieu thereof, but that the housing means 12M is free to actually physically move in a chamber-space-modifying manner in response to the rotation of the bearing means 168M and the two supporting means 58M and 25M around the axis of operation which, in this modification of the invention is coincident with the piston axis 24M. The power transmission means 34M in this case may merely comprise an extension of the valve sleeve 100M which is provided with a drive belt groove 178M and a drive belt 180M functionally similar to those shown in FIGS. 15 and 28, although in this case adapted to power rotate the valve sleeve 100M around the axis of operation which is coincident with the piston axis 24M. However, any other means for rotating said valve sleeve 100M around the piston axis 24M may be employed. The eccentricity of the rotating supporting means 168M around the piston axis 24M causes the entire housing means 12M to move in a nonrotative but sequential chamber-space-modifying manner by reason of the eccentric positioning of the housing axis 16M relative to the combination axis of operation and piston axis 24M.

The above-mentioned eccentricity of the central rotating bearing means 168M around the combination axis of operation and piston axis 24M may impart a small degree of imbalance of the entire device, particularly when driven at high rotative speeds, and this may be neutralized by adding counterbalance weight portions 182 positioned on the opposite side of the combination axis of operation and piston axis 24M from the housing axis 16M and having either a mass, a spacing, or both, such as to substantially neutralize any rotative imbalance which might otherwise be produced by the eccentricity of the rotating supporting means and bearing.

It should be noted that in the FIG. 29 modification of the invention when the bearing means 168M and the two supporting means 58M and 25M are actually physically rotated around the combination axis of operation and piston axis 24M in a power-driven direction such as is imparted thereto by the drive belt 180M, it may be said that the housing means 12M and the piston means 20M are substantially simultaneously relatively rotated in an opposite direction, which will hereinafter be referred to as a first direction, with respect to said supporting means and centered on the combination axis of rotation and piston axis 24M, and that simultaneously the housing axis 16M may be said to be relatively rotated around said combination axis of operation and piston axis 24M in a second direction opposite to said first direction such as to effect the previously mentioned cyclic contraction and expansion of the three chamber spaces which are similar to those best shown at 30E in FIG. 14 of the FIGS. 14—19 form of the invention.

FIG. 30 is a view also generally like FIG. 15 but illustrates a further modification thereof, and, therefore, parts which are structurally or functionally substantially similar or equivalent to those of the FIG. 15 form of the invention are designated by similar reference numerals, followed by the letter "N," however. In this modification, it will be noted that the exterior surfaces 160N of the piston means 20N are longitudinally axially drafted or angled, or may be said to diverge toward the left as viewed in FIG. 30 or to converge toward the right as viewed in FIG. 30. This is also true of the interior wall surface 162N of the chamber block, 172N of the housing means 12N and, thus, it will be understood that interior pressure within any of the chamber spaces will tend to relatively move the piston means 20N toward the left and the housing means 12N toward the right with respect to each other. In the event that the housing means 12N is fixedly mounted by the base support 18, it will of course be the piston means 20N which will tend to be actually physically moved toward the left, while in the event that the piston means 20N is the one which is actually physically mounted (such as in the manner illustrated in FIG. 29, for example, or in any other substantially functionally equivalent manner), it will of course be the housing means 12N which will be actually physically moved toward the right.

However, in the exemplary form illustrated in FIG. 30, the housing means 12N is fixedly mounted and, thus, the piston means 20N tends to be pressure biased toward the left and in order to compensate for this and to maintain proper relative positioning of the piston means 20N and the housing means 12N, a thrust bearing, such as is very generally designated by the reference numeral 183, is provided and may be of any suitable type. Otherwise, this modification of the invention is substantially similar to previously described forms of the invention and, therefore, no detailed description thereof is thought necessary or desirable.

INcidentally, it should be noted that the entire device shown in FIG. 30 may be rotated substantially 90° in a clockwise manner and the base support 18N may be appropriately modified in view of its new 90° clockwise displaced position so as to underlie the device when in such an axially vertically direction orientation, and it will be found that the thrust bearing can now be eliminated under certain conditions of operation since the upward force produced on the piston means 20N by reason of pressure contained within the chamber spaces may be of a magnitude such as to be substantially neutralized by the downward force produced by gravity acting on the mass of the piston means 20N. Conversely, when the piston means 20N is the one which is rigidly supported, the entire device would be rotated counterclockwise 90° from its position as shown in FIG. 30, and it will be found that the axial upward force exerted on the nonfixedly mounted housing means 12N may be employed to neutralize the downward force exerted on the housing means 12N by gravity acting on the mass thereof.

FIG. 31 is a fragmentary, somewhat schematic and diagrammatic view taken from an end position generally similar to that of FIG. 14, but primarily comprising an end elevational view rather than sectional view as in the case of FIG. 14. This view illustrates a slight modification of the invention for varying the eccentricity of the piston means and the housing means and, correspondingly, of the piston axis and the housing axis and, therefore, parts which are structurally or functionally substantially similar to these of previously described forms of the invention are designated by similar reference numerals, followed by the letter "P," however. In this modification it will be noted that the base support portion 18P has one part 184 which adjustably carries the supporting means or mount 58P which relatively rotatably supports the housing means 12P and that said base support portion 18P has another part 186 which adjustably mounts the supporting means 25P which relatively rotatably supports the piston means 20P. This of course makes it possible to adjust the position of both the housing axis 16P and the piston axis 24P so that the eccentricity of spacing therebetween around whichever one of said axes comprises the effective axis of operation of the entire device (or around such an axis of operation positioned therebetween) can be controllably adjusted for the purpose of varying the effective displacement of the entire device and, thus, in the case of a pump, its volumetric capacity at a given number of revolutions per minute and/or the pressure of the working fluid emitted therefrom, which are inversely related.

It will be noted that in the exemplary form of the invention illustrated in both FIGS. 31 and 32, the above-mentioned adjustable mounting of the supporting means 58P and 25P is provided by a very simple type of adjusting means, in each case generally designated by the reference numeral 188 and taking the form of an adjusting screw 190 threaded upwardly through the corresponding threaded mounting part 184 and 186, respectively, of the mounting base 18P for upward extension and/or retraction in each case with respect to the corresponding mounting part 184 and 186, respectively. The upper end of the adjusting screw 190 in each case may effectively engage the circumferential exterior of the corresponding supporting means 58P and 25P, respectively, by being relatively rotatively engaged and longitudinally fastened thereto by means of a hollow longitudinally retaining receiver or boss, or may otherwise cooperate therewith in a manner such as to be capable of vertically shifting the position of the entire corresponding supporting means 58P and/or 25P, ad desired. It should be clearly noted that it is not necessary that there be two such adjustment means 188 in all cases where such eccentricity adjustment is desired. Actually, all that is really necessary is that there be one such adjustment means 188, and either of the two such adjustment means illustrated in FIGS. 31 and 32 may be retained with the other being eliminated, if desired. Also, it should be noted that the type of adjustment means illustrated in FIGS. 31 and 32 is purposely of a very simple type employed for purposes of drawing simplicity and clarity and is not intended to be construed as specifically limiting the invention to the actual structure of the adjustment means shown in FIGS. 31 and 32. Actually, a great variety of other adjustment means employing lead screws, cams, eccentrically mounted adjustment rings, or any other substantial structural or functional equivalent capable of effectively shifting the position of either the housing axis 16P or the piston axis 24P may be employed within the broad scope of the present invention. Furthermore, it should be clearly understood that such adjustment means may be provided at each end of the device for similarly varying the eccentricity at both ends of the device and that, if desired, two such opposite end-positioned eccentricity adjustment means may be coupled together for synchronized actuation form a single operating or adjustment location. This may be done by gearing or coupling means well known in the art and, therefore, the detailed structure of such coupling or synchronizing means is not shown.

It should also be noted that a substantial portion of the reset of the apparatus of the device, such as has been illustrated in other figures and/or previously described, is not shown in FIGS. 31 and 32 for reasons of drawing simplification and clarity, although it is to be understood that any or all of such additional structural elements requisite to the operation of the device or intended to be included and comprehended in a modified eccentricity-adjustable structure of the type illustrated in FIGS. 31 and 32.

It should be noted that adjustment of the eccentricity by operating either of the adjustment means 188, or any substantial functional equivalent thereof, will cause a variable displacement in the pump or compressor and this, of course, normally will correspondingly vary the volumetric output of the working fluid pumped therefrom and, in the case of a compressible fluid, will normally vary the output pressure of the working fluid. Either or both of these characteristics of the output working fluid can be manually adjusted by such modification of the eccentricity of the device, or such eccentricity variation can be made automatically in response to fluid pressure, fluid flow, or any other variable, so that automatic operation of the eccentricity adjustment means 188 can be effected for purposes of maintaining constant output pressure of the working fluid, constant output volumetric flow of the working fluid, or, in the case of an engine, constant output torque or constant output speed, and any of these desirable end results may be achieved by merely providing any suitable type of appropriate sensing means coupled to any suitable type of appropriate servomechanism means for operating the eccentricity-adjustment means 188, or any other functional equivalent thereof, for the purposes briefly outlined above. Since pressure-sensing, volumetric-flow-sensing (or mass-flow-sensing), speed-sensing, and/or torque-sensing means, and any of a variety of such servomechanism means are all well known in the art, they are not shown in FIGS. 31 and 32, although all such arrangements are intended to be specifically included and comprehended within the broad scope of the present invention.

Otherwise, the modification fragmentarily illustrated in FIGS. 31 and 32 operates in a manner similar to that previously described, and no further detailed description thereof is thought necessary or desirable.

FIGS. 33 and 34 illustrate fragmentarily, in a somewhat diagrammatic and schematic way and with substantial portions of the device removed for reasons of drawing simplicity and clarity, one portion of a slightly modified type of synchronizing means which, in this case, is indicated generally by the reference numeral 32Q. Since these views do illustrate a modification, parts which are structurally or functionally substantially similar to those of previously described forms of the invention are designated by similar reference numerals, followed by the letter "Q," however. In the FIGS. 33 and 34 modification, the synchronizing means 32Q is of a very slightly different type from the synchronizing means 32E illustrated in the FIGS. 14—19 form of the invention and takes the form of a bolt or pin 152Q carrying a spacer or sleeve 192 and positioned in the oversize hole 156Q. Of course, in this case the diameter of each such hole 156Q equals the diameter of the complete spacer 192 and bolt, shank, or pin 152Q plus two times the eccentric spacing between the housing axis and piston axis such as is best indicated at 16E and 24E in the FIGS. 14—19 form of the invention. In other words, in this modification of the invention, each bolt, shank, or pin 152Q is device. Otherwise, the FIG. 38 modification of the invention is both structurally and functionally substantially very similar to the FIG. 37 form of the invention and, therefore, no further detailed description thereof is thought necessary or desirable.

FIG. 38*a* is a fragmentary view similar to the top portion only of FIG. 38, but illustrates a very slight modification thereof and, therefore, parts which are structurally or functionally substantially similar to those of the FIG. 38 form of the invention are designated by similar reference numerals, primed, however. In this modification it will be noted that the intake check valve means 112T′ is positioned at the radial outer extreme of the fluid port or passage 116T′, which comprises the intake passage, and still is normally biased into closed relationship until suction in the corresponding chamber space 30T′ causes same to temporarily open at the proper time. It should also be noted that similarly the exhaust check valve means 114T′ is located at the radial outer extremity of the other fluid port or passage 116T′, which comprises the exhaust fluid port or passage, and that the exhaust check valve 114T′ is normally biased into closed relationship until increasing pressure in the chamber space 30T′ temporarily causes same to open so as to cause the entire device to operate in accordance with the previously described cycle of operations.

It should be clearly noted that certain major portions of the apparatus requisite for its operation are not shown in FIG. 38*a* for reasons of drawing simplification and clarity and since they have been shown elsewhere. O2herwise, the figure 38*a* modification of the invention is similar to and operates in a manner similar to previously described forms of the invention and, therefore, no detailed description thereof is thought necessary or desirable.

FIG. 39 is a fragmentary, somewhat diagrammatic view with certain major portions of the device removed for reasons of drawing simplicity and clarity and is taken from an aspect generally similar to FIGS. 15, 37, and 38 but illustrates a modified form of valving means. In this modification, parts which are structurally or functionally substantially similar to those of previously described forms of the invention are designated by similar reference numerals, followed by the letter "U," however. It will be noted that the valving means, generally designated by the reference numeral 40U, comprises a spool valve including an intake valving member 212 and an exhaust valving member 214 mounted on a common valve shaft 216 and biased by a biasing spring 218 toward the right as viewed in FIG. 39. In the position of the valve means 40U shown in FIG. 39, the exhaust valving member 214 is shown effectively closing the left-hand exhaust fluid port 116U while the intake valving member 212 is shown in a position such that the right-hand intake fluid portion 116U is open. This would correspond to the FIGS. 14—19 form of the invention in any rotative position thereof between a position which is just slightly clockwise of that shown in FIG. 14 and just slightly counterclockwise of the position shown in FIG. 18, during which time the intake portion 112U is adapted to be open and the exhaust portion 114U is adapted to be closed. The entire valve means 40U is adapted to be cam operated by a cam member 220 which is positioned outwardly of the end plate 50U of the housing means, indicated generally at 12U, and which may be carried by a fixed exterior casing similar to that shown at 126S in FIG. 37 or 126T in FIG. 38 or said cam means 220 may be carried by a bearing member such as that shown at 168 in the FIGS. 14—19 form of the invention, or by the base support 18E thereof, or by any other appropriate mounting means. It will be noted that the right end of the valve shaft 216 extends outwardly through an opening 221 in the housing means 12U and may be said to effectively comprise a cam follower movable during rotation of the piston means 20U and the housing means 12U along the inside surface of the stationary cam 220 for appropriate actuation of the complete spool valve means 40U so that during the remaining very nearly half-cycle of operation from that described above, during which the intake port 112U is open, the cam-following valve stem 216 and the complete spool valve 40U will be actuated toward the left, as viewed in FIG. 39, in a manner such that the intake valving member 212 will close the intake port 112U while the exhaust valving member 214 will move out of engagement with and effectively open the exhaust valve port 114U for causing the entire device to operate in a manner substantially similar to that previously described in connection with the FIGS. 14—19 form of the invention. Of course, it should be noted that the spool valve means 40U may be appropriately modified for four-cycle operation, or for operation in any other desired manner, and it should further be noted that the intake and exhaust fluid ports 116S, 116T, and 116U in the FIGS. 37, 38, and 39 variations of the valve means may all be appropriately positioned so as to be in different circular angular locations with respect to the axis of operation of the device and relative to the vanes, such as those best shown at 26E in the FIGS. 14—19 form of the invention, so that the proper operation of the device will follow according to the desired mode of operation thereof.

It should be noted that the showing of FIG. 39 is merely illustrative of one of many different forms which the valving means may take within the broad scope of the present invention and is not to be construed as specifically limiting the invention to the exact structure shown in FIG. 39. Otherwise, the FIG. 39 form of the invention is structurally and functionally similar to previously described forms of the invention and, therefore, no detailed description thereof is thought necessary or desirable.

FIG. 40 is a fragmentary cross-sectional view of a modified form of valving means taken on substantially the same plane as the valving means 40E shown in FIG. 15. In this modification, parts which are structurally or functionally substantially similar to previously described forms of the invention are designated by similar reference numerals, followed by the letter "V," however, and it will be noted that the valving means 40V includes an outer tubular intake portion 36V and a concentrically inwardly spaced smaller diameter tubular exhaust portion 38V positioned therein, with the intake portion 36V having the intake portion 112V and the exhaust portion 38V having the exhaust port 114V. One advantage of this concentric arrangement is the fact that it provides a more uniform temperature distribution around the complete valve means 40V. Another advantage of this type of structure is that it is very adaptable for providing proper valve porting for engines or motors having many chamber spaces, which is easily done by staggering the corresponding fluid ports of the piston or rotor for appropriate and properly timed communication with corresponding multiple intake and exhaust ports of such a valve means 40V. This also makes it possible to properly valve and port several motors in series through a single composite valving structure.

FIG. 41 is a fragmentary view, generally similar to a portion of FIG. 3 of the first form of the invention, but illustrates a different type of vane. In this modification, parts which are functionally or structurally substantially equivalent to corresponding parts of previously described forms of the invention are designated by similar reference numerals, followed by the letter "W," however. In this modification, it will be noted that each of the vanes 26W is no longer slidably carried by the piston or rotor 20W but instead is made of a flexible material, such as rubber, plastic of an elastomeric type, or any other material suitably flexible or resilient to a degree such as to be capable of deflecting between maximum and minimum effective extension positions, and all intervening position, such as illustrated by comparing the two different degrees of vane extension shown at the top and at the bottom of FIG. 41. It should be noted that in the FIG. 41 modification, said flexible vanes 26W may be integrally attached to the piston or rotor 20W which is, therefore, made of the same rubberlike or elastomeric plastic material or may be suitably effectively unitarily attached to the piston or rotor means 20W which is made of a different material. This modification of the vane structure provides a very effective and relatively inexpensive form of the invention which is particularly suitable for pumps and compressors, although not specifically so limited.

not provided with an eccentric such as is shown at 154 in the FIGS. 14—19 form of the invention completely filling each of the holes 156. Instead, in the FIGS. 33 and 34 form of the invention, each spacer 192 is symmetrically positioned on the bolt, shank, or pin 152Q and is smaller than the hole 156 in which it is mounted. However, the operation thereof is substantially the same as that previously described in connection with the FIGS. 14—19 form of the invention and effective synchronization of the piston means 20Q and the housing means 12Q occurs by reason of the spacer or sleeve 192 rolling around the inside surface of the hole 156Q during one complete rotative cycle of operation of the device.

It should be noted that, if desired, the spacer or sleeve 192 may be eliminated in certain variations of this form of the invention and the bolt, shank, or pin 152Q may be employed directly for the above-mentioned synchronizing purposes. Also, the synchronization means 32Q may be positionally reversed with respect to the housing means 12Q and the piston means 20Q in certain forms of the invention.

Otherwise, this modification of the invention functions very similarly to the FIGS. 14—19 form of the invention and, therefore, no further detailed description thereof is thought necessary or desirable.

FIGS. 35 and 36 are fragmentary, partially broken-away somewhat diagrammatic and schematic views roughly similar in aspect to FIGS. 34 and 33, respectively, and illustrate a further modification of the synchronization means which takes the form of crank pin means, indicated generally at 194, and having one end 196 rotatively coupled to one end surface of the piston means indicated generally at 20R and having another end 198 rotatively coupled at a location offset by the housing and piston axis eccentricity to an end wall or chamber plate 50R of the housing means, indicated generally at 12R. It should be particularly noted that in this form of the invention it is possible to construct the crank pin 194 so as to be adjustable as to the spacing between the two portions 196 and 198 thereof, thus making it possible to use this with an eccentricity adjustable form of the invention, such as exemplified fragmentarily by the showing of FIGS. 31 and 32. It should also be noted that one or more such crankpins 194 may be employed in a manner similar to the showing of a plurality of the eccentric bushings 154 in the FIGS. 14—19 form of the invention. Otherwise, the FIGS. 35 and 36 form of the invention is substantially the same in structure and function as previously described forms of the invention and, therefore, no further detailed description thereof is thought necessary or desirable.

FIG. 37 is a fragmentary, partly diagrammatic and schematic view, partly in section and partly in elevation, and similar in aspect to FIG. 15, but illustrates a modified form of the invention showing a modified valving arrangement, and because it is a modification, parts which are structurally or functionally substantially similar to those of previously described forms of the invention are designated by the same reference numerals, followed by the letter "S," however. In this modification, it will be noted that the intake, indicated generally at 36S, extends into the device coaxial with the piston axis 24S in a manner similar to the intake 36E of the FIG. 15 form of the invention. However, the engine exhaust indicated generally by the reference numeral 38S is entirely differently constructed and located in the FIG. 37 modification of the invention and is actually carried by a portion of an exterior engine casing 126S positioned outside of the housing means generally designated by the reference numeral 12S. The inner end of the intake 36S connects to fluid ports 116S connected to each of the chamber spaces 30S, such as the three chambers spaces 30E, for example, best shown in FIG. 14, although not specifically so limited, and is provided with an intake check valve, generally designated by the reference numeral 112S, and including a valve member or ball 200 biased by a biasing spring 202 against a valve seat 204 in a manner normally effectively closing the intake check valve means 112S until the outward pressure differential acting thereacross, the produced primarily by reason of the vacuum produced within the corresponding one of the plurality of chamber spaces 30S during its expanding phase, causes said intake check valve 112S to open and to effectively function in a manner similar to the intake port 112E of the FIGS. 14—19 form of the invention. As soon as the chamber space vacuum-caused pressure differential, which temporarily opens the normally closed intake check valve means 112S, drops in magnitude because of the fact that the chamber space 30S now enters the contraction phase, the intake check valve 112S immediately closes and again functions in a manner substantially similar to the intake valve portion 112E of the FIGS. 14—19 form of the invention.

The modified valving arrangement illustrated in FIG. 37 also includes an exhaust check valve, such as is generally designated by the reference numeral 114S, positioned in the chamber block portion 172S of the housing means 12S and having a check valve member or ball 206 normally biased by a biasing spring 108 against a valve seat 210 in a manner normally closing same until such time as the outward differential pressure acting thereacross as a result of the corresponding chamber space 30S entering into a contraction phase of its cyclic operation causes the temporary opening of the normally closed exhaust check valve means 114S and allows the working fluid to be exhausted outwardly therethrough into the interior of the outer casing 126S and then outwardly through the exhaust 38S in a manner substantially functionally equivalent to the operation of the exhaust port 114E and the complete exhaust means 38E of the previously described FIGS. 14—19 form of the invention.

In other words, the arrangement illustrated in FIG. 37 may comprise any of the different structures of the various different forms of the invention, with the valving means merely modified to be of the check valve type and mounted in the manner illustrated in FIG. 37, or in a variety of other manners such that chamber space pressure variation will cause the proper timed operation of the intake and exhaust check valves 112S and 114S, respectively, for either two-cycle operation of the device in the manner previously described in connection with the FIGS. 14—19 form of the invention, four-cycle operation of the device (with appropriate modifications, of course), or for operation in any of a variety of desired manners.

It should be noted that the intake and exhaust check valve means may be ball valves, poppet valves, or any other configuration or type of valve located in any manner functionally equivalent for the purposes of the present invention.

It should be clearly noted that certain major portions of the apparatus (such as vanes and/or other ports) requisite for its operation are not shown in FIG. 37 (and in a number of the other views) for reasons of drawing simplicity and clarity and since they have been shown elsewhere, and all such views are to be considered as including such requisite ports.

Otherwise, the FIG. 37 modification of the invention is similar to and operates in a manner similar to previously described forms of the invention and, therefore, no detailed description thereof is thought necessary or desirable.

FIG. 38 is another view similar in many respects to FIG. 37 with certain major portions of the device removed for reasons of drawing simplicity and clarity and merely illustrates a modified arrangement wherein the intake and exhaust check valves are differently located and positioned so as to avoid any spurious operation thereof as a result of centrifugal force. In this modification, parts which are centrifugal or functionally substantially similar to those of the FIG. 37 form of the invention are designated by similar reference numerals, followed by the letter "T," however, and it will be noted that the intake, indicated generally at 36T, connects to the intake check valve means 112T in an axial rather than a radial manner as shown in FIG. 37 and that similarly the exhaust 38T connects to the exhaust check valve means 114T in a substantially axial manner rather than in a radial manner, thus causing both of said intake and exhaust check valves 112T and 114T to be insensitive to centrifugal force during rotative operation of the

It should be noted that various portions of the requisite structure for the modified form of the invention illustrated fragmentarily in FIG. 41 are removed for reasons of drawing simplicity and clarity and in view of the fact that they have been disclosed elsewhere in detail in this application.

FIGS. 42 and 43 illustrate a piston means of the type shown at 20E in the FIGS. 14—19 form of the invention which is provided with a very effective type of seal means for both side and end wall sealing engagement. In this modification, parts which are structurally or functionally substantially similar to previously described forms of the invention are designated by similar reference numerals, followed by the letter "X," however. In this modification, each end surface of the piston means 20X carries immediately adjacent to the outer confronting surface edge 160X thereof a longitudinal groove, which is a continuous rectangular groove 222, and which has mounted therein a resilient or elastomeric sealing ring 224, thus, in the case of the triangular piston means 20X illustrated in FIGS. 42—44 requiring there such sealing rings 224. Each vane means 26X similarly has a groove 226 along the complete rectangular edge thereof which carries therein a resilient or elastomeric sealing ring 228, thus, in the three-vane type of structure illustrated in FIGS. 42—44, requiring three such vane-sealing rings 228. This provides virtually complete sealing of not only the piston means 20X, but each of the vane means 26X with respect to both oppositely positioned end walls of a housing means and the peripheral or sidewall of a housing means, such as are shown at 50E in the first case and at 162 in the second case in the FIGS. 14—19 form of the invention, when the piston means 20X of the FIGS. 42—44 modification is mounted in such a housing means as that shown at 12E in the FIGS. 14—19 form of the invention.

Instead of using resilient or elastomeric sealing rings as referred to above, they may be split metal rings or any other suitable type of sealing ring or member and it should also be noted that the above sealing concept is not limited to the triangular type of piston means 20X shown in FIGS. 42—44 but may be employed in connection with the piston means of any of the various different forms of the invention disclosed in this application.

It should be noted that other requisite portions of a complete operative device are not shown in the FIGS. 42—44 modification of the invention for reasons of drawing simplicity and clarity and since they have been disclosed in detail elsewhere in this application.

In all respects other than those detailed hereinabove, the FIGS. 42—44 form of the invention is structurally and functionally similar to previously described forms of the invention and, therefore, not further detailed description thereof is thought necessary or desirable.

FIG. 45 illustrates a further modification of the invention and is a view generally similar to FIG. 15 but illustrates a modified form of the invention having the supporting means positively power rotated and having the axis of operation not coincident with either the piston axis of the housing axis, but positioned therebetween. In this modification, parts which are structurally or functionally substantially equivalent to those of previously described forms of the invention are designated by similar reference numerals, followed by the letter "Y," however.

It will be noted that in this modification the input power transmission means, or means for positively driving the device, is generally designated by the reference numeral 34Y and takes the form of a driven shaft 230 which rotates around an axis of operation 232 which lies between the housing axis 16Y and the piston axis 24Y. Since both the housing means 12Y and the piston means 20Y are prevented form rotating by a stop pin 234 extending through a slot 236 in the housing means 12Y, and with the stop pin being adapted to be externally held by any rotatively fixed mounting means (not shown and, preferably vertically slotted, or provided with a hole similar to that shown at 156 in the FIGS. 14—19 form of the invention), the housing means 12Y and the piston means 20Y will each follow an eccentric path or wobble corresponding to the eccentricity between the housing axis 16Y and the axis of operation 232 and the eccentricity between the piston axis 24Y and the axis of operation 232, respectively, which will be opposed and so arranged that the imbalance of each directly opposes and substantially neutralized and cancels out the imbalance of the other and, thus, results in smooth operation of the complete device, considered as a system, without the use of any other auxiliary counterbalances. It should be noted that the central valve means and the valve ports and the vane means are not detailed in this view since they have been illustrated in detail in other views and have been fully described previously. It should also be noted that certain portions of the device requisite for providing a complete operative device have also been removed from FIG. 45 for reasons of drawing simplicity and clarity and since they have been adequately disclosed elsewhere herein. With the exception of the detailed description referred to above, the modified form of the invention illustrated in FIG. 45 is constructed and operates substantially in accordance with the teachings disclosed hereinbefore with respect to previously fully described forms of the invention and, therefore, no further detailed description thereof is thought necessary or desirable.

FIG. 46 illustrates a further modification of the invention and is a view of aspect generally similar to FIG. 15 but illustrates a simplified form of the invention wherein the piston means is effectively provided with a flange which cooperates with a simplified one-sided form of housing means for the purpose of providing an extremely simple structure not requiring a completely enclosing housing means of the type previously described and illustrated in various of the other figures of the drawings. In this modification, parts which are structurally or functionally substantially equivalent or similar to those of previously described forms of the invention are designated by similar reference numerals, followed by the letter "Z," however.

It will be noted that in this modification the piston means 20Z is provided with a radially outwardly projecting peripheral flange 238 and that the housing means, indicated generally at 12Z is no longer a completely enclosing housing means as in previously described forms of the invention but instead is a one-sided housing means having one end wall 50Z and a peripheral sidewall portion 172Z which terminates in an abutment end 240 which is pressed into sealing contact with the piston flange 238 by a takeup nut 242 threaded onto the exterior of the sleeve valve pipe or tube 100Z so that the takeup nut 242 may be used to adjust the pressure of the opposed pressure surfaces where the abutment end 240 of the housing means sidewall 172Z presses against the piston flange 238 and also the pressure of the opposed pressure surfaces where the inner face of the housing means end wall 50Z presses against the corresponding face 244 of the piston means 20Z. It should be noted that said pressure surfaces just referred to above effectively maintain alignment between the rotor 20Z and the housing means 12Z and that the first-mentioned pressure surfaces effectively provide sealing engagement of the piston mean 20Z with respect to the housing means 12Z so that each chamber space 30Z is effectively sealed from ambient atmosphere. If desired, appropriate sealing gasket means, O-ring means, or the like, may be employed between the abutment end 240 of the housing means sidewall 172Z and the extended piston flange 238 for further increasing the positive nature of the sealing engagement between the piston means 20Z and the housing means 12Z.

The left end of the sleeve valve or pipe 100Z is effectively provided with a radially outwardly extending enlarged retaining abutment 246 which may be said to effectively comprise both a bearing mount and retainer for the thrust bearing, indicated generally by the reference numeral 183Z, which is similar to the thrust bearing 183 of the FIG. 30 form of the invention. It should also be noted that, if desired, a spring may be positioned somewhere between the takeup nut 242 and the bearing retaining abutment 246 so as to cause the retaining force or pressure exerted by the takeup nut 243 on the assembly of the rotor means 20Z and the housing means 12Z to be of a resilient spring-biased but controllably adjustable nature. This is an optional feature.

It should be clearly noted that the valve means is not shown in detail in FIG. 46, but is generally similar to any of the various valve means previously described hereinbefore and that the vane means are not shown at all in FIG. 46 but that same may be of any of the types previously described hereinbefore. It should also be noted that no support is shown in FIG. 46 and that various other portions of the requisite structure for the modified form of the invention illustrated fragmentarily and in a somewhat simplified form in FIG. 46 are removed for drawing simplicity and clarity in view of the fact that they have been disclosed elsewhere in detail in this application.

In all respects other than those detailed hereinabove, the FIG. 46 form of the invention is structurally and functionally similar to the previously described forms of the invention and, therefore, no further detailed description thereof is thought necessary or desirable.

It should be noted that in any of the various different forms of the invention referred to herein, sealing means, such as O-rings or any of various other types of seals, may be employed at appropriate locations such as at any of the bearing means where relative rotation between the various parts of the device occurs or at any other appropriate locations to facilitate operation of the device in a friction-minimized manner and/or to provide a substantially hermetically sealed device, if desired. It should also be noted that various types of lubrication means for positively lubricating the relatively moving parts may be employed in any of the various forms of the invention and that various of the parts may be Teflon-coated, carbon-coated, coated or laminated with various different materials for the purpose of increasing strength while minimizing friction and/or to otherwise improve performance and/or wear-ability of the apparatus and, in certain cases, to cause it to be capable of operating without any additional lubricant.

Although specific embodiments of the present invention have been illustrated and described herein, it will be understood that the same are merely exemplary of presently preferred embodiments capable of attaining the objects and advantages hereinbefore mentioned, and that the invention is not limited thereto; variations will be readily apparent to those versed in the art, and the invention is entitled to the broadest interpretation within the terms of the appended claims.

I claim:

1. A radial chamber, positive displacement, fluid power device comprising: housing means defining an internal piston chamber having a central transversely directed housing axis; piston means positioned within said chamber and having a central transversely directed piston axis; said chamber having a larger cross-sectional area than said piston means in a plane perpendicular to said transversely directed housing and piston axes; a pair of relatively eccentrically related supporting means having two eccentrically related axes, coaxial, respectively with said housing axis and said piston axis and having a substantially parallel axis of operation positioned in a plane terminating at one end and being coincident with said housing axis and terminating at the other end and being coincident with said piston axis and relatively rotatively supporting said housing means around said housing axis and relatively rotatively supporting said piston means around said piston axis, with said housing and piston axes being disposed in spaced parallel relationship to each other; the relatively eccentric positioning of said piston means and the one of said pair of supporting means relatively rotatably supporting said piston means, and the relative cross-sectional shape of said piston means with respect to the larger cross-sectional shape of said chamber being so related as to provide and define radially varying chamber spaces at different relatively angularly spaced locations between said piston means and said housing mean defining said chamber, each such chamber space radially varying in extent as a function of relative rotative angular location of one relatively rotated axis of said housing and piston axes around said axis of operation, with said chamber space lying between the corresponding radially spaced portions of said piston means and said housing means; at least one movable vane sealingly cooperating with said piston means and a corresponding outwardly spaced inner wall of said housing means defining said chamber and circularly angularly dividing that portion of the chamber between the piston means and the inner wall of the housing means defining said chamber into at least two angularly adjacent chamber spaces; means for effecting substantially simultaneous relative rotation in a first direction of said housing means and said piston means with respect to said supporting means and centered on said axis of operation thereof while simultaneously effecting relative rotation in said first direction of said housing means with respect to said supporting means centered on said housing axis and for simultaneously effecting relative rotation in said first direction of said piston means with respect to said supporting means and centered on said piston axis while also effecting relative rotation of at least one of said housing and piston axes of said supporting means with respect to said housing means and said piston means around said axis of operation of said supporting means in a second direction opposite to said first direction in a manner such as to effect cyclic contraction and expansion of said chamber spaces without any substantial relative angular movement between said piston means and said housing means; and means for admitting a working fluid into and venting the working fluid from said chamber spaces, respectively, in timed relation to chamber-space-modifying relative movement of said piston means and said housing means in response to said substantially simultaneous relative rotation in said first direction of said housing means and said piston means around said axis of operation of said supporting means and said simultaneous relative rotation in said second opposite direction of at least one of said housing and piston axes of said supporting means around said axis of operation of said supporting means and relative to said housing means and said piston means.

2. A device as defined in claim 1, including two or more of said movable vanes, each sealingly cooperating with a different angularly displaced portion of said piston means and a corresponding different angularly displaced portion of the inner wall of said housing means whereby said angular displaced vanes define therebetween two or more of said angularly adjacent chamber spaces.

3. A device as defined in claim 2, wherein at least one of said housing means and said piston means is effectively provided with intake and exhaust passages for the working fluid; said means of admitting a working fluid into and venting the working fluid from said chamber spaces comprises valve means for admitting the working fluid into and exhausting said working fluid from said chamber spaces through said passages, respectively, in timed relationship to the substantially simultaneous relative rotation in said first direction of said housing means and said piston means around said axis of operation of said supporting means and said simultaneous relative rotation in said second opposite direction of at least one of said housing and piston axes of said supporting means around said axis of operation of said supporting means and relative to said housing means and said pistons means.

4. A device as defined in claim 3, wherein said means for effecting substantially simultaneous relative rotation of said housing means and said piston means comprises rotary synchronizing effective power transmission and coupling means effectively coupled therebetween for substantially preventing relative angular displacement between said housing means and said piston means while freely allowing only said substantially simultaneous relative rotating in said first direction of said housing means and said piston means with respect to said supporting means centered on said axis of operation thereof and said simultaneous relative rotation in said first direction of said housing means with respect to said supporting means centered on said housing axis and said

simultaneous relative rotation in said first direction of said piston means with respect to said supporting means centered on said piston axis and said simultaneous relative rotation of at least one of said housing and piston axes of said supporting means with respect to said housing means and said piston means around said axis of operation in said second direction opposite to said first direction in said manner such as to effect cyclic contraction and expansion of said chamber spaces.

5. A device as defined in claim 4, wherein said piston means and said chamber are noncircular in transverse cross section and have confronting surfaces defining the inner and outer walls of said chamber spaces, respectively.

6. A device as defined in claim 5, wherein similar portions of said respective confronting surfaces are disposed in virtual contact over their entire areas when the intervening chamber space is in its minimum volume condition, thereby providing said device with a maximum compression ratio.

7. A device as defined in claim 4, wherein said piston means has a generally cylindrical outer surface, the inner wall of said chamber also being of generally cylindrical shape and having a generally cylindrical inner surface defining the outer walls of said chamber spaces respectively and having an effective average internal radius of curvature greater than but closely approximating the external radius of curvature of said piston means.

8. A device as defined in claim 4, wherein said piston means has a generally cylindrical outer surface, the inner wall of said chamber having a number of axially extending generally uniformly spaced arcuate scallops defining the outer walls of said chamber spaces, respectively, and having substantially equal radii of curvature closely approximating the external radius of curvature of said piston means.

9. A device as defined in claim 4, wherein said piston means and said chamber are generally polygonal in transverse cross section and have generally parallel confronting wall surfaces extending between said vanes, respectively, and defining the inner and outer sides of said chamber spaces, respectively.

10. A device as defined in claim 4, wherein said device comprises an engine to be operated by said working fluid; and including power transmission means effectively coupled with respect to the actually rotating one of said relatively rotating coupled piston means and housing means and said pair of relatively eccentrically related supporting means relatively rotatively supporting same and adapted to be coupled to an external mechanism.

11. A device as defined in claim 4, wherein said device comprises an internal combustion engine; said working fluid comprising a combustible mixture which is compressed in said chamber spaces during contraction of said spaces; and ignition means on said engine for igniting the compressed combustible mixture in each chamber space in timed relation to said substantially simultaneous relative rotation in said first direction of said housing means and said piston means around said axis of operation of said supporting means and said simultaneous relative rotation in said second opposite direction of at least one of said housing and piston axes of said supporting means around said axis of operation of said supporting means and relative to said housing means and said piston means.

12. An engine as defined in claim 11, wherein said ignition means comprise spark plugs carried by said housing means adjacent to and in effective communication with corresponding ones of said chamber spaces.

13. A device as defined in claim 4, wherein said device comprises an internal combustion engine; said working fluid comprising a combustible mixture which is compressed in said chamber spaces during contraction of said spaces; and spark plugs carried by said piston means for igniting the compressed combustible mixture in each chamber space in timed relation to said substantially simultaneous relative rotation in said first direction of said housing means and said piston means around said axis of operation of said supporting means and said simultaneous relative rotation in said second opposite direction of at least of said housing and piston axes of said supporting means around said axis of operation of said supporting means and relative to said housing means and said piston means.

14. A device as defined in claim 4, wherein said device comprises a four-cycle internal combustion engine; said working fluid comprising a combustible mixture; said valve means comprising intake and exhaust valve means for providing each of said chamber spaces with an operating cycle including an intake phase during which the respective chamber space undergoes expansion while in communication with said intake passage to induce flow of said combustible mixture into the respective chamber space, a compression phase during which the respective chamber space undergoes contraction while isolated from said intake and exhaust passages to effect compression of the combustible mixture in the respective chamber space, a power phase during which the respective chamber space undergoes expansion while isolated form said intake and exhaust passages and the compressed combustible mixture within the respective chamber space is burned to produce a driving torque on one of the two relatively rotatable structures of the engine comprising the simultaneously relatively rotatable housing means and piston means and the pair of relatively eccentrically related supporting means relatively rotatively supporting said housing means and said piston means, and an exhaust phase during which the effective chamber space undergoes contraction while in communication with said exhaust passage to effective expulsion of spent combustion gas from the respective chamber space; and ignition means on said engine for igniting the compressed combustible mixture in each of said chamber spaces in timed relation to said substantially simultaneous relative rotation of said housing means and said piston means around one of said axes of said supporting means and said simultaneous relative rotation of the other of said axes of said supporting means around said first-mentioned axis of said supporting means in the opposite direction in a manner such as to effect burning of said combustible mixture in said chamber spaces during the power phase of their respective operating cycles.

15. An engine as defined in claim 14, wherein said synchronizing means for effectively rotatably coupling said piston means and said housing means comprises rotary power transmission means effectively coupling said piston means and said housing means.

16. A device as defined in claim 4, wherein said device comprises an internal combustion engine; said working fluid comprising a combustible mixture which is compressed in said chamber spaces during contraction of said spaces; and including ignition means on said engine for igniting the compressed combustible mixture in each chamber space in timed relation to said substantially simultaneous relative rotation in said first direction of said housing means and said piston means around said axis of operation of said supporting means and said simultaneous relative rotation in said second opposite direction of at least one of said housing and piston axes of said supporting means around said axis of operation of said supporting means and relative to said housing means and said piston means; said housing means and said piston means having communicating passages extending therethrough through with a coolant may be circulated to cool said engine.

17. An engine as defined in claim 16, including a casing enclosing said housing means, said casing having an inlet adjacent to one end of said housing means through which air may enter said casing; means communicating the interior of said casing adjacent to the end of said housing means to said engine intake passage; and cooling fins on said piston means and said housing means for aiding heat transfer from said engine and said air and for inducing air flow through said engine.

18. A device as defined in claim 4, including vane-actuating means operative to normally maintain said vanes in said cooperative sealing relationship with respect to said piston and a corresponding wall portion of said housing means defining said chamber when said substantially simultaneous relative rotation of said housing means and said piston means around one of said axes of said supporting means and said simultane-

ous relative rotation of the other of said axes of said supporting means around said first-mentioned axis of said supporting means in the opposite direction occurs.

19. A device as defined in claim 18, wherein said vane-actuating means comprises fluid pressure actuated means operatively associated with said vanes for urging said vanes into fluid sealing relation with respect to both the inner wall of the housing means defining said chamber and the piston means; and including passage means communicating said fluid pressure actuated means to a source of fluid under pressure to permit flow of pressurized fluid to said fluid pressure actuated means.

20. A device as defined in claim 18, wherein said vane-actuating means comprises fluid pressure actuated means operatively associated with said vanes for urging said vanes into fluid sealing relation with respect to both the inner wall of the housing means defining said chamber and the piston means; and including passage means communicating said fluid pressure actuated means to said chamber spaces, respectively, to permit flow of pressurized fluid from said chamber spaces to said fluid pressure actuated means.

21. A device as defined in claim 18, wherein said vane-actuating means comprises mounting means outwardly movably mounting said vanes with respect to said piston means in a manner responsive to centrifugal force caused by relative rotation thereof with respect to said supporting means rotatively supporting said piston means for causing the outward urging of said vanes into fluid-sealing relation with respect to the adjacent wall of said housing means defining said chamber.

22. A device as defined in claim 18, wherein said vane-actuating means comprises biasing means normally biasing said vanes into extended relationship effectively sealingly engaged between corresponding portions of said piston means and the wall of said housing means defining said chamber.

23. A device as defined in claim 4, wherein said vanes are effectively interconnected between corresponding portions of said piston means and said housing means in a lost-motion manner permitting the relative circular point-for-point relative circular displacement of corresponding parts of said piston means and said housing means during said substantially simultaneous relative rotation in said first direction of said housing means and said piston means around said axis of operation of said supporting means and said simultaneous relative rotation in said second opposite direction of at least one of said housing and piston axes of said supporting means around said axis of operation of said supporting means and relative to said housing means and said piston means.

24. A device as defined in claim 20, wherein said fluid pressure actuated means for each of said vanes comprises cylinder means in said piston means opening to the lower edge of the respective vane, plunger means movable in said cylinder means and engaging the inner edge of the respective vane, said passage means communicating the several cylinder means in said piston means to the adjacent chamber spaces.

25. A device as defined in claim 20, wherein said fluid pressure actuated means for each of said vanes comprises a pair of cylinders adjacent to the ends and opening toward the inner edge of the respective vane, and plungers movable in said cylinders and engaging the inner edge of the respective vane, said passage means communicating the several cylinder means in said piston means to the adjacent chamber spaces.

26. A device as defined in claim 4, wherein each vane is outwardly extendably carried by said piston means toward a corresponding inner wall portion of the housing mans defining said chamber for sealing engagement therewith and has an effective groove in its outer chamber wall engaging edge, each such outer vane groove being provided with passage means communicating said vane groove to a reduced-pressure region.

27. In a radial chamber fluid power device, the provision of: a hollow housing means defining an interior chamber; and a piston means mounted within the housing means and having at least certain portions spaced from the housing means wall and provided with outwardly directed vanes sealingly carried by the piston and sealingly engaging corresponding portions of the housing means wall, each vane having an effective groove in its outer housing means wall engaging edge, each such outer vane groove being provided with passage means communicating said vane groove to a reduced-pressure region.

28. In a radial chamber fluid power device, the provision of: a hollow housing means defining an interior chamber; and a piston means mounted within the housing means and having at least certain portion spaced from the housing means wall and provided with outwardly directed vanes sealingly carried by the piston and sealingly engaging corresponding portions of the housing means wall; and means for venting the region between the outer edge of each such vane and the corresponding portion of the housing means wall defining said chamber to a low-pressure region.

29. A device as defined in claim 18, wherein said vane-actuating means comprises fluid pressure actuated means operatively associated with said vanes for urging said vanes into fluid sealing relation with respect to both the inner wall of the housing means defining said chamber and the piston means; and including means for venting the region between the outer edge of each such vane and the corresponding portion of the housing means wall defining said chamber to a low-pressure region.