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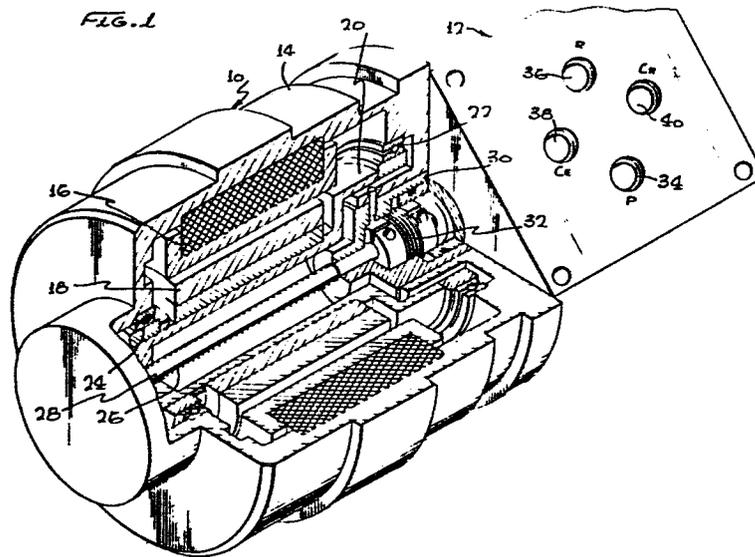
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54 **Direct drive servo valve.**

57 A direct drive servo valve includes a rotary torque motor (10) having an output shaft (28) connected to a spool member (42) forming part of a hydraulic control valve. The valve further includes a housing (12) having conduits (34, 36, 38, 40) connected to high (34) and low (36) pressure sides of a fluid pressure source and to opposite sides (38, 40) of an actuator. A sleeve (44a, 171) in the housing (12) includes a plurality of passageways (74, 78, 174, 176) connecting the conduits with channels in the sleeve (44a, 171) to direct the working fluid as required to cause the associated actuator to move in a desired direction. The sleeve (44a, 171) is formed of a plurality of disks (60, 60', 62, 64, 66) having the desired internal patterns such that when they are assembled, brazed together, and machined to the desired dimensions, the passages are formed with openings as required. A torque tube (26) fastened between the shaft (28) and the sleeve housing (12) acts as a centering spring and seals operating fluid from the motor windings (16).

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This invention relates to a direct drive servo valve.

A direct drive servo valve includes a housing containing conduits connecting fluid from a high pressure source to and from a hydraulic actuator and includes a sleeve in the housing including passageways connected to the various conduits and a
5 spool member movable to interconnect the passageways as desired to control the flow of operating fluid to the actuator, with motor means being employed to drive the spool.

The usual servo valve for controlling hydraulic actuators includes a spool valve movable linearly to direct fluid to one side or the other of an actuating piston while
10 permitting flow from the opposite side to a return or low pressure source. The spool member may be movable manually or it may be controlled by means of an electrohydraulic torque motor which receives electrical control signals from a control system. One disadvantage of such a system is that the electrohydraulic torque motor, since it includes a pair of fluid jets with a flapper member movable to
15 open one jet and partially close the other, constantly leaks a certain amount of operating fluid and thus imposes a load on the pumping system. Another disadvantage is that such a torque motor drives a spool valve which is connected to both its input signal source and its output through a series of fluid conduits. This usually requires that the system incorporate at least a direct mechanical position feedback
20 means and perhaps an electrical feedback to the torque motor as well. For a number of applications it would be advantageous if the electrical motor could drive the servo valve directly to avoid such a "floating" spool valve. And since the torque motor inherently has a rotary output but the desired servo valve output is linear, the rotary motion of the torque motor armature must be converted to a linear motion,
25 accomplished by the jet and flapper structure discussed above which varies the fluid pressure on opposite ends of the spool valve to cause it to move linearly.

The direct drive servo valve of the invention utilizes a rotary torque motor having a limited displacement which operates through an output shaft to directly
30 drive the spool of a rotary servo valve. A torque tube is sealed at one end to the output shaft and at its opposite end to either the sleeve or housing and thereby provides the dual functions of sealing operating fluid away from the motor windings and of acting as a return spring to center the output shaft and spool in the desired null position. The rotatable valve structure consists of a housing containing a sleeve made up of a number of annular disks having various patterns of flow passages
35 therethrough, which disks are carefully arranged, radially aligned and brazed together with endcaps, and the assembly then machined to the desired diameter to expose the desired passageways which are aligned with conduits in the housing. The spool member is machined to the desired diameter to fit in the center of the sleeve

and includes a series of channels which are rotated by the torque motor to provide the desired interconnections among the sleeve passageways.

One advantage resulting from the invention is that the direct drive rotary valve arrangement eliminates the necessity of converting the torque motor rotary
5 motion to linear motion.

Another advantage is that the rotary arrangement facilitates pressure-balancing of the spool in that the spool can be made symmetrical with fluid pressure forces acting on opposite sides simultaneously to reduce the required operating forces.

10 A further advantage of the present invention is that the torque tube is utilized not only as a seal but also as a centering spring to assure that the spool returns to null position with electrical power off.

A further advantage is that the leakage of operating fluid referred to above is eliminated.

15 A still further advantage is that the direct drive valve, although having rather complicated patterns of passageways in its sleeve structure, is amenable to production through the use of stacked disks having various patterns of cutouts made with electrical discharge milling (EDM) techniques or photo-etching techniques.

20 Other objects and advantages will become apparent from the following specification taken in connection with the accompanying drawings in which:

Figure 1 is a perspective drawing, partially in section, of the torque motor portion of my direct drive valve;

Figure 1A is a perspective drawing, partially in section, of a valve structure operated by the torque motor of Figure 1.

25 Figure 2 is a plan view showing the manner in which a number of disks are assembled to form the sleeve used in one embodiment of our invention;

Figure 3 is an end view of the assembly shown in Figure 2;

Figure 4 is a plan view of one of the end blocks shown in Figures 2 and 3;

Figure 5 is a side view of the end block of Figure 4;

30 Figures 6, 7, 8, 9 and 10 are plan views of disks shown in Figure 2;

Figure 11 is a sectional view of a sleeve used in one embodiment of our invention and formed from the disks and end blocks described in Figures 4 through 10;

Figure 12 is an end view of the sleeve of Figure 11;

35 Figure 13 is a side view of a spool member usable with the sleeve of Figures 11 and 12;

Figure 14 is a sectional view taken along lines 14-14 of Figure 13;

Figure 15 is a sectional view taken along lines 15-15 of Figure 13;

Figure 16 is a sectional view of an assembly including the sleeve of Figure 11 located in its housing and also the spool of Figure 13;

Figure 17 is a sectional view taken along line 17-17 of Figure 16;

Figure 18 is a sectional view taken along line 18-18 of Figure 16;

5 Figure 19 is a side view of an assembly of disks used in a second embodiment of our invention;

Figure 20 is an end view of the assembly of Figure 19;

Figures 21, 22, 23 and 24 are plan views of disk configuration used in the assembly of Figures 19 and 20;

10 Figure 25 is a sectional view of a finished sleeve formed from the assembly of Figures 19 and 20;

Figure 26 is a side view of a spool assembly adapted to be installed in the sleeve of Figure 25;

Figure 27 is a sectional view taken along line 27-27 of Figure 26;

15 Figure 28 is a top view of the spool of Figure 26;

Figure 29 is a sectional view taken along line 29-29 of Figure 28;

Figure 30 is a sectional view of an assembly including the sleeve of Figure 25 and the spool of Figures 26-29;

Figure 31 is a sectional view taken along line 31-31 of Figure 30; and

20 Figure 32 is a sectional view taken along line 32-32 of Figure 30.

Referring now to Figure 1, it will be seen that this is a perspective drawing, partially in section, showing our direct drive valve assembly including the torque motor 10 which drives a spool in the mechanical housing assembly 12. The torque motor includes a housing 14 containing electrical windings 16, a magnet structure 18, and a rotatable armature member 20 which is supported in the housing in bearings 22 and 24. At its left end armature 20 is sealed to a torque tube 26 which, in turn, is sealed to an output shaft 28. The opposite end of torque tube 26 is sealed to a member 30 which is pinned or otherwise secured to the housing 14. Member 30 may be, and preferably is, a part of the torque tube. With this arrangement, it will be understood that when the windings 16 are energized the armature 20 will rotate over a small arc, carrying the output shaft and the left end of torque tube 26 while the right end of torque tube 26 is securely held to member 30. Output shaft 28 is secured to a flexible coupling member 32 which, in turn, is secured to the rotatable spool in housing 12. It will be observed that housing 12 includes a plurality of ports, port 34 being connected to a source of operating fluid under high pressure (P), port 36 being connected to the return side of said source (R), port 38 being connected to supply pressure to drive an associated actuator in one direction such as to extend it

(C_E) and port 40 being connected to the opposite side of said actuator to drive it in the opposite direction such as to retract it (C_R).

Figure 1a constitutes an extension of the sectional structure of Figure 1 in that the output shaft 28 is shown connected to the flexible coupling 32 which, in turn, is connected to a spool member 42 rotatable within a sleeve 44 shown in parts 5 in this particular schematic presentation. In the view pictured, it is shown that operating fluid under high pressure enters the sleeve through an opening 46 where it finds a flow path along a channel in the spool 42 permitting it to reach a radial slot 48 in the sleeve 44 communicating with return pressure (C_R) at port 40 (Figure 1). 10 Flow directed to port 40 will also flow along the sleeve toward a port 50, but this port is blocked. At the same time the spool will be in a position to open a port 52 which permits flow from the actuator (C_E) to the return port 36 (R). Again, the flow from the extend side of the actuator C_E flows along the spool to a port 54 but flows no farther because this port is blocked by the spool 42. This, of course, is only one of the patterns of flow through this valve, and others will be discussed below.

Figures 2 and 3 depict the arrangement of parts making up a typical sleeve assembly for our direct drive valve, Figure 2 being a side view showing endcaps 56 and 58 and a plurality of stacked disk members 60, 62, 64, 66, 64, 62, and 60'. Figure 3 is an end view of the assembly shown in Figure 2, showing the endcap member 56 as well as a tab 60a forming part of disk 60 as will appear hereafter. 20 Also visible in this view is tab 64a forming part of disk 64, but similar tabs aligned with 64a are behind it forming parts of disks 62 and 60' appearing near the right end of the assembly of Figure 2. The center bores of these tabs are drilled slightly off-center so as to produce this desired misalignment when the disks are assembled to indicate which disks are reversed. 25

Figures 4 and 5 are plan and side views, respectively, of the end blocks of the assembly shown in Figure 2. It will be seen that these are simple annular structures with a flat at the top as shown in Figure 3.

Figure 6 is an enlarged plan view of disk 60 shown in Figure 2 which includes 30 tab 60a at the top with a center bore located slightly off center of the tab but centered on a radius of the disk 60. This view of disk 60 shows a center bore 68 communicating with opposite radial passages or openings 70 and 72 and also with a plurality of openings 74, 76, 78 and 80 which are located at 0°, 90°, 180°, and 270°, respectively, with 0° being chosen as the top position. Openings 74 and 78 are larger than openings 76 and 80 and extend farther toward the outside of the disk. When the disk is ultimately trimmed to its final dimensions, each of openings 74 and 78 will provide openings from the outside of the sleeve to the center of the sleeve assembly. Figure 7 is a disk of essentially the same configuration as Figure 6, but

with one significant exception in that disk 60' includes a tab 60'a which is displaced 90° from tab 60a relative to the rest of the openings in the disk. Thus, tab 60'a is positioned at approximately 90° or in alignment with opening 76'.

From the foregoing, it will be clear that when disk 60' is placed in the stack of Figure 2 in the position shown, with the tab 60'a at the top, one significant difference becomes apparent. The larger openings 74' and 78' are now at the 90° and 270° positions so that this is where the exterior openings will appear when the sleeve is trimmed to its desired dimensions. The elongated large area slots 70' and 72' will also rotate 90° to the 135° - 315° positions.

Figure 8 is a plan view of the two disks indicated at number 62 in Figure 2. It has a tab 62a at the top which is also slightly out of alignment with the center of the disk. This disk has a plurality of large area openings 86, 88, 90 and 92, none of which are designed to open to the outside surface when the sleeve is trimmed. When an identical copy of this disk is reversed, but with the tab still at the top, the reversed disk is aligned with disk 64a (see Figure 3). Reversing of this disk will place the elongated large area slots 82 and 84 at the 135° - 315° positions (as measured with 0° at the top) rather than at the 45° - 225° positions. Figure 9 is a plan view of a disk 64 which is quite similar to disk 62 except for the elongated large area slots 94 and 96 which are oriented similarly to slots 82 and 84. These slots which extend a greater distance toward the periphery of the disk than slots 82 and 84 include outwardly extending radii which will remain when the sleeve is trimmed to approximately the radius of the dashed line to create openings into the center. These disks 64 are located in two positions on the assembly of Figure 2 with the disk toward the right being reversed from the position shown so that the large area slots 94 and 96 are also reversed.

The single disk 66 is shown on Figure 10. In addition to the center opening 98, it has openings 100, 102, 104 and 106 which align axially at 0°, 90°, 180°, and 270° with similar openings in the other disks described above but none of which provide an opening to the outside when the sleeve is trimmed, nor do any of these openings communicate with the center sleeve opening 98.

The composite of the disks described above stacked and brazed together as shown in Figure 2 is then machined to produce the sleeve 44a shown in Figure 11, which is a vertical section through the sleeve. In this view, the vertical openings 74 and 78 at the position of disk 60 (Figures 2 and 6) are visible, which openings provide passageways communicating with actuator port C_E (part 38, Figure 1). The small slot 107 communicating opening 80 with the internal spool chamber 109 is also visible. The openings to actuator port C_R (part 40, Figure 1) at the right end of the sleeve 44a are at 90° with respect to this section and thus not visible, but openings

to the center spool chamber 109 are visible. The openings at top and bottom of the disks described above appear in this sleeve as elongated axial passageways 108 and 110. Visible in the wall of the center spool chamber 109 are a first elongated slot 112 resulting from the elongated large area openings of disks 60, 62 and 64 and a second such slot 114 resulting from the large area elongated openings in reversed disks 60', 62 and 64.

Figure 12 is an end view of the sleeve structure shown in Figure 11, showing the central spool chamber 109 and a large diameter flange 116 appearing at the right end of Figure 11 which assists in securing the sleeve to the housing. A small port 118 communicates operating fluid at return pressure with chamber 120 at the end of the sleeve. System pressure (C_p) or operating pressure C_E is contained by means of lap-fitting of the spool to the sleeve; therefore, there is some leakage across the spool which will tend to increase the fluid pressure acting on the end of the spool and make operation more difficult. To prevent this pressure build-up, port 118 permits any such increased pressure to be drained to return pressure.

Figure 13 is a side view of a spool 121 which is rotatable in sleeve 44a. This spool carries lands 122, 124, and 126. Land 124 contains grooves to assist in balancing the pressures P and R on the spool. Land 122 contains channels 128 which can be oriented to connect control pressures C_E and C_R to return pressure R. Similarly, land 126 contains channels 130 which can be moved to connect control pressure C_R and C_E to system pressure P. These channels are shown in Figures 14 and 15 which are cross-sectional views through lines 14-14 and 15-15 of Figure 13, respectively. It will be observed that each channel has sides which are only slightly displaced from radii and parallel thereto, and these slots are movable to communicate with the small passageways shown at the 0°, 90°, 180°, and 270° positions on disks 60 and 60'. Channels 128 are always in communication with the large elongated slots 112 (Figure 11), and channels 130 are always in communication with slots 114.

Figure 16 is a sectional view of the sleeve 44a and the spool 121 described above assembled together in a housing 12. Housing 12 includes conduits 132, 134, 136 and 138 connected with control pressure C_E , system pressure R, system return pressure P, and control pressure C_R , respectively. Figure 17 is a sectional view taken along line 17-17 of Figure 16. This view shows a section through the spool at the channels 128 in combination with the sleeve at the location of disk 60. From this view it will be seen that channels 128 are aligned with large diagonal openings 70 and 72 but are not aligned with the passageways leading to the spool 121 from openings 74, 76, 78, and 80. Rotation of spool 121 a small amount in a counterclockwise direction will cause the large diagonal openings 70 and 72 to

communicate through channels 128 with openings 74 and 78, respectively. Since channel 128 communicates with return pressure R (see Figures 9 and 13), rotation of the spool as described results in flow decreasing control pressure C_E in conduit 132.

Referring to Figure 18, rotation of the spool 121 in the same counterclockwise direction results in connecting large diagonal openings 70' and 72' with openings 74' and 78' which connect with the controlled pressure C_R conduit 138. Since the large diagonal openings connect with system supply pressure P (Figures 9 and 13), the operating fluid in passage 138 is increased to supply pressure through conduit 136. Thus, movement of the spool in a counterclockwise direction will result in moving the actuator in a first direction which, in the case of a conventional piston in a cylinder connected to an actuating rod, may be such as to retract the actuating rod.

Rotation of the spool 121 in the clockwise direction permits flow to the large diagonal openings 70 and 72 (Figure 17) from openings 76 and 80, respectively, which are part of elongated passageways running the length of the sleeve terminating at openings 78' and 74', respectively, and which thereby exhausts pressure C_R from conduit 138 to return pressure conduit 134 (C_R). At the same time, clockwise movement of spool 121 at the opposite end of the sleeve (Figure 18) results in a connecting diagonal opening 72' with opening 80' and diagonal opening 70' with opening 76'. Since diagonals 70' and 72' are connected to conduit 136 carrying system supply pressure P, this effectively connects control pressure C_E conduit 132 with supply pressure conduit 136. Thus, rotation of the spool 121 in a clockwise direction results in moving the actuator in a second direction which, in the case of the above described piston in a cylinder, would be such as to extend the actuating rod.

A somewhat different embodiment of my invention is discussed below. In this embodiment, operation is essentially the same as that discussed above, but the details of the spool and sleeve are different. Figure 19 is an assembly of disks somewhat similar to Figure 2 described above with Figure 20 being an end view of this assembly. The end blocks 56' and 58' are, or may be, identical to end blocks 56 and 58 of Figure 2. The disks immediately adjacent end blocks 56' and 58' are shown on Figure 21 at numeral 144. One disk 144 is installed with its tab 144a at the top of the left end of the sleeve assembly, and another such disk is installed reversed adjacent end block 58'. Each of disks 144 has openings 143 and 145 diagonally across its center bore and a small bore 178 just above the center opening. The next disks toward the center are shown on Figures 22 and 23. Disk 146' of Figure 23 is almost identical to disk 146 of Figure 22 except that the disk 146' includes a tab 146'a which is rotated 90° counterclockwise as compared with the tab 146a of disk 146. Disk 146 includes a center bore 148 in which a spool is received. Opening into

center bore 148 are a plurality of slots communicating with openings 150, 152, 154, and 156, all of which form parts of passageways within the completed sleeve. Also opening into center bore 148 are elongated slots 158 and 160 which extend radially a greater distance from the center than the above described openings. When the sleeve assembly is machined to the final dimensions, slots 158 and 160 become exterior openings into the sleeve.

The center disk 162 is shown in Figure 24. This disk has openings 164, 166, 168, and 170 corresponding to openings 150, 152, 154, and 156, respectively, in Figure 22, but with no openings into the center bore.

The above described disks are brazed together as described above and the entire sleeve assembly 171 machined to the configuration shown in the sectional drawing, Figure 25, which shows the internal bore 172, the vertical radial passageways resulting from slots 158 and 160 (Figure 22) and the opening to the horizontal passageway 160' appearing in disk 146' and also the adjacent slots communicating with chambers 152' and 154'. In this view the elongated passageways 174 and 176 show in dotted outline. Passageway 174 is formed from opening 145 in disk 144 (Figure 21), opening 156 in disk 146 (Figure 22), opening 170 in disk 162 (Figure 24), and opening 154' in disk 146' (Figure 23). Similarly, the elongated passageway 176 is formed from opening 154 in disk 146, 168 in disk 162, 152' in disk 146', and 143 in the reversed disk 144 at the right end of the sleeve. This view also shows a small diameter bore 178 extending from the left end of the sleeve through the end block member 56' and through disk 144 which communicates with slot 158. At the opposite end of the sleeve 171 is a similar small diameter bore which is drilled through the reversed disk 144 but which is not utilized.

Figure 26 is a side view showing the spool 180 which cooperates with the sleeve 171. On this view a port is shown consisting of a rectangular opening 182 adjacent a circular bore 184, which openings are connected by means of a short slot all extending through the spool as shown on Figure 27, which is a cross-sectional view taken along line 27-27 of Figure 26, and Figure 28 which is a top view of spool 180. In Figure 28 an additional port is shown rotated 90° from openings 182 and 184, which port is also formed of a rectangular opening 186 and a bore 188 connected by a small slot. Figure 29 is a cross-sectional view along lines 29-29 of Figure 28 and shows opening 186 extending across the width of the spool 180. The compound port arrangement provides a means for controlling flow with great precision, particularly at the point of opening, since the bore is just slightly larger in diameter than the width of the rectangular opening; therefore, the initial valve opening is through an edge of the bore which can be lapped to very close tolerances to provide the desired initial flow pattern. A plurality of unnumbered longitudinal slots are shown in

Figures 26 through 29 whose function is to assist in pressure balancing of the spool, as will be understood by those skilled in the art.

Figure 30 is a cross-sectional view showing the spool 180 installed in the sleeve 171, both of which are installed in a housing 12'. This housing is the same as housing 12. In this drawing the system pressure conduit P is shown at numeral 190, the system return pressure R is carried in conduit 192, controlled pressure C_E to one side of the actuator at conduit 194 and controlled pressure C_R to the other side of the actuator at conduit 196. Each of conduits 190, 192, 194, and 196 communicates with an annulus surrounding sleeve 171. In this view, which is a vertical section through the sleeve 171, it will be seen that return pressure conduit 192 is directly connected with the spool 180. Figure 31 is a cross-sectional view taken along line 31-31 of Figure 30 and shows the elongated slots 158 and 160 (Figure 22) which communicate with spool 180 and the port 188 extending through the spool. With the spool in the position shown, there is flow across the spool through port 188 but no flow from any of the openings 150, 152, 154 or 156 (Figure 22) which form part of the elongated passages 174, 175, 176, or 177. Figure 32 is a cross-sectional view taken along line 32-32 of Figure 30. Fluid at system pressure P is connected through conduit 190 to an annulus 198 which surrounds the sleeve 171 so that this pressure is in communication through radial slots 158' and 160' with spool 180.

Operation of the assembly of Figure 30 is similar to that described above. Referring to Figures 31 and 32, a small clockwise rotation of spool 180 connects slot 158 to opening 175 and slot 160 to opening 176. This connects conduit 194 (C_E) to return pressure (R). This same rotation causes slot 158' to be connected to opening 177 and slot 160' to opening 174, which causes system pressure (P) in conduit 190 to be connected to conduit 196 (C_R). This results in moving the associated actuator in a given direction which may be the retracted position.

Rotation of the spool 180 in a counterclockwise direction connects slot 160(R) to opening 177 and slot 158 to opening 174 which results in conduit 196 (C_R) being connected to return pressure (R) conduit 192. At the same time, slot 158' (P) is connected to opening 175 and slot 160' is connected to opening 176. This connects control pressure C_E in conduit 196 to system pressure (P) in conduit 190, causing the actuator to be moved in the opposite direction which may be the extended position.

From the foregoing it will be appreciated that the direct drive servo valve described above provides the several advantages enumerated above as compared with the conventional electrohydraulic servo valve. It incorporates a somewhat complex manifold structure in the sleeve, but this structure is readily fabricated through the use of the stacked or assembled disks which are preferably formed either by electrical discharge milling or by photo-etching techniques.

CLAIMS

1. A direct drive rotary servo valve comprising a housing (12) including conduits (134, 136) connected to a source of operating fluid under pressure and to a controlled actuator (132, 138), a sleeve (44, 44a) in said housing including a plurality of passageways (74, 78, 174, 176) therein connected to said conduits (34, 36, 38, 40),
5 a spool member (42) including channels (108, 110) to direct operating fluid as desired among said passageways and motor means (10) operatively connected to drive said spool member,

characterized in that said spool member (42) is rotatable over a limited range of movement, said motor means (10) is a rotatable torque motor having a housing
10 (14), a stator and a rotor (20) in said housing (14), an output shaft (28) is connected to said spool and said rotor (20), a torque tube (26) surrounds said output shaft and is sealed at one end to said rotor (20) and at its opposite end to one of said housing (14) and said sleeve (44, 171),

said sleeve (44, 171) is formed of endcaps (56, 58 and 56', 58') and a plurality
15 of annular disks (60, 60', 62, 64, 66) having axially directed passages therethrough including some disks having edge openings communicating with said conduits (34, 36, 38, 40) and internal openings communicating with said spool member (42), said disks and endcaps being brazed together to form a unitary manifold structure.

2. A direct drive rotary servo valve as claimed in claim 1 wherein said
20 passageways (74, 78, 174, 176) and channels (108, 110) direct operating fluid on opposite sides of said spool member such that said spool member (42) is essentially pressure-balanced during operation.

3. A direct drive servo valve as claimed in claim 1 wherein said torque
25 tube output shaft (28) and said spool member (42) are connected together along an approximate common center line.

4. A direct drive servo valve as claimed in claim 1 wherein said torque
tube output shaft (28) and said spool (42) are connected together through a flexible coupling (32) which is extremely stiff in torsion but which permits a slight angular deflection.

30 5. A direct drive servo valve as claimed in claim 1 wherein said sleeve (44, 171) includes a first passageway near its center connected to said high fluid pressure source (136), a second passageway near its center connected to the return side of said high fluid pressure source (134), and third and fourth passageways near the ends of said sleeve (132, 138) connected to said controlled actuator.

35 6. A direct drive servo valve as claimed in claim 1 wherein said sleeve (44, 171) includes a first pair of channels communicating said first passageway with said third passageway and a second pair of channels communicating said second passageway with said fourth passageway.

7. A direct drive servo valve as claimed in claim 1 wherein said channels in said spool member (121) consist of a first pair of grooves (128) in the surface of said spool near one end thereof whose sidewalls are parallel to and displaced only a small distance from radii 90 degrees apart, said grooves being centered 180 degrees apart and a second pair of similar grooves (130) near the opposite end of said spool displaced 90 degrees apart from said first pair.

8. A direct drive servo valve as claimed in claim 1 wherein said torque tube (26) operates always to center said spool member (42) to block communication between said passage ways in the absence of a signal to said motor.

9. A direct drive servo valve including a housing (12') and ports (34, 36, 38, 40) in said housing connected to a high fluid pressure source (190), a low fluid pressure source (192), a first controlled fluid pressure conduit (194) and a second controlled fluid pressure conduit (196), a sleeve (171) in said housing (12') including conduit means (158, 160, 158', 160') directing operating fluid to the interior of said sleeve (171), a spool member (180) movable in said sleeve (171) including passages (182, 184, 186, 188) to direct the controlled fluid among said ports (34, 36, 38, 40), and torque motor means (10) connected to move said spool (180) in said sleeve (171),

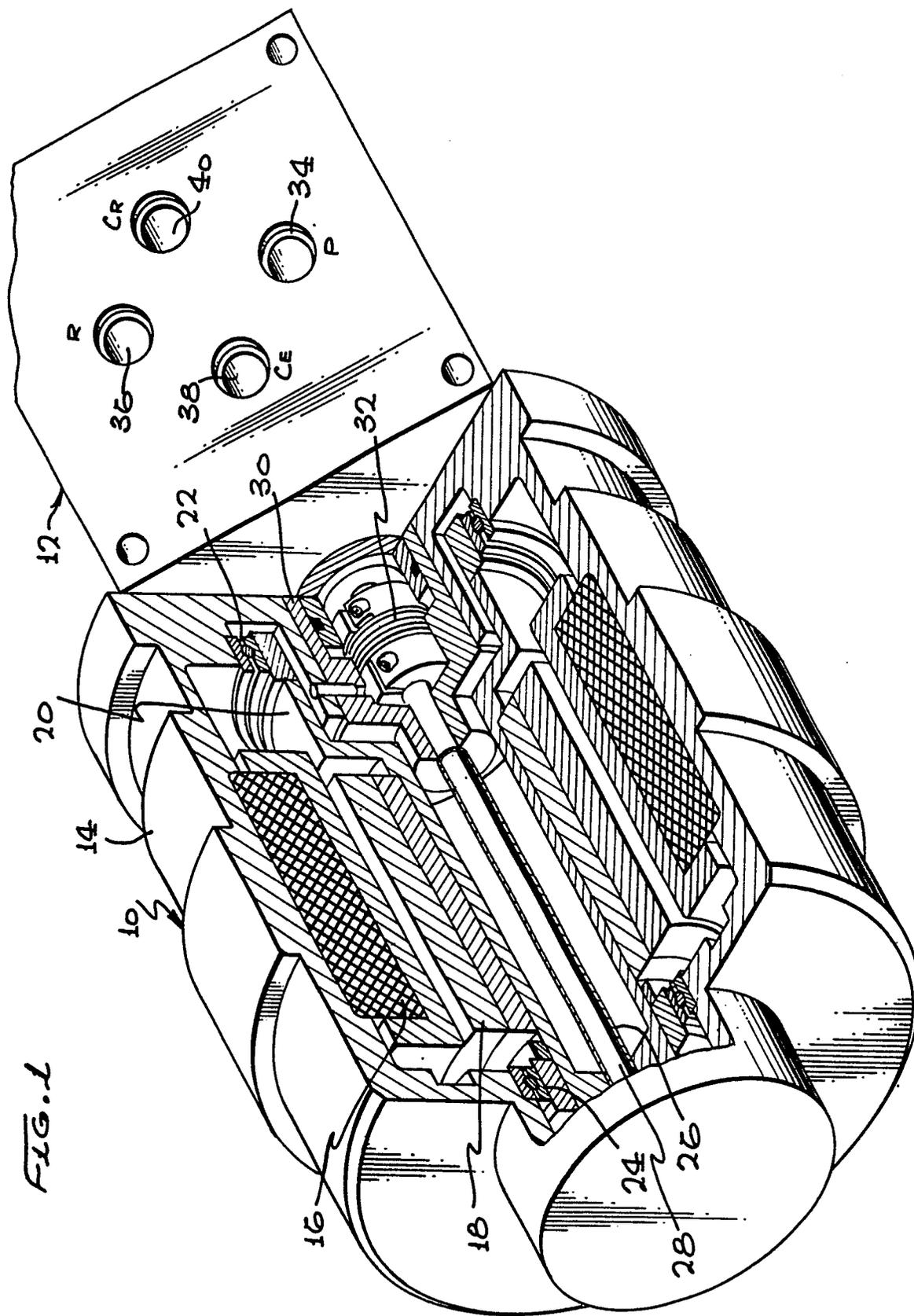
characterized in that each of said ports (34, 36, 38, 40) is connected to an annulus in said housing (12') surrounding said sleeve, said sleeve (171) being formed of a pair of generally disk-shaped end caps (56', 58') and a plurality of perforated disks (144, 146, 146', 162) therebetween, said disks and end caps being brazed together and machined such that said sleeve has a first radially directed passage (158', 160') communicating said high fluid pressure source (190) with said spool (180) and a second radially directed passage (158, 160) connecting said low fluid pressure source (192) with said spool (180), a first axially directed internal passage (174) communicating said first controlled fluid pressure conduit (196) with said spool (180) adjacent said first (158', 160') and second (158, 160) radially directed passages, a second axially directed internal passage (176) communicating said second controlled fluid pressure conduit (194) with said spool (180) adjacent said first (158', 160') and second (158, 160) radially directed passages;

said spool member (180) being rotatable by said torque motor means (10) in a first direction to control communication between said first radially directed passage (158', 160') and said first axially directed internal passage (174) and also between said second radially directed passage (158, 160) and said second axially directed internal passage (176) to direct high fluid pressure to said first controlled fluid pressure conduit (194) and in a second direction to control communication between said first radially directed passage (158', 160') and said second axially directed internal passage (176) and also between said second radially directed passage (158,

160) and said first axially directed internal passage (174) to direct high fluid pressure to said second controlled fluid pressure conduit (196).

5 10. A direct drive servo valve as claimed in claim 9 wherein said spool (180) includes a plurality of metering ports (182, 184, 186, 188), at least one of which controls flow between said high fluid pressure source (190) and one of said axially directed internal passages (174) and another of which controls flow between the other of said axially directed internal passages (176) and said low pressure source (192).

10 11. A direct drive servo valve as claimed in claim 10 wherein each of said metering ports (182, 184, 186, 188) includes a rectangular orifice (182, 186) interconnected with a circular orifice (184, 188), said orifices being sized and located such that the initial opening of said ports occurs between an edge of one of said radially directed passages and an edge of one of said circular orifices.



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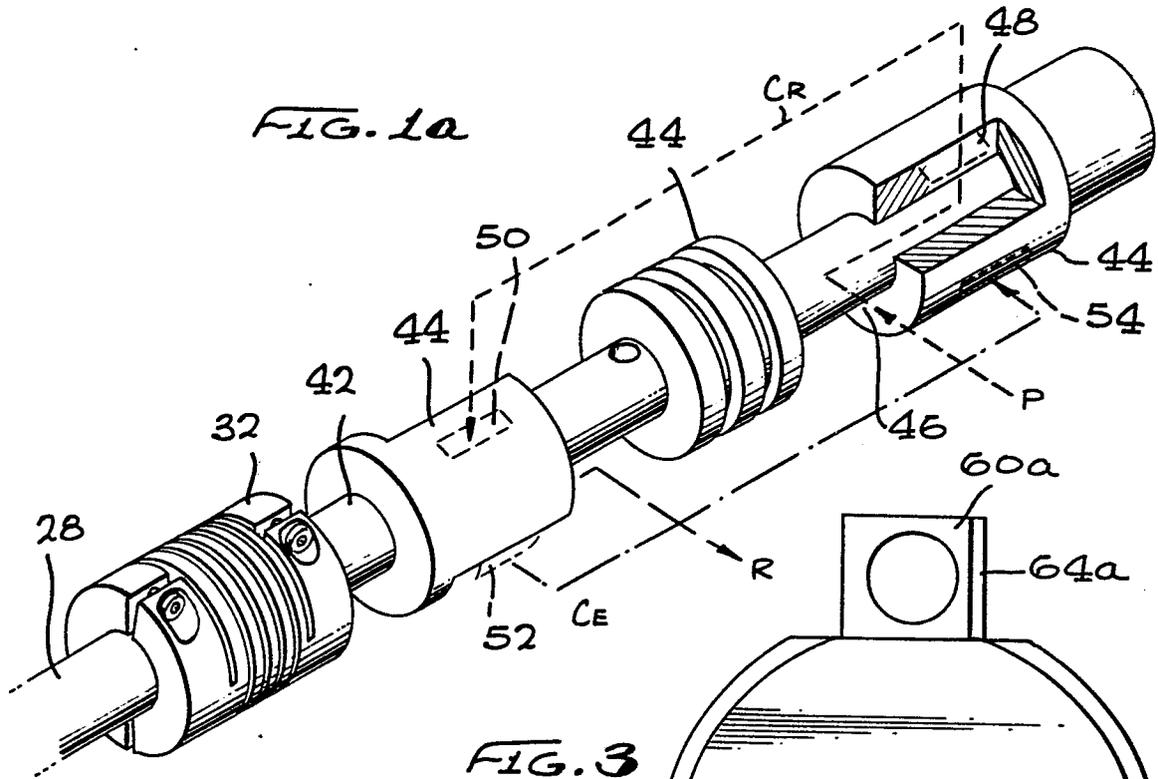


FIG. 3

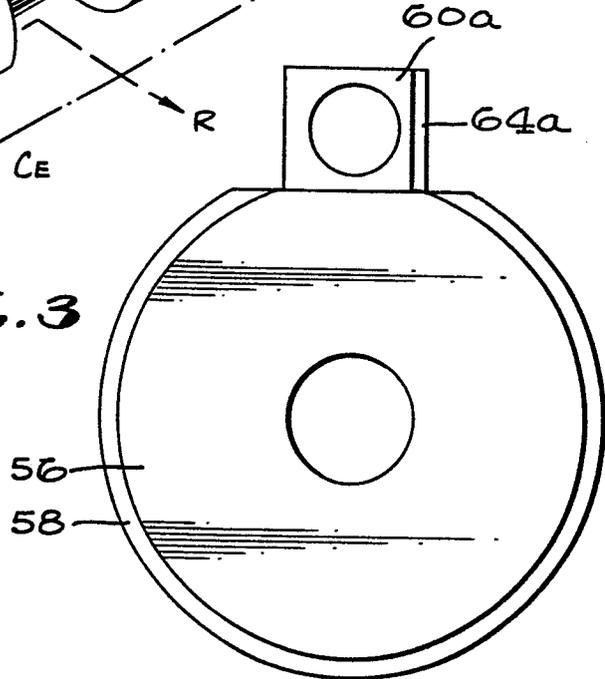


FIG. 2

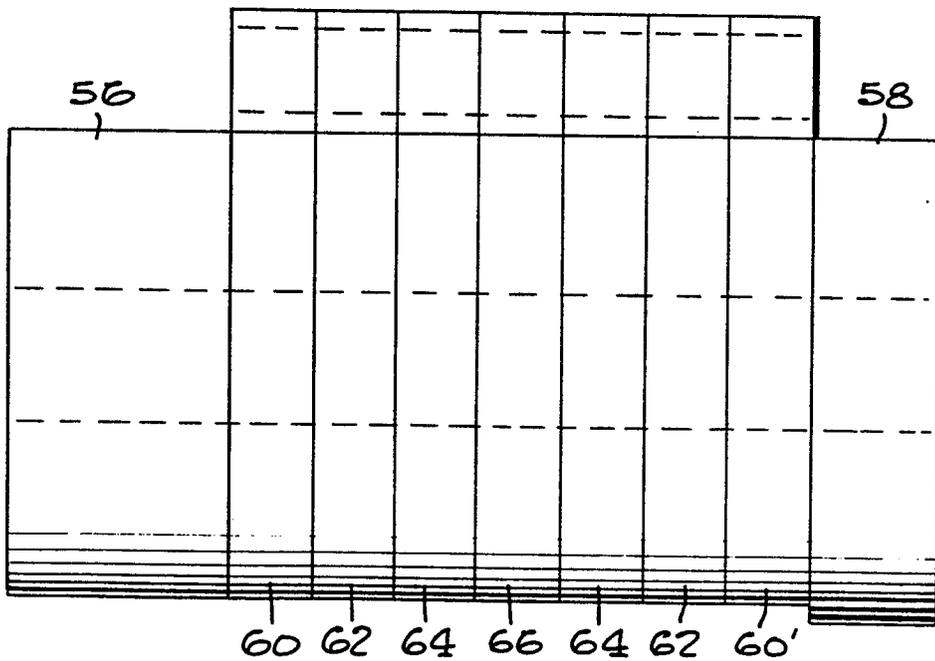


FIG. 4

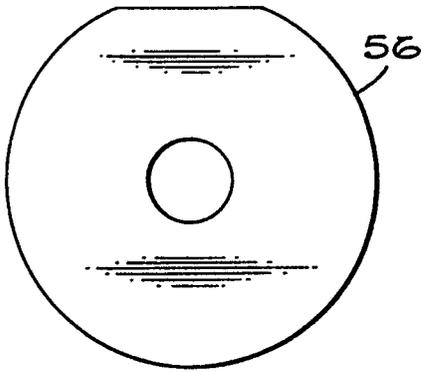


FIG. 5

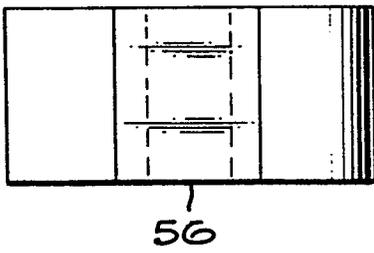
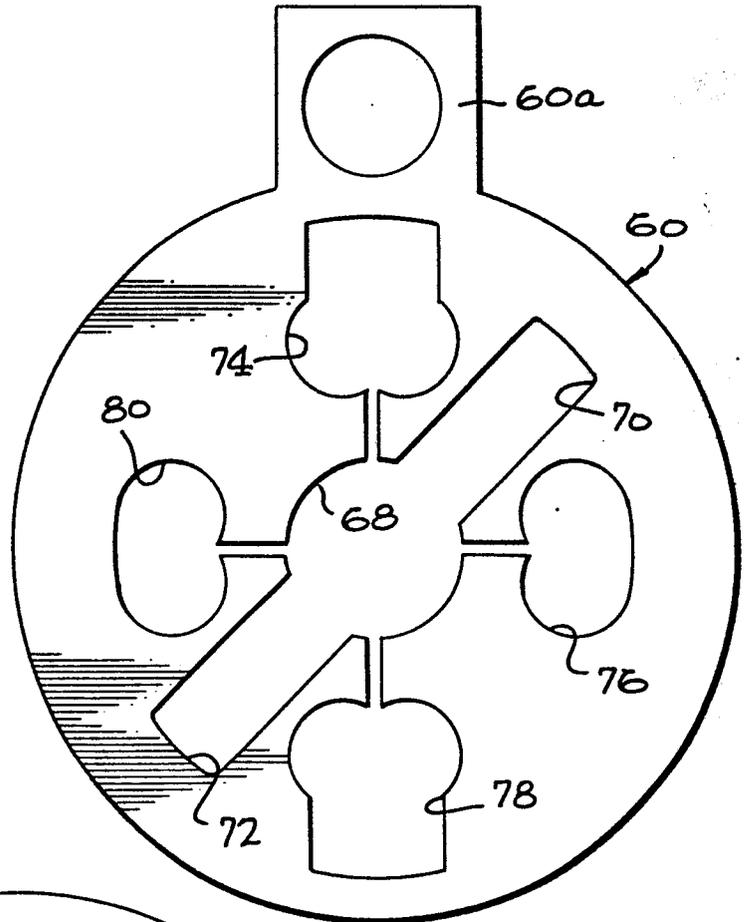


FIG. 6



60'

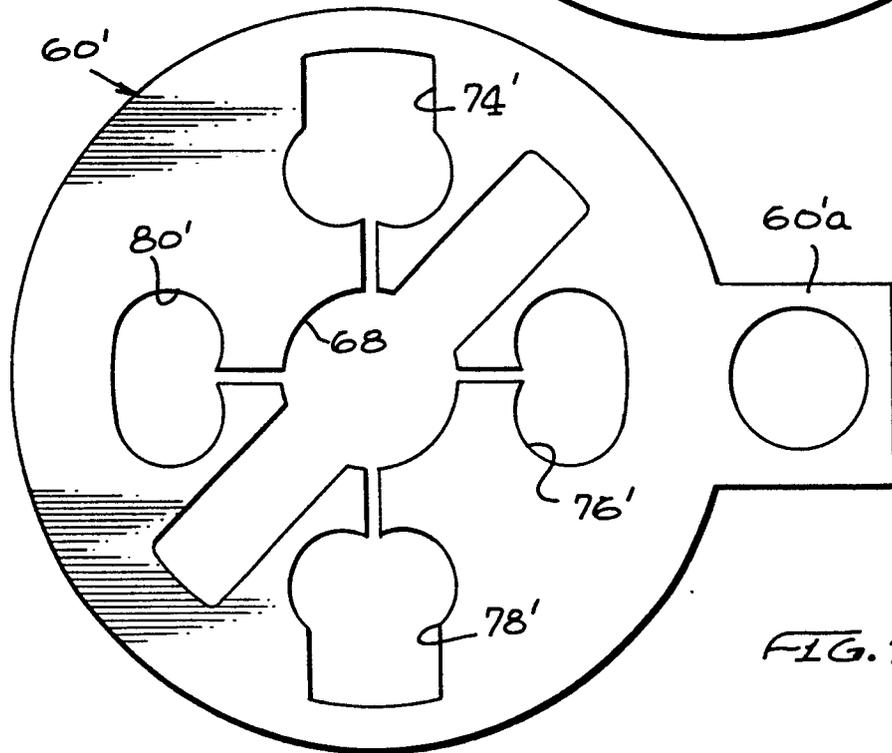


FIG. 7

FIG. 8

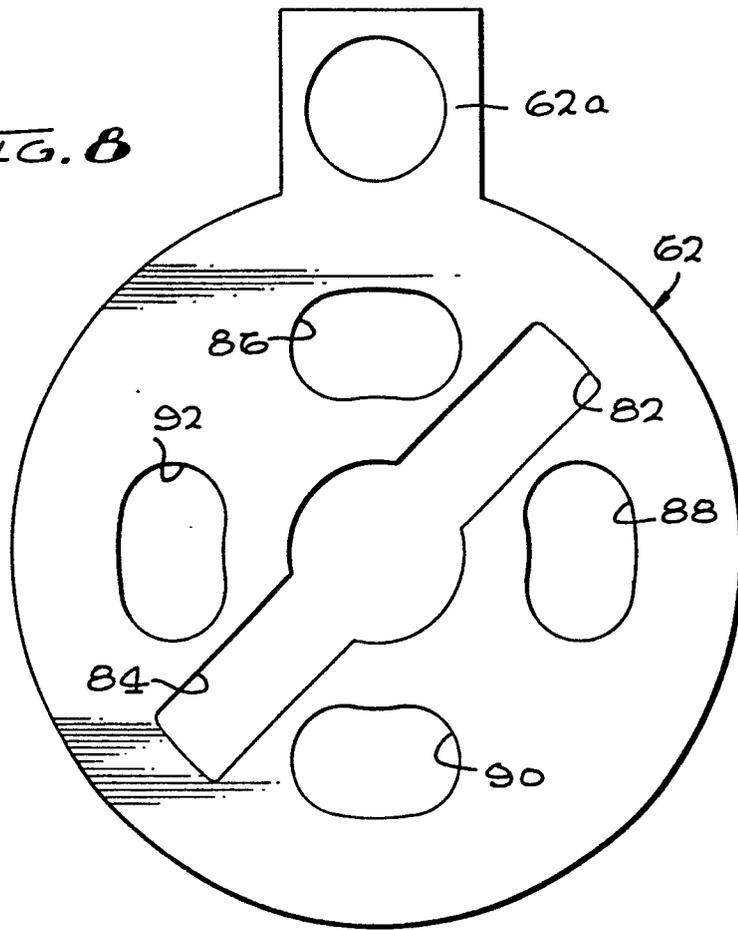
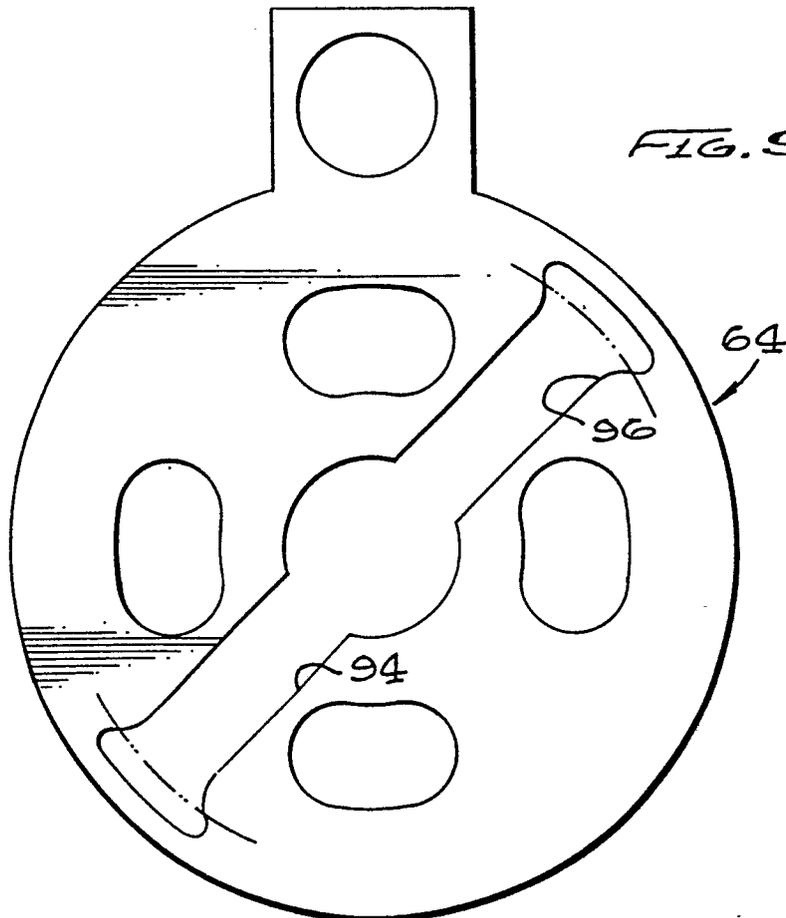


FIG. 9



5 / 11

FIG. 10

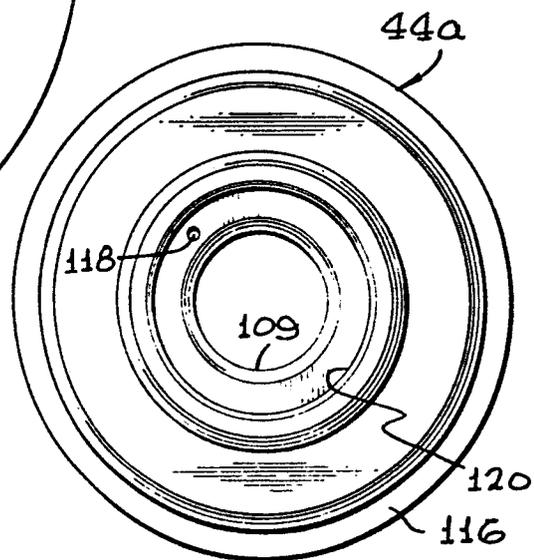
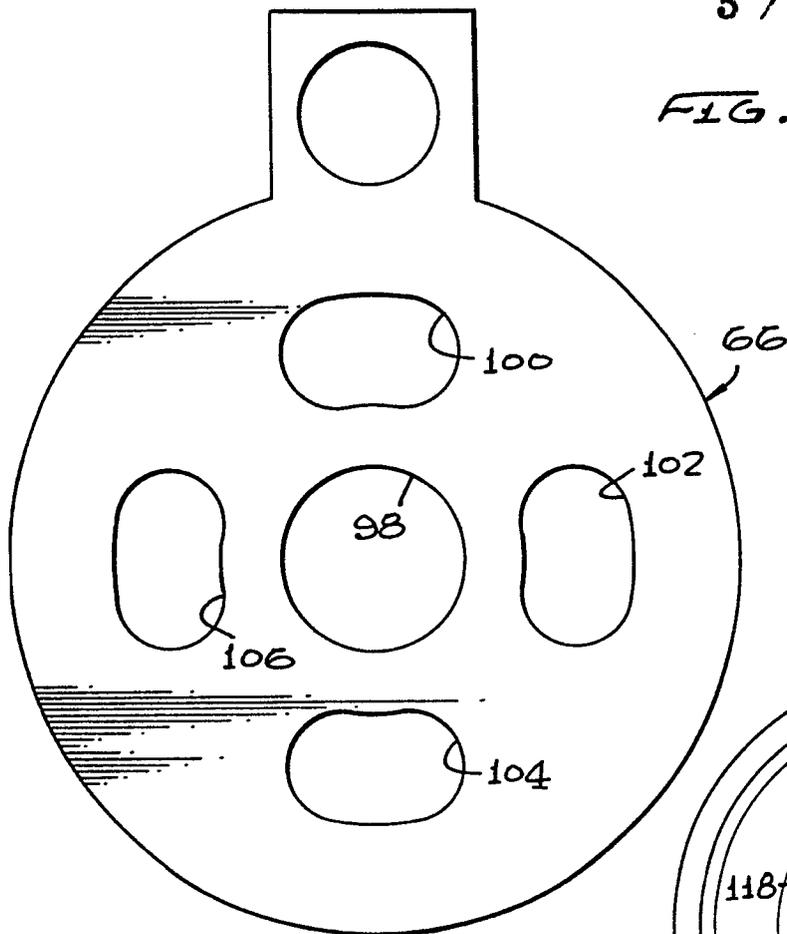
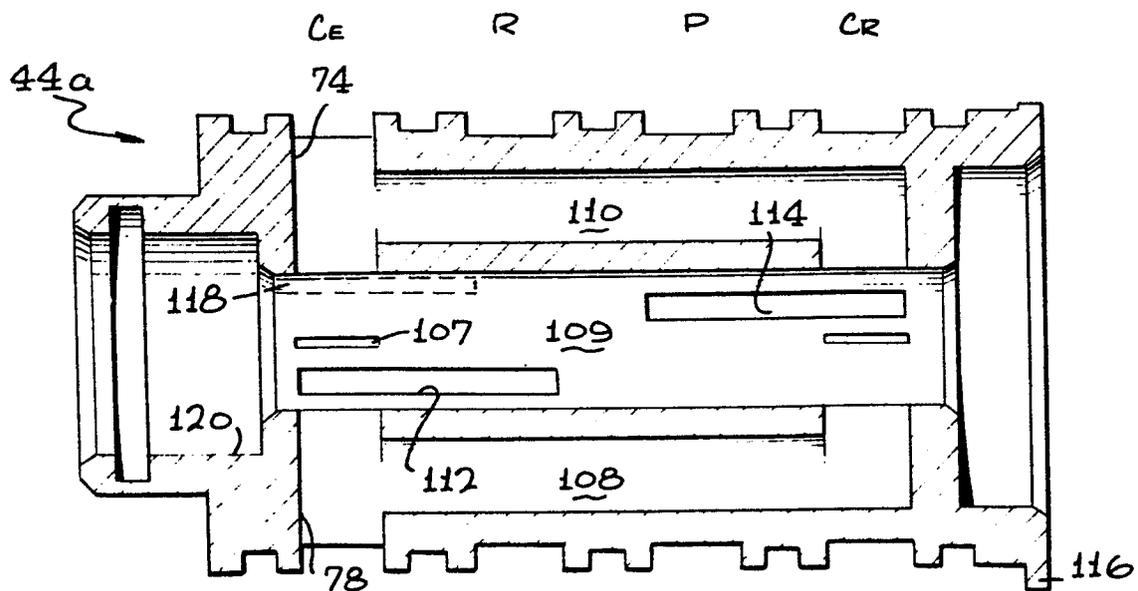


FIG. 11

FIG. 12



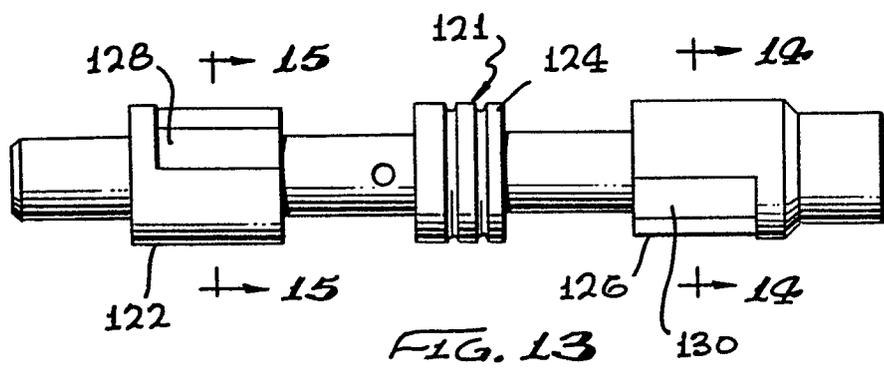


FIG. 14

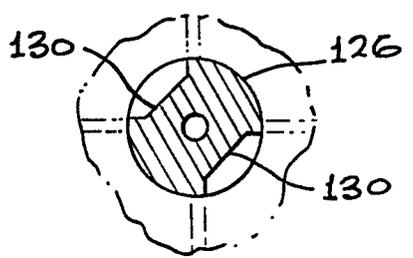


FIG. 15

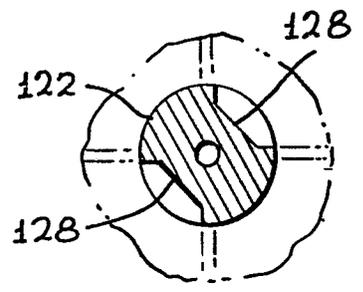
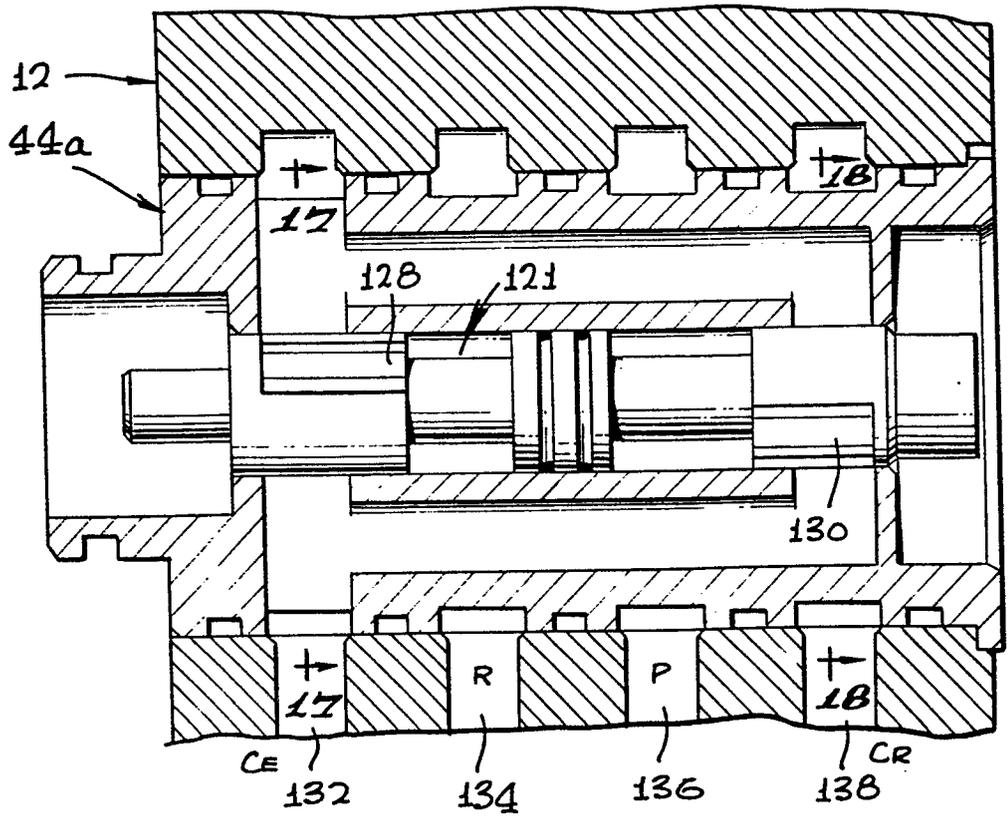


FIG. 16



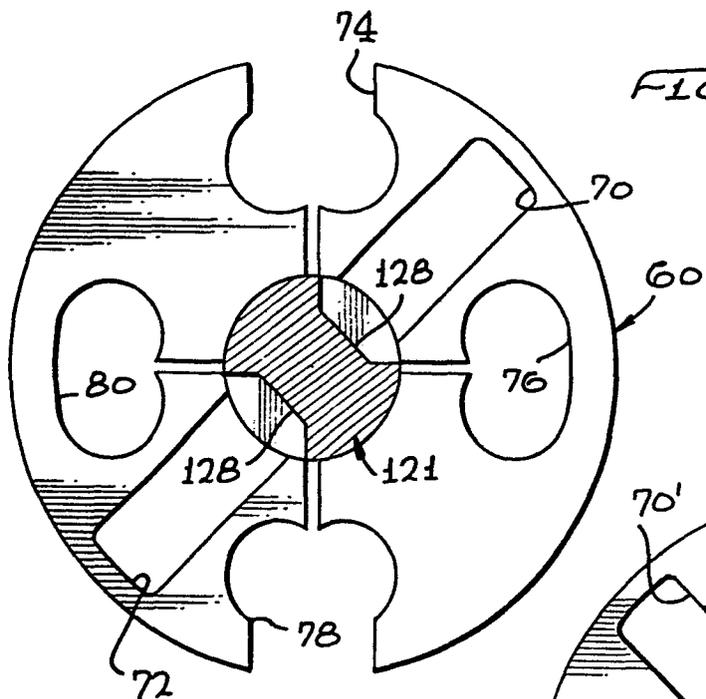


FIG. 17

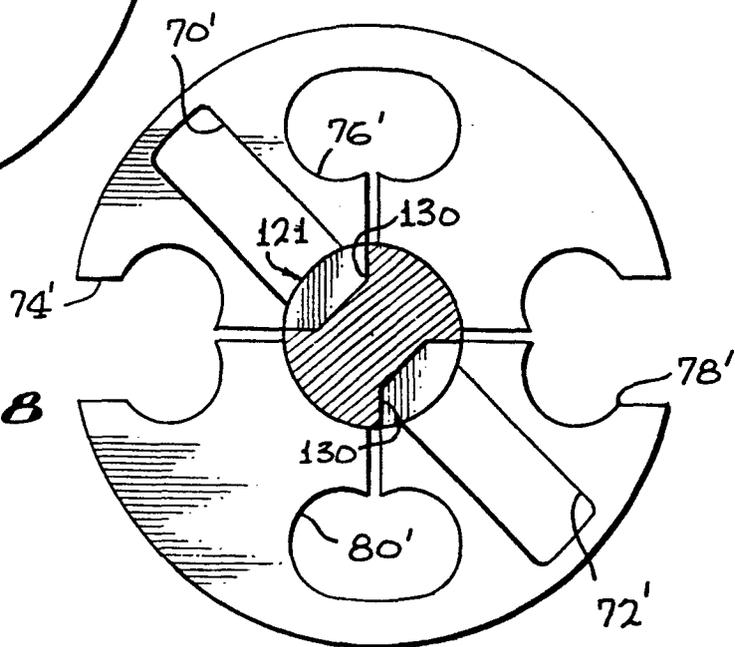


FIG. 18

FIG. 19

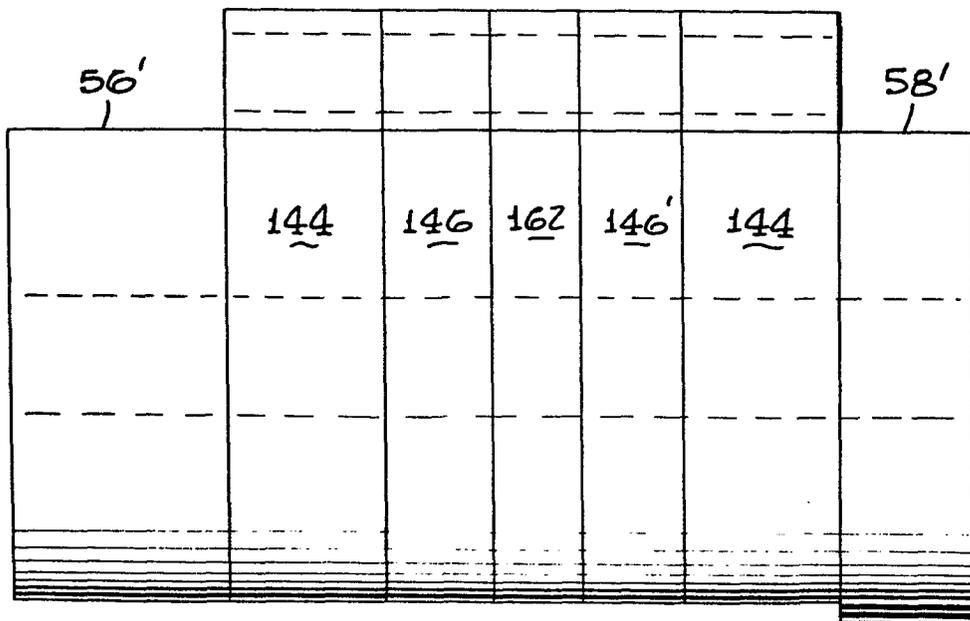
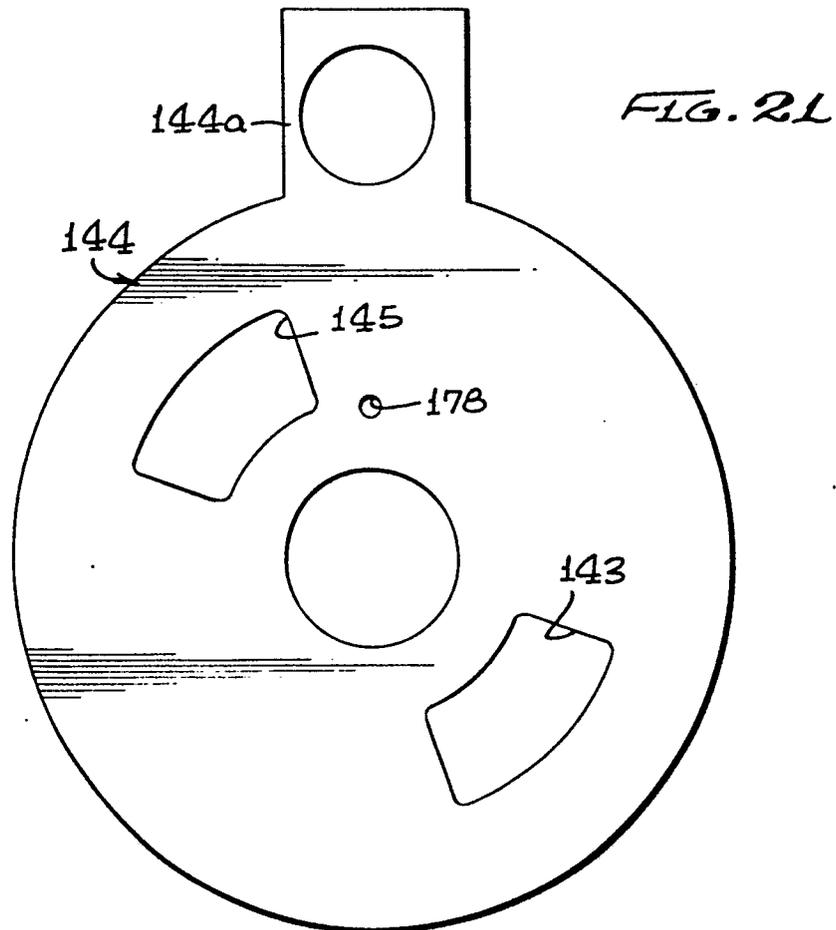
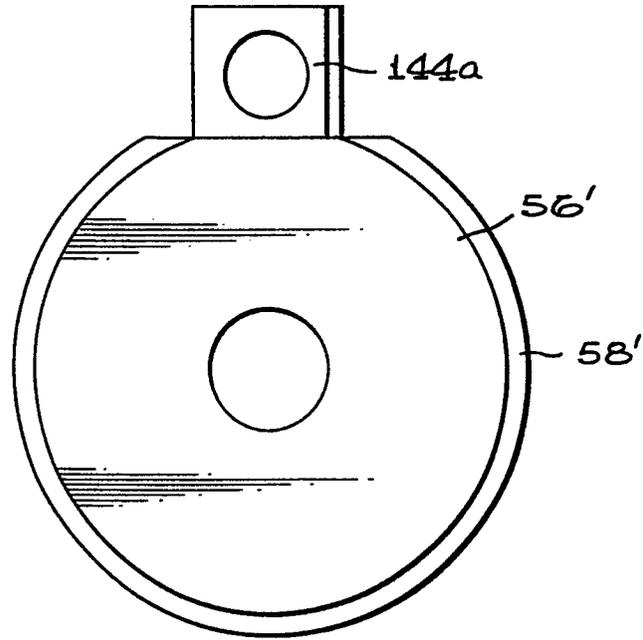


FIG. 20



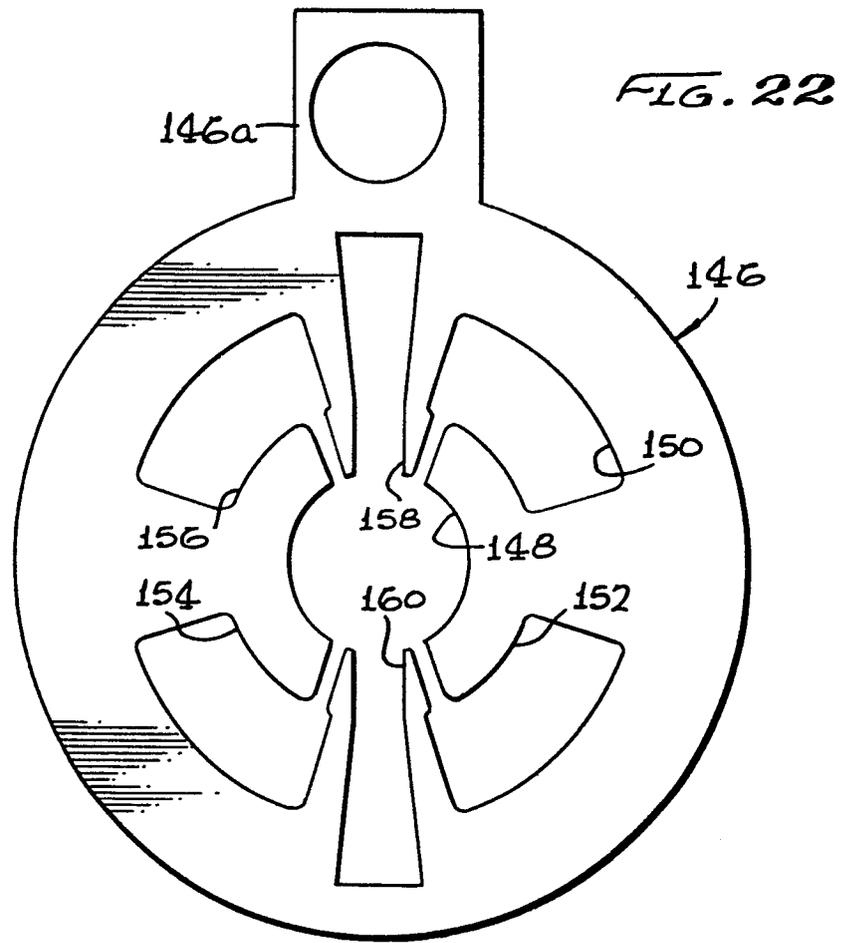


FIG. 23

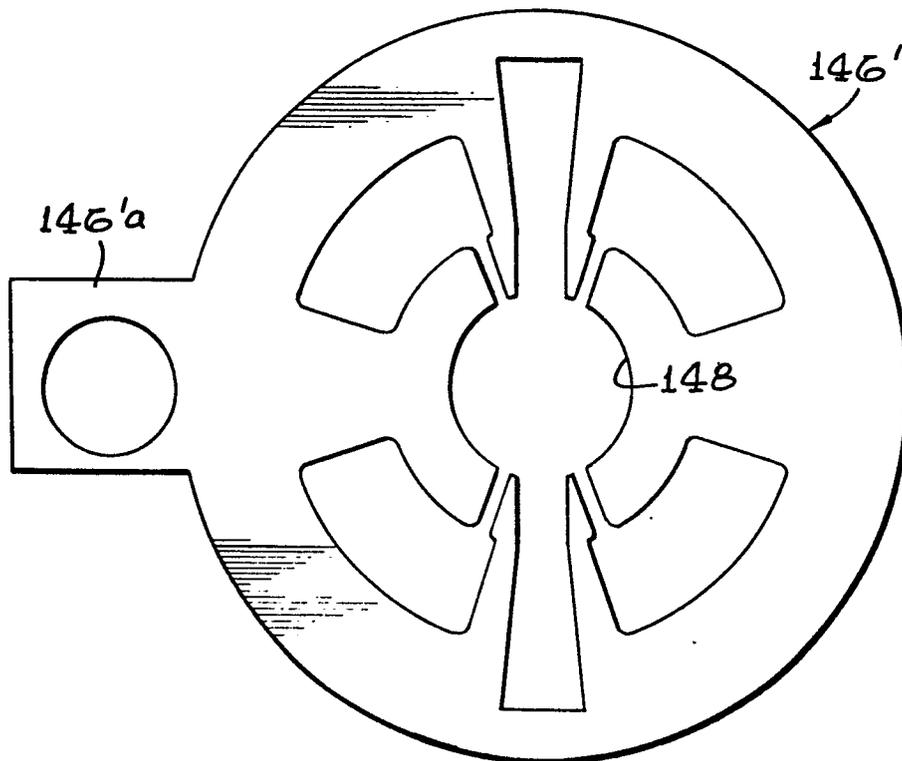


FIG. 24

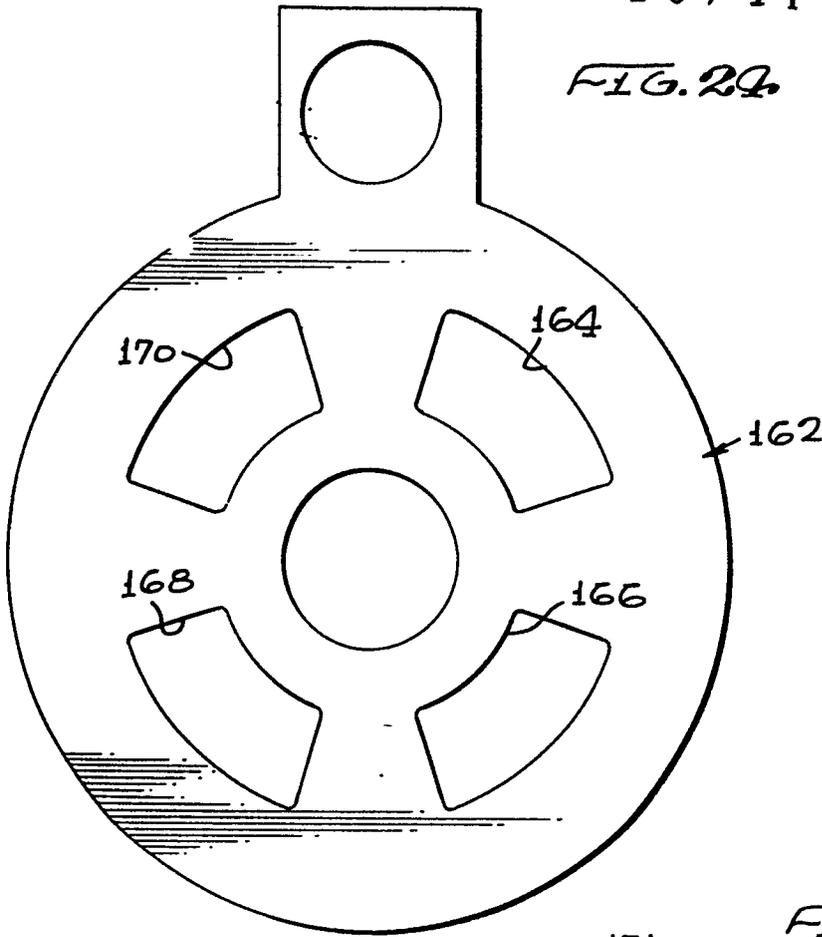


FIG. 27

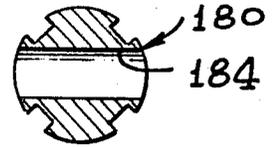


FIG. 29

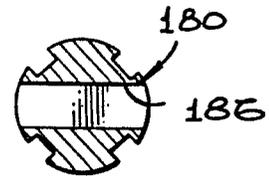


FIG. 25

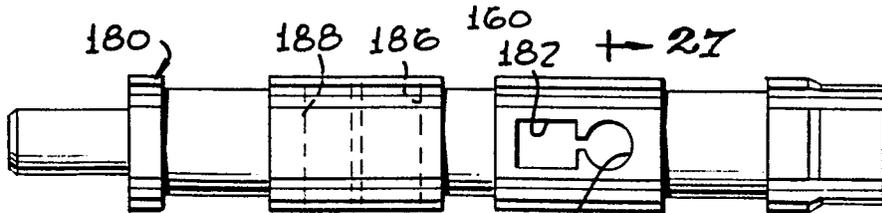
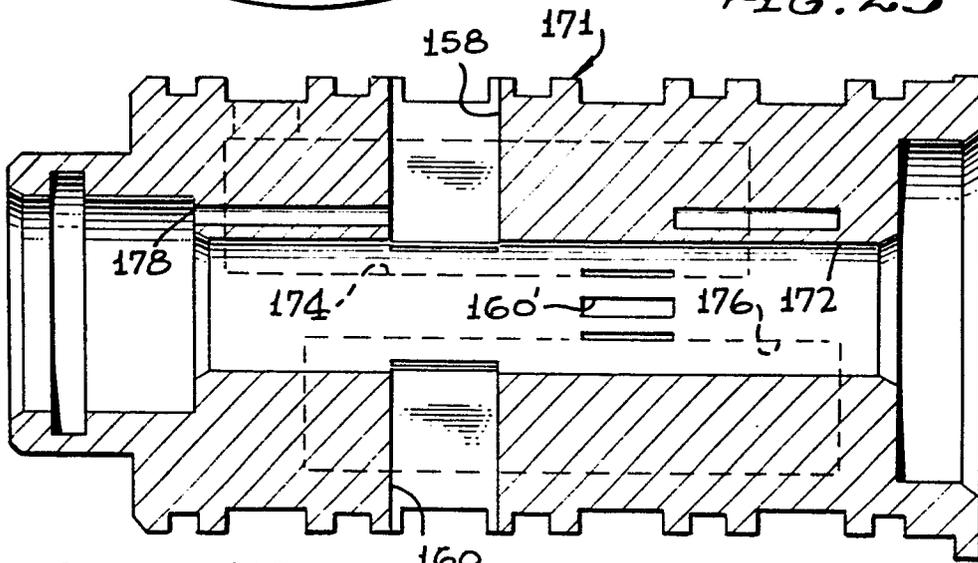


FIG. 26

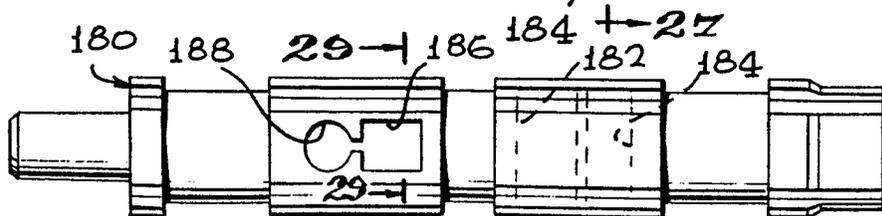


FIG. 28

FIG. 30

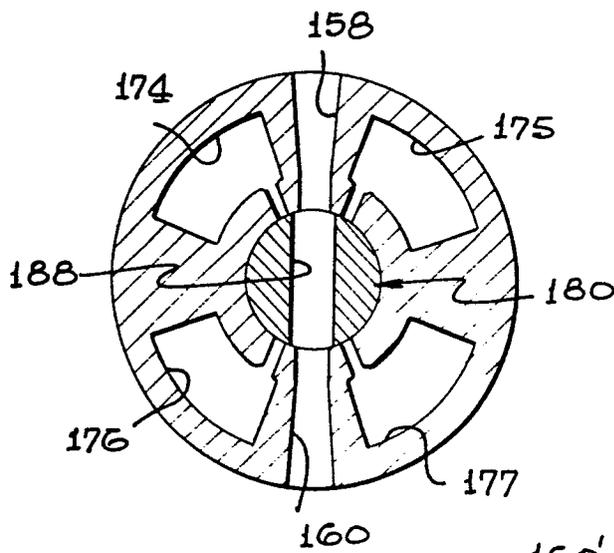
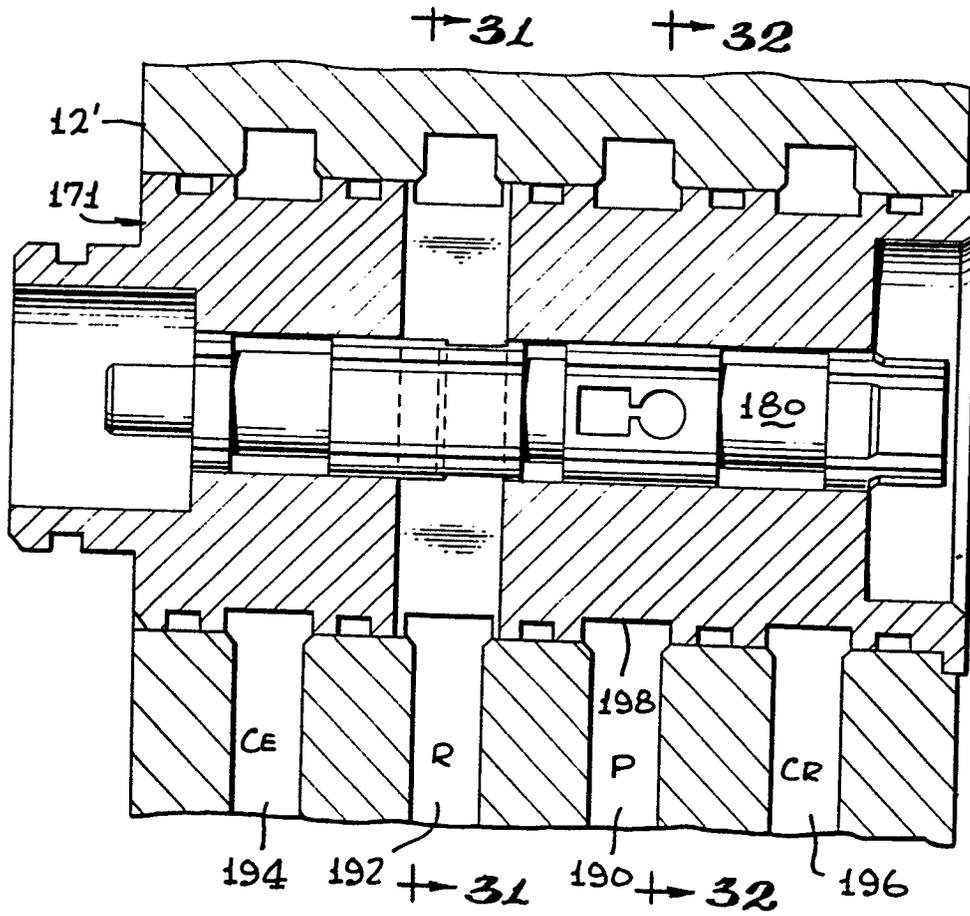


FIG. 31

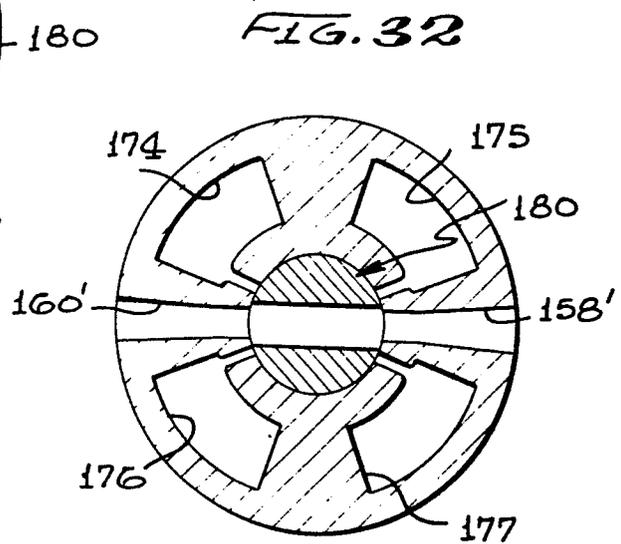


FIG. 32



European Patent
Office

EUROPEAN SEARCH REPORT

0102884

Application number

EP 83 40 1596

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. ³)
A	HYDRAULICS & PNEUMATICS, no. 7, July 1980 CLEVELAND OHIO (US) Y.M. EL-IBIARY et al.: "Fluid Power Research Update", pages 86,87,100.	1,9	F 15 B 13/044
	--		
A	<u>DE - B - 1 225 933</u> (LUDWIG) * The whole document *	1,9	
	--		
A	<u>US - A - 3 598 152</u> (ANDREWS) * The whole document *	1,9	
	--		
A	<u>US - A - 2 807 280</u> (KITTREDGE)		
A	<u>US - A - 3 504 703</u> (BOZOYAN)		

The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 10-11-1983	Examiner BENZE
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