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(54) ELECTRIC ACTUATED EXHAUST GAS RECIRCULATION VALVE

ELEKTRISCH BETRIEBENES ABGASRÜCKFÜHRVENTIL

SOUPAPE COMMANDEE ELECTRIQUEMENT DESTINEE A LA RECIRCULATION DES GAZ D'ECHAPPEMENT

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Description

Field of the Invention

[0001] This invention relates to exhaust gas recirculation (EGR) valves for internal combustion engines, and is particularly directed to a novel construction for improving the accuracy and response of the valve to electric control signals and for improving the ability of the valve to withstand intrusion of foreign substances, especially muddy water, into the interior mechanism of the valve via an ambient air cooling space.

Background and Summary of the Invention

[0002] Controlled engine exhaust gas recirculation is a commonly used technique for reducing oxides of nitrogen in products of combustion that are exhausted from an internal combustion engine to atmosphere. A typical EGR system comprises an EGR valve that is controlled in accordance with engine operating conditions to regulate the amount of engine exhaust gas that is recirculated to the induction fuel-air flow entering the engine for combustion so as to limit the combustion temperature and hence reduce the formation of oxides of nitrogen.

[0003] Since they are typically engine-mounted, EGR valves are subject to a harsh operating environment that includes wide temperature extremes and vibrations. Exhaust emission requirements impose more stringent demands for improved control of such valves. Use of an electric actuator is one means for obtaining improved control, but in order to commercially successful, such an actuator must be able to operate properly in such extreme environments for an extended period of usage. Moreover, in mass-production automotive vehicle applications, component cost-effectiveness is also essential. An EGR valve electric actuator that possesses more accurate and quicker response results in improved driveability and fuel economy for a vehicle having an internal combustion engine that is equipped with an EGR system. It also provides better control over tailpipe emissions.

[0004] An example of a known solenoid activated exhaust gas recirculating valve is disclosed in PCT application number WO-A-95/19497. The valve includes a valve body having a gas inlet and a gas outlet connected by a passageway. A flow control member is supported in the valve body and regulates the flow through the passageway. An electronically actuated field-generating solenoid moves a magnetic drive member to control the flow. The solenoid and a sensor for monitoring the position of the drive member are supported in a plastics moulded housing which partially encapsulates a pole piece that forms a magnetic circuit in combination with the drive member.

[0005] The present invention relates to a new and unique construction for certain component parts of such a valve that enables accuracy and response to be improved and also provides better resistance to the intrusion of muddy water into the internal valve mechanism via an ambient air cooling space.

[0006] Generally speaking, the invention relates to improvements in an area of the valve that contains a lower stator member that forms part of the magnetic circuit and a bearing member that guides the valve pintle. The organisation and arrangement of these two, and some related parts improves part-to-part concentricity and also is useful in resisting intrusion of muddy water into the interior operating mechanism.

[0007] The problem of muddy water intrusion arises because of the desirability of providing air ambient circulation through a portion of the valve. The pintle head and associated valve seat are in the hot exhaust path through the valve and are exposed to very high temperatures. The electric actuator is operatively connected to the pintle, but is slightly farther away from the engine. It is desirable to provide for air circulation through the valve housing between the actuator and the parts that are closer to the engine. However, since it is engine-mounted, the valve will be subject to the outside environment, and one of the hazards is muddy water intrusion due to road splash, etc.

[0008] Various features, advantages, and benefits of the invention for achieving the desired objectives will be seen in the ensuing description and claims that are accompanied by drawings. The drawings disclose a presently preferred embodiment of the invention according to the best mode contemplated at this time for carrying out the invention.

Brief Description of the Drawings

[0009] Figs. 1, 2, 3, and 4 are respective top plan, front elevation, left side elevation, and bottom views of an electric EGR valve (EEGR valve) embodying principles of the invention.

[0010] Fig. 5 is an enlarged view, partly in cross section, of the EEGR valve of Figs. 1-4.

[0011] Fig. 6 is a top plan view of one of the parts of the EEGR valve shown by itself on an enlarged scale, namely a valve seat.

[0012] Fig. 7 is a cross sectional view taken in the direction of arrows 7-7 in Fig. 6.

[0013] Fig. 8 is an enlarged view in circle 8 of Fig. 7.

[0014] Fig. 9 is an elevational view of another of the parts of the EEGR valve shown by itself on a slightly enlarged scale, namely a pintle valve element.

[0015] Fig. 10 is a top view of Fig. 9.

[0016] Fig. 11 is a fragmentary cross sectional view taken in the direction of arrows 11-11 in Fig. 10 on a larger scale.

[0017] Fig. 12 is a full bottom view of Fig. 11 on the same scale.

[0018] Fig. 13 is a top plan view of another of the parts of the EEGR valve shown by itself on an enlarged scale,

namely a bearing member.

[0019] Fig. 14 is a cross sectional view as taken in the direction of arrows 14-14 in Fig. 13.

[0020] Fig. 15 is an enlarged view in circle 15 of Fig. 14.

[0021] Fig. 16 is a top plan view of still another of the parts of the EEGR valve shown by itself on a slightly enlarged scale, namely a lower stator member.

[0022] Fig. 17 is a cross sectional view as taken in the direction of arrows 17-17 in Fig. 16.

[0023] Fig. 18 is a top plan view of yet another part of the EEGR valve shown by itself, namely an upper stator member.

[0024] Fig. 19 is a cross sectional view as taken in the direction of arrows 19-19 in Fig. 18.

[0025] Fig. 20 is an enlarged view in circle 20 of Fig. 19.

[0026] Fig. 21 is a top plan view of another of the parts of the EEGR valve shown by itself on a slightly enlarged scale, namely a spring washer.

[0027] Fig. 22 is a cross sectional view as taken in the direction of arrows 22-22 in Fig. 21 on a slightly larger scale.

[0028] Fig. 23 is a top plan view of still another of the parts of the EEGR valve shown by itself on a larger scale than in Fig. 5, namely a spring washer.

[0029] Fig. 24 is a front elevational view of Fig. 23.

[0030] Fig. 25 is a top plan view of yet another part of the EEGR valve shown by itself in a condition prior to assembly to the EEGR valve, namely a clinch ring.

[0031] Fig. 26 is a cross sectional view as taken in the direction of arrows 26-26 in Fig. 25.

[0032] Fig. 27 is an enlarged fragmentary view in circle 27 of Fig. 25.

[0033] Fig. 28 is a fragmentary cross sectional view as taken in the direction of arrows 28-28 in Fig. 27.

[0034] Fig. 29 is a top plan view of still another of the parts of the EEGR valve shown by itself on a slightly enlarged scale, namely a bobbin.

[0035] Fig. 30 is a front elevational view of Fig. 29.

[0036] Fig. 31 is a bottom plan view of Fig. 30.

[0037] Fig. 32 is a fragmentary cross sectional view as taken in the direction of arrows 32-32 in Fig. 30.

[0038] Fig. 33 is a cross sectional view as taken in the direction of arrows 33-33 in Fig. 29.

[0039] Fig. 34 is a fragmentary view, on an enlarged scale, as taken in the direction of arrows 34-34 in Fig. 29.

[0040] Fig. 35 is an enlarged cross sectional view as taken in the direction of arrows 35-35 in Fig. 30.

[0041] Fig. 36 is a full left side view of Fig. 35.

[0042] Fig. 37 is a front elevational view of yet another part of the EEGR valve shown by itself on a larger scale than in Fig. 5, namely an electrical terminal.

[0043] Fig. 38 is a top plan view of Fig. 37.

[0044] Fig. 39 is a right side elevational view of Fig. 37.

[0045] Fig. 40 is a left side elevational view of Fig. 37.

[0046] Fig. 41 is a bottom plan view of yet another part of the EEGR valve, namely a sensor cap.

[0047] Fig. 42 is a fragmentary cross sectional view, on an enlarged scale, as taken in the direction of arrows 42-42 in Fig. 41.

[0048] Fig. 43 is a fragmentary cross sectional view, on an enlarged scale, as taken in the direction of arrows 43-43 in Fig. 42.

[0049] Figs. 44, 45, and 46 are views of another form of clinch ring corresponding to the views of Figs. 25, 27, and 28 respectively.

Description of the Preferred Embodiment

[0050] Figs. 1-4 illustrate the exterior appearance of an electric EGR valve (EEGR valve) 60 embodying principles of the present invention. EEGR valve 60 comprises a metal base 62, a generally cylindrical metal shell 64 disposed on top of base 62, and a non-metallic cap 66 forming a closure for the otherwise open top of shell 64.

[0051] Base 62 comprises a flange 68 having a flat bottom surface adapted to be disposed against a surface of an exhaust manifold of an internal combustion engine, typically sandwiching a suitably shaped gasket (not shown) between itself and the manifold. Flange 68 comprises two through-holes 70 that provide for the separable attachment of EEGR valve 60 to an exhaust manifold. For example, the manifold may contain a pair of threaded studs which pass through through-holes 70 and onto the free ends of which lock washers are first placed, followed by nuts that are threaded onto the studs and tightened to force flange 68 toward the manifold, thereby creating a leak-proof joint between valve 60 and the manifold.

[0052] Reference numeral 72 designates a main longitudinal axis of EEGR valve 60. Base 62 further comprises four through-holes that are parallel to axis 72 and are centered on a common imaginary circle at 90 degree intervals about axis 72. Four fasteners 74 fasten base 62 and shell 64 tightly together via the four through-holes in base 62 and four holes in a bottom wall of shell 64 that register with the four through-holes in base 62. Each fastener comprises a bolt, a lock washer, and a nut. The head of each bolt is received in a suitable recess in flange 68 while a corresponding lock washer is disposed onto the free end of the respective bolt shank that extends through the respective hole in shell 64, and the corresponding nut is threaded onto the threaded end of the bolt shank and tightened.

[0053] With additional reference to Fig. 5, a suitable gasket 75 is sandwiched between the base and shell. Also, an annular air space 76 is provided within shell 64 immediately above the shell's bottom wall. This air space is open to the exterior by means of several through-slots 78 formed in the shell side wall immediately above the shell's bottom wall. This arrangement provides for ambient air circulation through EEGR valve 60 between base 62 and internal parts within shell 64

above the shell's bottom wall. Such air circulation provides beneficial cooling that serves to reduce the amount of engine heat that might otherwise be transferred to internal parts.

[0054] Cap 66 is a non-metallic part, preferably fabricated from suitable polymeric material. In addition to providing a closure for the otherwise open upper end of shell 64, cap 66 comprises a central cylindrical tower 80 and an electrical connector shell 82 that projects radially outwardly from tower 80. Tower 80 has a hollow interior shaped to house a position sensor that is utilized for sensing the extent to which EEGR valve 60 is open. Cap 66 further contains several electrical terminals that provide for such a sensor and an electric actuator to be operatively connected with an engine electrical control system, as will hereinafter be described in greater detail. Ends of these terminals are contained within shell 82 to form an electrical connector plug that is adapted to mate with a mating plug (not shown) of an electrical wiring harness of the engine electrical system. Cap 66 also comprises a series of integral triangularly shaped walls 84 spaced circumferentially around the cap that provide improved structural rigidity for tower 80 to a bottom wall 85 of the cap with which the tower is integrally formed. A clinch ring 86 engages an outer perimeter rim of wall 85 to securely attach cap 66 to shell 64 with radial sealing of the cap to the shell being provided by an O-ring 87 disposed in a radially outwardly open groove extending circularly around a portion of bottom wall that is below and radially inwardly of the wall's outer perimeter rim that is engaged by clinch ring 86. O-ring 87 provides a radial seal between the cap and the inside wall of shell 64 proximate the shell's top end.

[0055] Attention is now directed to details of the internal construction of EEGR valve 60 with continued reference to Fig. 5 and also to a number of subsequent drawing figures showing individual parts in greater detail.

[0056] Base 62 comprises an exhaust gas passageway 88 having an entrance 90 coaxial with axis 72 and an exit 92 that is spaced radially from entrance 90. Both entrance 90 and exit 92 register with respective passages in the engine exhaust manifold.

[0057] A valve seat 94, details of which are shown in Figs. 6, 7, and 8, is disposed in passageway 88 coaxial with entrance 90. Valve seat 94 has an annular shape comprising a through-hole having a frusto-conically tapered surface 96a extending from the top face of the valve seat to a straight circular cylindrical surface 96b extending to a frusto-conical chamfer 96c at the bottom of the valve seat. A circular perimeter rim 98 extends around the outside of valve seat 94 at the top. Immediately below rim 98, the outer perimeter surface of the valve seat comprises a straight circular cylindrical surface 100 that is coaxial with axis 72 and extends to a frusto-conical chamfer 102. Between surface 100 and chamfer 102 is a frusto-conically tapered surface 104 that begins at the upper circular edge of chamfer 102, which is essentially at the same diameter as surface 100. Surface 104 tapers outwardly toward the top of the valve seat at an angle designated by the numeral 106 in Fig. 8. It ends at a shoulder 108 that extends radially back to the lower edge of surface 100. Base 62 is constructed with a counterbore providing a shoulder 109 onto which rim 98 seats. Moreover, the provision of tapered surface 104 provides a wedge fit of the valve seat to base 62 when the valve seat is axially aligned with entrance 90 and pressed into the base to seat rim 98 on shoulder 109. Rim 98 is then captured against shoulder 109 by means of staking a portion 110 of base 62 against the top surface of the rim. It is to be appreciated that Fig. 5 portrays the assembled position of valve seat 94 in base 62 and that the staking portion 110 is created by displacing material of base 62 after rim 98 has been seated on shoulder 109. The wedging fit provided by surface 104 being in interference with the wall of entrance 90 immediately below shoulder 109 provides a secure, accurate, and gas-tight assembly of the valve seat to the base.

[0058] Fig. 5 further shows that EEGR valve 60 comprises an armature-pintle assembly 112 that is coaxial with axis 72 and that comprises a pintle 114 and an armature 116. Details of pintle 114 are illustrated in Figs. 9-12. Pintle 114 comprises a shaft having a head 117 at the lower end and a threaded stud 118 at the upper end. Head 117 is shaped for cooperation with seat 94 while stud 118 provides for attachment of the pintle to armature 116. Head 117 has an outer perimeter that is shaped to comprise a straight circular cylindrical surface 120 from the lower edge of which a frusto-conical tapered surface 122 flares radially outwardly to a further frusto-conical tapered surface 124 of larger taper, but shorter axial dimension, than that of surface 122. The pintle further comprises a flat bottom surface 128 that has a generally circular shape but contains a central blind hole 130. This blind hole comprises a chamfer 132 extending from surface 128 to a polygonally shaped surface 134 which in the illustrated embodiment is a hexagon shape. Immediately inwardly of surface 134 is a straight circular cylindrical surface 136 of slightly smaller diameter than the maximum diameter across surface 134. The innermost part of hole 130 is a conically shaped space 138 extending from surface 136 to a tip lying on axis 72. As can be seen in Fig. 5, which represents the closed position of EEGR valve 60, surface 124 seats against chamfer 96c. Preferably the taper of surface 124 is less than one degree smaller than that of chamfer 96c.

[0059] EEGR valve 60 further comprises a bearing member 140, details of which appear in Figs. 13-15. Bearing member 140 comprises a circular rim 142 at the bottom. The radially outer surface of rim 142 comprises a chamfer 144 extending from the flat bottom surface 145 of the bearing member. At several circumferentially spaced apart locations, the outer perimeter of the rim comprises formations 147. Each formation comprises a frusto-conically tapered surface section 146 that tapers outwardly from the upper circular edge of chamfer 144

to a straight, circularly cylindrically contoured surface section 148. Each surface section 148 extends to the top of rim 142. There are eight such formations 147 distributed uniformly around the perimeter of rim 142 in the illustrated embodiment. The formations are dimensioned for a wedging fit of member 140 to a partially cylindrical wall surface 149 in base 62 (see Fig. 5). Wall surface 149 is only partially cylindrical because that portion of passageway 88 that leads to exit 92 intersects this surface and hence there is no material available for forming the portion of wall surface 149 at the mutual intersection. This wedging fit of bearing member 140 to base 62 serves the purpose of accurately and securely locating the two parts in assembly.

[0060] Immediately below wall portion 149 is a shoulder 150. The outwardly turned upper rim 152 of a cup shaped metal shield 154 is captured between rim 142 and shoulder 150 after bearing member 140 has pressed into assembly with base 62. Shield 154 comprises a central circular clearance hole 156 for passage of the shaft of pintle 114 therethrough.

[0061] Fig. 14 shows that bearing member 140 further comprises a central through-hole having a cylindrical portion 156 extending upwardly from the bottom surface of the bearing member to a frusto-conical surface 158 which in turn extends to a straight cylindrical surface 160 that occupies a majority of the overall axial length of the bearing member. The upper end of surface 160 ends at a chamfer 162, where the bearing member top surface 164 has a slight crown. The outside diameter of bearing member 140 above rim 142 comprises a ridge 166 that has a circular shape. Above ridge 166 and continuing to top surface 164 are a series of circumferentially spaced apart flutes 168 that cooperatively define a series of parallel ribs 170 extending axially from ridge 166. The plan shape of these ribs 170 can be seen in Fig. 13 which shows six such ribs by way of example. The radially outer surfaces of these ribs lie on a common circle that is concentric with axis 72 and provide for accurately centering a lower stator member 174 (Fig. 5) in the assembled EEGR valve 60. Fig. 13 also shows that rim 142 has a semi-circular notch 172 disposed between two immediately adjacent formations 147 in the outer surface of the rim.

[0062] Details of lower stator member 174 appear in Figs. 16 and 17. Member 174 comprises a circular flange 176 immediately below which is a smaller diameter cylindrical wall 178 and immediately above which is a tapered cylindrical wall 180. A central through-hole of member 174 extends upwardly from an inwardly tapered surface 182 to a straight cylindrical section 184. The latter expands to a larger diameter cylindrical surface 186 that extends to a still larger diameter cylindrical surface 188. The upper edge surface 190 of wall 180 is relatively pointed and although it does have a finite radial thickness, that thickness is considerably smaller than the radial thickness 192 at the base of wall 180. The relatively pointed tapering of wall 180 is for the purpose of enhancing the magnetic circuit characteristics of the magnetic circuit of EEGR valve 60, to be hereinafter described in detail.

[0063] Valve 60 further comprises an upper stator member 194 that is cooperatively associated with lower stator member 174 in the magnetic circuit. Details of upper stator member 194 appear in Figs. 18-20. Member 194 comprises a straight cylindrical side wall 196 having a flange 198 extending around its outside proximate its upper end. The outer surface of flange 198 is constructed to have a wedging press fit to the inside wall of shell 64 and comprises a straight cylindrical section 200 extending upwardly from its lower face to an outwardly tapered surface 202. Surface 202 terminates at a shoulder 204 that extends radially inwardly back to a cylindrical surface 206 that extends to the upper face of the flange. In the assembled valve 60, member 194 is pressed into the shell 64 to seat flange 198 on an internal shoulder 64b (Fig. 5) of shell 64. The upper stator member further comprises a straight cylindrical through-hole 212 extending from a small chamfer 211 at the bottom of side wall 196 to a larger chamfer 210 at a raised ridge 208 at the top end of the member. A slot 214 is provided in a portion of flange 198 and ridge 208 to provide a clearance for an electrical connection between cap 66 and a bobbin assembly 222 (see Fig. 5) that is disposed within shell 64 in cooperative association with the two stator members. Additionally, flange 198 comprises a through-hole 216 diametrically opposite slot 214 and two smaller through-holes 218, 220 at 90 degrees from hole 216.

[0064] Fig. 5 shows solenoid coil assembly 222 disposed within shell 64 between stator members 174 and 194. Solenoid coil assembly 222 comprises a non-metallic bobbin 224 having a straight cylindrical tubular core 226 coaxial with axis 72, and upper and lower flanges 228 and 230 at the opposite axial ends of core 226. A length of magnet wire is wound on core 226 between flanges 228, 230 to form an electromagnet coil 232.

[0065] Detail of bobbin 224 appears in Figs. 29-36 in a condition prior to winding of coil 232. The bobbin is preferably an injection-molded plastic that possesses dimensional stability over a range of temperature extremes that are typically encountered in automotive engine usage. Lower flange 230 has a circular shape whose outer perimeter is interrupted at one location by a small inwardly extending slot 234. Upper flange 228 also has a circular shape, but its outer perimeter is interrupted by two closely adjacent slots 236 and 238 that have somewhat different shapes. Slot 236 is basically U-shaped. One side of slot 238 is slightly more than a half-U-shape while the other side 239 runs along a straight line extending from a point of tangency 240 with the first side at about 55 degrees to a radial 241 to where it meets the circular outer perimeter of the flange. The lower face of flange 228 comprises an indentation 242 that is seen in Fig. 32 to be somewhat triangularly shaped. Indentation 242 comprises an edge surface 244 that extends from a point of tangency 246 with the

O.D. of core 226 to a location on the perimeter of flange 228 that is between slots 238 and 236. Edge surface 244 makes an angle 250 with radial 241 that is approximately 35 degrees.

[0066] The upper face of flange 228 contains two upstanding cylindrical posts 252 and 254 that are diametrically opposite each other and equidistant from axis 72 and whose upper ends are tapered. At 90 degrees to both posts 252, 254 is a further upright post 256 having a generally rectangular shape with a radially outwardly projecting overhang 258 at its top that is also slightly wider in the circumferential sense about axis 72.

[0067] Generally diametrically opposite post 256 on the upper face of flange 228 are a pair of upright, side-by-side, walled sockets 260 and 262. Each socket is adapted for receiving a respective electrical terminal like the one depicted in Figs. 37-40 (to be described in detail later) and to provide for the electrical connection of a respective terminal with a respective end segment of the magnet wire forming coil 232. Fig. 5 shows one such terminal 264 received in a respective one of the sockets. Each socket has a generally rectangular wall that is open at the top for insertion of a terminal. The opposed radially inner and radially outer portions of each socket wall contain straight narrow slots 266 and 268 respectively that are in parallel and mutual alignment across the respective socket. The slots are open at the top where they have a lead that facilitates the passage of respective segments of the coil magnet wire into the slots, as will be explained in greater detail later on. A respective grooved ramp 270 and 272 slopes upwardly from a respective slot 236, 238 to the bottom of the radially outer slot 268 of a respective socket 260, 262. A respective short grooved track 274 and 276 is provided on the radially inner wall of the respective socket 260, 262 slightly above the upper face of flange 228, each track 274, 276 having a groove that extends from the bottom of the radially inner slot 266 of the respective socket 260, 262 toward the open center of the bobbin as viewed in plan.

[0068] Figs. 37-40 illustrate an electric terminal 264 prior to its insertion into a respective one of the sockets 260, 262. Terminal 264 is fabricated as a single piece from flat strip stock to comprise a generally U-shaped body having a base 388 whose opposite ends join with flat sides 390 and 392 respectively along 90 degree radii, as shown by Fig. 37. Each side contains a centrally located axial slot 394 that is open at base 388 and extends upwardly therefrom for about one-half the overall axial length of the side. At base 388, a slot 394 comprises an entrance lead 396 that extends to a straight section 398 which in turn extends via a tapered section 400 to a narrower straight section 402. The material is slit, as shown at 404 in Figs. 39 and 40, adjacent each side of section 398. The outer edges of sides 390, 392 contain pointed retention barbs 406. A somewhat T-shaped tab 408 inclines downwardly and inwardly from the central portion of the top edge of side 392, stopping short of the opposite side 390 to provide an insertion space 410 for a mating terminal (not shown). The wings 412 of the T-shape are curled back toward, but stop short of, side 392.

[0069] The method of fabricating the solenoid coil assembly will now be briefly explained. Magnet wire is tightly wrapped around post 256 below overhang 258. It is then brought across the bobbin to run in and along the groove of track 274, thence pass through slot 266 of socket 260 and across the socket's interior to exit the socket by passing through slot 268. From slot 268 the magnet wire runs in and along the groove of ramped track 270 to enter slot 236 where it loops around the edge of the slot to the bottom face of flange 228. The magnet wire extends within recess 242 from the edge of slot 236 to tangency with core 226 where it begins to form convolutions around the core between the bobbin flanges to ultimately create the electromagnet coil 232. By "precision winding" of the coil, maximum convolutions are placed in minimum space, and they are accurately located so that the electromagnetic characteristics of the coil are accurately defined.

[0070] Magnet wire extends from the final convolution of the coil to slot 238 where the magnet wire loops around the edge of the slot to the upper face of flange 228. The magnet wire extends from slot 238 to run in and along the groove in ramped track 272 and thence enter socket 262 by passing through slot 268 of that socket. The magnet wire passes across the interior of the socket, exiting via slot 266 to run in and along the groove in track 276. Upon leaving track 276, the magnet wire extends across the bobbin to an end segment of the magnet wire that is wrapped, or tied, securely around post 256.

[0071] At all times during the running of the magnet wire on the bobbin, it is kept tensioned so that not only are the coil convolutions tensioned, but also the segments that extend from the coil to post 256.

[0072] Terminals 264 are then assembled by aligning each with the open end of a respective socket 260, 262 and forcefully inserting them into the sockets. As a terminal is being inserted into a socket, the portion of the magnet wire spanning the interior of the socket enters slots 394. Leads 396 facilitate entry into the narrow portions of the slots. When the terminal has been fully inserted, the magnet wire is lodged in section 402 in electric contact with the terminal. Each slot is dimensioned in relation to the diameter of the magnet wire to scrape away the thin insulation covering the magnet wire so that the electric contact is thereby established. Barbs 406 embed slightly into the wall of the socket to securely retain the terminal in the socket. The tensioned magnet wire running across the interior of each socket is also wedged in the terminal slots so that the magnet wire is maintained in tension.

[0073] The process is completed by severing, or shearing, both tracks 274, 276 at the location where they join their respective sockets, severing the magnet wire

in the process, and by shearing post 256 from flange 228 at the base of the post.

[0074] Cap 66 is also an injection-molded plastic part, and its details can be seen in Figs. 3, 5, and 41-43. Surrounded by shell 82 are end portions of five electrical terminals 290, 292, 294, 296, and 298. Terminals 290, 292, 294 provide for electrical connection of the sensor within tower 80 to the engine electrical system, while terminals 296, 298 provide for electrical connection of coil 232 with the system. Each terminal 296, 298 is a blade-type that a flat end portion within shell 82 and an opposite end portion adapted for mating connection with a respective terminal 264 in a respective socket 260, 262. Each terminal 296, 298 has an intermediate 90 degree bend so that the opposite end portions are at a right angle to each other, with the end that mates with a terminal 264 having its length parallel to axis 72 and its width perpendicular to its length as viewed in Fig. 42. That Fig. further shows that this end of each terminal 296, 298 comprises a respective forked blade 300, 302 both of which are disposed within a surrounding shell 304 of the cap. Fig. 43 shows that each forked blade has a reduced thickness from that of the portion that is embedded within the plastic of cap 66. This allows the forked blades to be deflected in cantilever-like fashion, as shown in Fig. 5, when mated with a respective terminal 264. Shell 304 is shaped for fitting to sockets 260, 262, as also shown in Fig. 5.

[0075] Figs. 25-28 show the shape of clinch ring 86 prior to its being formed to the shape shown in Fig. 5. It comprises a cylindrical side wall 306 and an upper circular flange 308 projecting radially inward from the upper end of the side wall. Fig. 26 shows that flange 308 is at slightly less than a right angle to side wall 306. The radially inner edge of flange 308 also contains integral downward turned pointed barbs 310, the illustrated embodiment having four such barbs at ninety degree intervals around the ring by way of example. These barbs will bite slightly into the polymeric material of the outer perimeter rim of wall 85 of cap 66 in the finished valve 60 to aid in resisting rotational displacement of the cap relative to shell 64. Two barbs point in one circumferential sense while the remaining two point in the opposite circumferential sense.

[0076] After the cap has been placed onto the top of shell 64, the clinch ring is placed over the abutting perimeter rims of the cap and shell, and the lower portion of side wall 306 is turned inwardly to the position shown by Fig. 5. The initial shape of clinch ring 86 provides for a final shape that applies an axial holding force that effectively immovably clamps the two parts 64, 66 together, so that neither axial nor circumferential movement between them can occur.

[0077] Fig. 44-46 show an alternate form of clinch ring which is like the one of Figs. 25-28, but for the shape and location of barbs 310. In this alternate embodiment, the barbs are lanced from material of the upper flange that is spaced inwardly from the flange inner edge. Each barb points circumferentially as viewed in plan, two in one sense, two in the opposite sense, and is symmetrical about its pointed tip.

[0078] Returning once more to Fig. 5, one can see that upper stator member 194 and solenoid coil assembly 222 have been joined to form an assembly. The joining is done by placing upper stator member 194 onto the top of bobbin 224 such that posts 252, 254, while still in the condition shown in Figs. 29 and 30 but after coil 232 has been wound on core 226 and electric terminals 264 inserted into their sockets, pass through the holes 218, 220 in flange 198 of the upper stator member. The tapered ends of the posts are then deformed to create heads 314 that cooperate with upper bobbin flange 228 to capture the stator flange 198 between themselves. It should be noted that Fig. 5 shows one post and its head 314 ninety degrees out of position circumferentially, for illustrative clarity only.

[0079] Fig. 5 shows a spring wave washer 320 disposed between lower bobbin flange 230 and flange 176 of lower stator member 174. Details of spring wave washer 320 are shown in Figs. 21-22. Wave spring washer 320 serves to assure that upper bobbin flange 228 is maintained against upper stator flange 198 should there be any looseness in the bobbin flange attachment to the upper stator flange provided by posts 252, 254 and their heads 314. Under extremely harsh operating conditions, the polymeric material of the bobbin and its two integral posts with their formed heads might experience expansion and/or creep that would cause looseness, but this is prevented by the action of wave spring washer 320 keeping the upper bobbin flange against the upper stator flange. The spring characteristic of wave washer 320 can also keep the rim of flange 176 forcefully seated against an internal shoulder 64a of shell 64, although the press-fit of the lower stator member to bearing member 140 should not result in axial separation of the rim of flange 176 from shoulder 64a.

[0080] The upper stator/solenoid coil assembly is accurately and securely located within shell 64 by virtue of the previously described press fitting of flange 198 to the side wall of shell 64 at shoulder 64b. The upper and lower stator members are accurately axially positioned relative to one another by accurately controlling the axial distance between the two shoulders 64a and 64b in shell 64. Since both shoulders are in a single part, tighter tolerancing of that axial distance is made possible.

[0081] Greater control of the concentricity of the two stator members is also made possible by shell 64. By controlling the concentricity of the hole in the bottom wall of shell 64 into which ridge 166 of bearing member 140 is pressed, to the concentricity of shoulder 64b, the bearing member's concentricity is controlled, and through the press fit of lower stator member 174 to the bearing member, the concentricity of the lower stator member is controlled. Consequently, concentricity of the lower stator member to the upper stator member is controlled through shell 64 and bearing member 140. Shoul-

der 64a is made sufficiently wide not to interfere with this control.

[0082] The accurate relative positioning of the two stator members is important in achieving the desired air gap in the magnetic circuit that is provided by the two stator members and shell 64, all of which are ferromagnetic. The air gap is designated 322 is present between the respective walls 180 and 196 of the respective stator members.

[0083] A portion of armature 116 axially spans air gap 322, radially inward of walls 180 and 196. A non-magnetic sleeve 326 is disposed in cooperative association with the two stator parts and armature-pintle assembly 112. Part 326 has a straight cylindrical wall 328 extending from an outwardly curved lip 330 to keep armature 116 separated from the two stator members. Part 326 also has a lower end wall 332 that is shaped for seating on lower stator member 174 and for providing a spring seat 334 for a helical coil spring 336. Wall 332 also has a central hole to allow the shaft of pintle 114 to pass through.

[0084] Armature 116 is ferromagnetic and comprises a cylindrical wall 340 coaxial with axis 72 and a transverse internal wall 342 across the interior of wall 340 at about the middle of the length of wall 340. Wall 342 has a central hole that provides for the upper end of pintle 114 to be attached to the armature by the fastening means that includes a calibration nut 346, a shim 348, a wave spring washer 350. Wall 342 also has three smaller bleed holes 352 spaced outwardly from, and uniformly around its central hole.

[0085] Shim 348 is circular in shape having flat, mutually parallel end wall surfaces between which extends a straight circular through-hole that is coaxial with axis 72. The shim's O.D. is tapered, as shown. Shim 348 serves three purposes: 1) to provide for passage of the upper end portion of pintle 114; 2) to provide a locator for the upper end of spring 336 to be substantially centered for bearing against the lower surface of wall 342; and 3) to set a desired axial positioning of armature 116 relative to air gap 322.

[0086] Detail of wave spring washer 350 is shown in Figs. 23 and 24 in its uncompressed shape. It has the annular shape of a typical wave spring washer, but with three tabs 360 equally spaced about its inner perimeter that are dimensioned for a very slight interference fit with a portion of calibration nut 346 to allow it to be retained on the nut for assembly convenience when attaching the pintle to the armature.

[0087] The O.D. of calibration nut 346 comprises straight cylindrical end portions between which is a larger polygonally shaped portion (i.e. a hex). The lower end portion of the nut has an O.D. that provides some radial clearance to the central hole in wall 342. It is onto the lower end portion that wave spring washer 350 is assembled, prior to calibration nut 346 being threaded onto threaded stud 118 of the pintle. When calibration nut 346 is threaded onto threaded stud 118, wave spring washer 350 is axially compressed between the lower shoulder of the nut's hex and the upper surface of wall 342 surrounding the central hole therein. The nut is tightened to a condition where a shoulder on pintle 114 just below stud 118 engages shim 348 to force the flat upper end surface of shim 348 to bear with a certain force against the flat lower surface of wall 342. The calibration nut does not abut the shim. Wave spring washer 350 is, at that time, not fully axially compressed, and this type of joint allows armature 116 to position itself within sleeve 326 to better align to the guidance of the pintle that is established by bearing member 140. Hysteresis is minimized by minimizing any side loads transmitted from the pintle to the armature, or from the armature to the pintle, as the valve operates, and the disclosed means for attachment of the pintle to the armature is highly effective for this purpose.

[0088] Armature 116 is accurately axially positioned relative to air gap 322 by controlling the axial dimension of shim 348. The axial distance between the air gap and the valve seat is measured. The axial distance along the pintle between the location where valve head 117 seats on the valve seat and the location where the shoulder of the pintle bears against the shim is measured. Based on these two measurements, the axial dimension of the shim can be chosen such that the armature, when fastened to the pintle and disposed against the pintle shoulder, will be in a desired axial position to the air gap.

[0089] The position sensor that is housed within tower 80 of cap 66 comprises a plunger 414 that is self-biased against the flat upper end surface of nut 346. The sensor is accurately calibrated to the axial position of the armature-pintle assembly by setting the axial location of the flat upper end surface of calibration nut 346. The axial dimension of the calibration nut is at least a certain minimum. The flat upper surface is ground, as required, to achieve a desired location that will cause plunger 414 to assume a desired calibration position when abutting the upper end of the calibration nut.

[0090] The inventive features that are the subject of this disclosure relate to provision of concentricity of lower stator member 174 to bearing member 140 by the aforementioned press-fit, and to the shaping of the lower stator member 174 to resist muddy water intrusion. Because flutes 168 provide for communication between air space 76 and section 186 of the through-hole in lower stator member 174, muddy water that enters the air space via through-slots 78 can possibly intrude into section 186. Since a portion of pintle shaft 114 passes through section 186, it is possible that muddy water can reach the pintle shaft. However, by the same token, the flutes also provide a path for drainage. Additionally, the frusto-conical shaped section 182 of the lower stator member tends to deflect muddy water away.

[0091] Cylindrical wall 178 ends at a lower edge surface 400. Muddy water that intrudes through through-slots 78 tends to deposit on the inside of the bottom wall of shell 64 below the lower edges of through-slots 78. If

the lower edge surface 400 were to be situated below the lower edges of through-slots 78, negative pressure in section 186 (caused by leakage of vacuum through the very small sliding clearance between the pintle shaft and member 140) could draw the muddy water into section 186 where it might intrude into the sliding clearance. Edge surface 400 is therefore situated above the lower edges of through slots 178. Consequently, as muddy water, or drops, fall from the lower surface of lower stator member 174, or run downwardly along the outside of cylindrical wall 178, they will tend to fall toward the shell's bottom wall, rather than being sucked into section 186 via flutes 168. Because surface 182 tapers downwardly and outwardly away from straight section 184 to the inner edge of lower edge surface 400, it helps to guide water away from section 186.

[0092] While the foregoing has described a preferred embodiment of the present invention, it is to be appreciated that the inventive principles may be practiced in any form that falls within the scope of the following claims.

Claims

1. An electric exhaust gas recirculation (EEGR) valve (GO) for an internal combustion engine comprising an enclosure (64) including a base (62), an entrance (90) at which engine exhaust gas to be recirculated enters said base (62), a passage (88) that extends through said base for conveying engine exhaust gas that has entered said entrance (90), an exit (92) at which engine exhaust gas that has passed through said passage (88) exits said base (62), a valve mechanism (94, 112, 117) disposed within said base (62) for controlling flow through said passage (88), an electric actuator (222) disposed within said enclosure for operating said valve mechanism, said enclosure (64) comprising a sidewall having openings (78) to an interior air space (76) providing for ambient air to flow through said air space (76), a bearing member (140) extending axially within said air space (76) and comprising a central through-hole (156) for guidance of a shaft extending from said electric actuator (222) to said valve mechanism, (94, 112, 117), stator structure (174, 194) providing a magnetic circuit path for said actuator and comprising a stator member (174) disposed as an axial boundary of said air space, said stator member (174) having a central through-hole (186), wherein said bearing member (146) is arranged concentric to said stator member through-hole, characterised in that said bearing member (146) extends into said stator member through-hole, said stator member (174) comprises a cylindrical wall (178) containing said stator member through-hole (180) and said cylindrical wall (178) comprises a frusto-conical surface (182) extending toward said air space from where said bearing member (140) extends into said stator member through-hole, which frusto-conical surface acts as a deflection means to guide any water, which has entered via said openings (78), away from the said central through-hole (186).

2. An EEGR valve as set forth in Claim 1 in which said frusto-conical surface (182) is disposed axially approximately at the middle of said air space.

3. An EEGR valve set forth in Claim 1 or Claim 2, in which said valve mechanism comprises a valve seat (94) in said base and a pintle (114) on said shaft that co-acts with said valve seat (94).

Patentansprüche

1. Elektrisches Abgasrezirkulations(EEGR)ventil (60) für eine Brennkraftmaschine mit einer Umfassung (64) einschließlich einer Basis (62), einem Einlaß (90), an dem zu rezirkulierendes Abgas der Brennkraftmaschine in die Basis (62) eindringt, einem Kanal (88), der sich durch die Basis erstreckt und Abgas der Brennkraftmaschine, das über den Einlaß (90) eingedrungen ist, fördert, einem Auslaß (92), an dem Abgas der Brennkraftmaschine, das durch den Kanal (88) gedrungen ist, die Basis (62) verläßt, einem Ventilmechanismus (94, 112, 117), der innerhalb der Basis (62) angeordnet ist, um den Durchfluß durch den Kanal (88) zu steuern, einer elektrischen Betätigungseinheit (222), die innerhalb der Umfassung angeordnet ist und den Ventilmechanismus betreibt, wobei die Umfassung (64) eine Seitenwand mit Öffnungen (78) zu einem inneren Luftraum (76) aufweist, die bewirken, daß Umgebungsluft durch den Luftraum (76) strömt, einem Lagerelement (140), das sich axial innerhalb des Luftraumes (76) erstreckt und ein zentrales Durchgangsloch (156) zur Führung eines Schaftes umfaßt, der sich von der elektrischen Betätigungseinheit (222) zum Ventilmechanismus (94, 112, 117) erstreckt, und einer Statoreinheit (174, 194), die einen Magnetkreis für die Betätigungseinheit vorsieht und ein Statorelement (174) umfaßt, das als axiale Begrenzung des Luftraumes angeordnet ist und ein zentrales Durchgangsloch (186) aufweist, wobei das Lagerelement (146) konzentrisch zum Durchgangsloch des Statorelementes angeordnet ist, dadurch gekennzeichnet, daß sich das Lagerelement (146) in das Durchgangsloch des Statorelementes erstreckt, daß das Statorelement (174) eine zylindrische Wand (178) aufweist, die das Durchgangsloch (180) des Statorelementes enthält, und daß die zylindrische Wand (178) eine kegelstumpfförmige Fläche (182) aufweist, die sich in Richtung auf den Luftraum erstreckt, von dem aus sich das Lagerele-

ment (140) in das Durchgangsloch des Statorelementes erstreckt, wobei die kegelstumpfförmige Fläche als Ablenkeinrichtung wirkt, um alles Wasser, das über die Öffnungen (78) eingedrungen ist, vom zentralen Durchgangsloch (186) wegzuführen.

2. EEGR-Ventil nach Anspruch 1, bei dem die kegelstumpfförmige Fläche (182) in Axialrichtung etwa in der Mitte des Luftraumes angeordnet ist.

3. EEGR-Ventil nach Anspruch 1 oder 2, bei dem der Ventilmechanismus einen Ventilsitz (94) in der Basis und einen Bolzen (114) am Schaft aufweist, der mit dem Ventilsitz (94) zusammenwirkt.

Revendications

1. Vanne électrique de recirculation de gaz d'échappement (EEGR) (60) destinée à un moteur à combustion interne, comprenant une enceinte (64) incluant une embase (62), une entrée (90) par laquelle les gaz d'échappement du moteur devant être recirculés pénètrent dans ladite embase (62), un passage (88) qui s'étend au travers de ladite embase pour canaliser les gaz d'échappement du moteur qui ont pénétré dans ladite entrée (90), une sortie (92) par laquelle les gaz d'échappement du moteur qui sont passé au travers dudit passage (88) sort de ladite embase (62), un mécanisme de vanne (94, 112, 117) disposé au sein de ladite embase (62) pour commander le flux traversant ledit passage (88), une actionneur électrique (222) disposé au sein de ladite fermeture pour commander ledit mécanisme de vanne, ladite enceinte (64) comprenant une paroi latérale ayant des ouvertures (78) vers un espace d'air intérieur (76) permettant à l'air ambiant de circuler au travers dudit espace d'air (76), un élément de support (140) s'étendant axialement au sein dudit espace d'air (76) et comprenant un orifice traversant central (156) qui permet le guidage d'un arbre s'étendant dudit actionneur électrique (222) audit mécanisme de vanne (94, 112, 117), une structure statorique (174, 194) établissant un trajet de circuit magnétique pour ledit actionneur et comprenant un élément statorique (174) disposé en tant que limite axiale dudit espace d'air, ledit élément statorique (174) comportant un orifice traversant central (186), dans laquelle ledit élément de support (146) est disposé concentriquement audit orifice traversant de l'élément statorique, caractérisée en ce que ledit élément de support (146) s'étend dans ledit orifice traversant de l'élément statorique, ledit élément statorique (174) comprend une paroi cylindrique (178) contenant ledit orifice traversant (180) de l'élément statorique et ladite paroi cylindrique (178) comprend une surface tronconique (182) s'étendant en direction dudit espace d'air à partir duquel ledit élément de support (140) s'étend dans ledit orifice traversant de l'élément statorique, laquelle surface tronconique agit en tant que moyen de déviation pour guider toute eau, qui a pénétré via lesdites ouvertures (78), à l'écart dudit orifice traversant central (186).

2. Vanne EEGR selon la revendication 1, dans laquelle ladite surface tronconique (182) est disposée axialement environ au milieu dudit espace d'air.

3. Vanne EEGR selon la revendication 1 ou 2, dans laquelle ledit mécanisme de vanne comprend un siège de vanne (94) dans ladite embase et une broche (114) sur ledit arbre qui agit en coopération avec ledit siège de vanne (94).

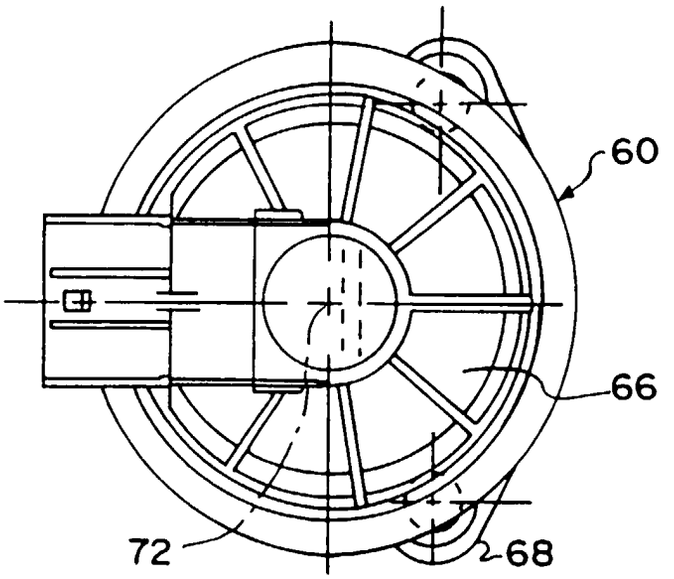


FIG. 1

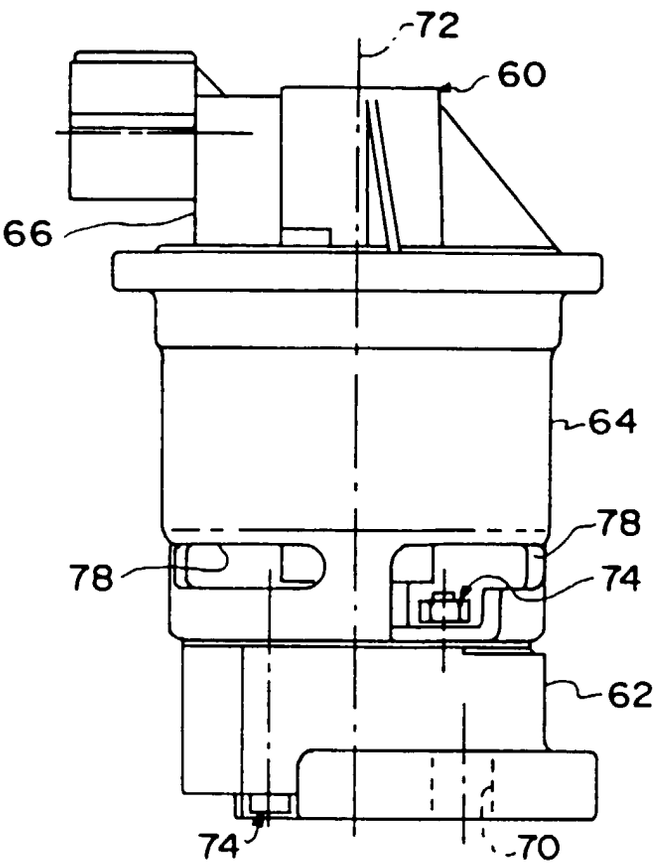


FIG. 2

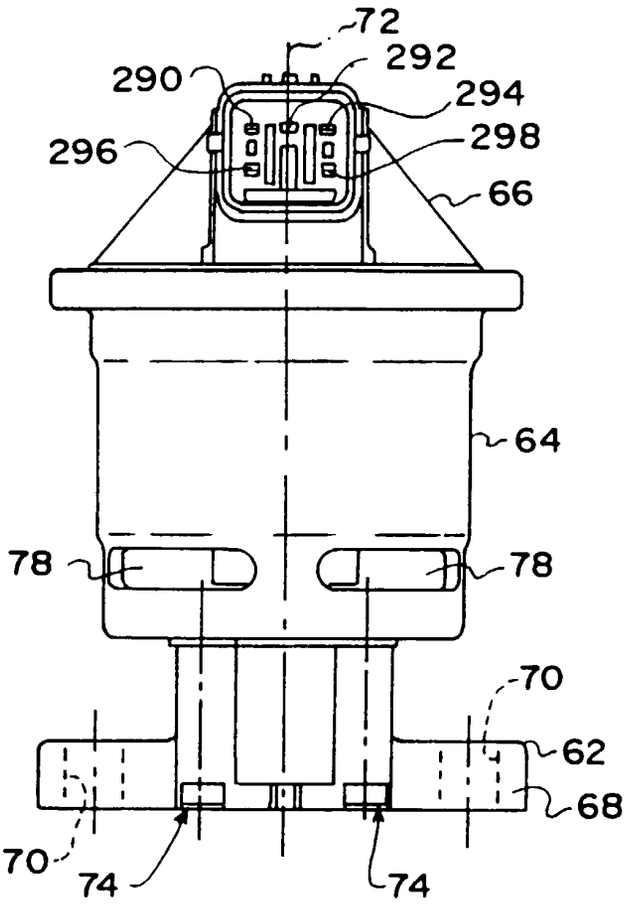

72
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292
294
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66
64
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70
62
68
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74
74

FIG. 3

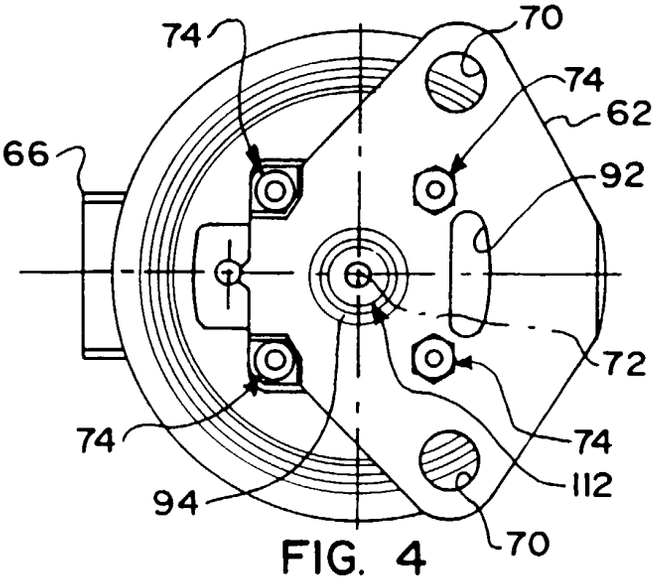

74
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74
62
66
92
72
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74
112
94
70

FIG. 4

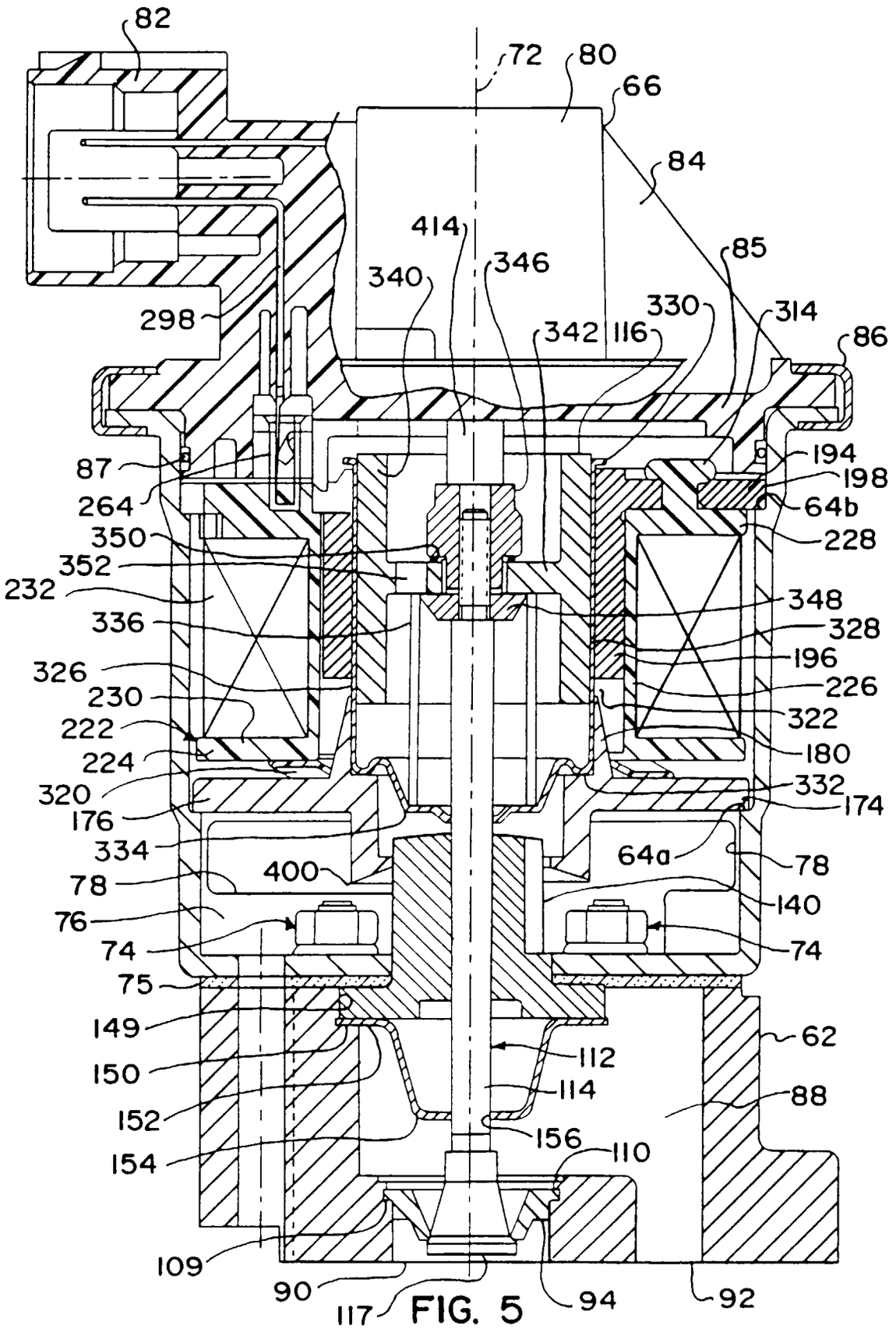

82
72
80
66
84
414
85
340
346
330
314
298
342
116
86
87
194
198
264
64b
350
228
352
232
348
336
328
196
326
226
230
322
222
180
224
320
332
174
176
334
64a
78
400
78
140
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FIG. 5

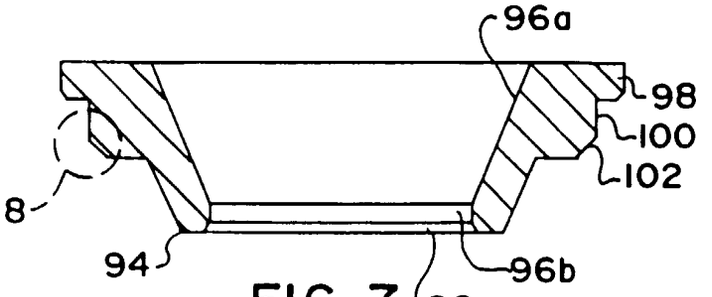


FIG. 7

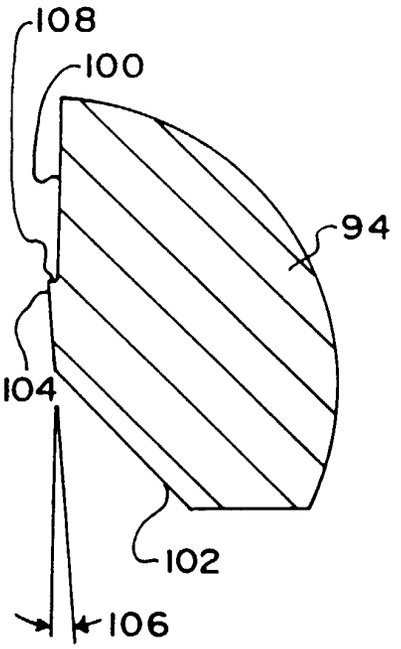


FIG. 8

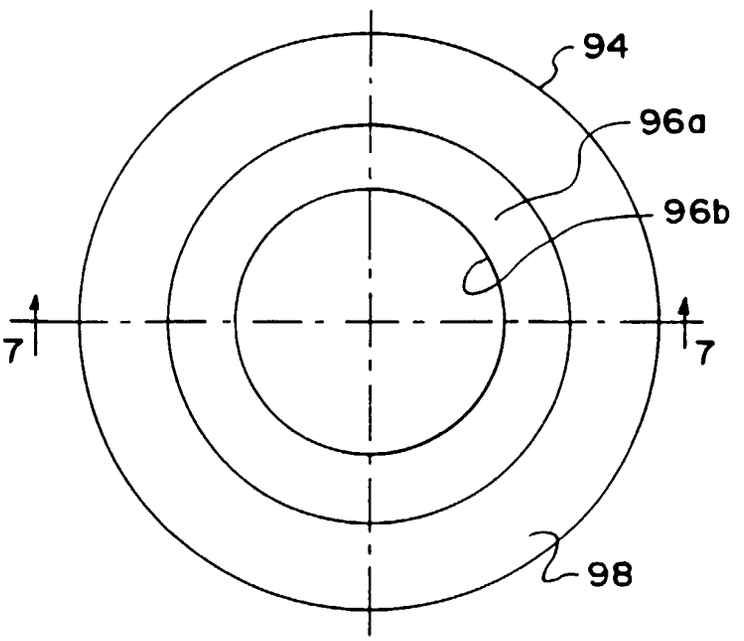


FIG. 6

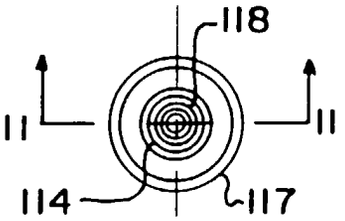


FIG. 10

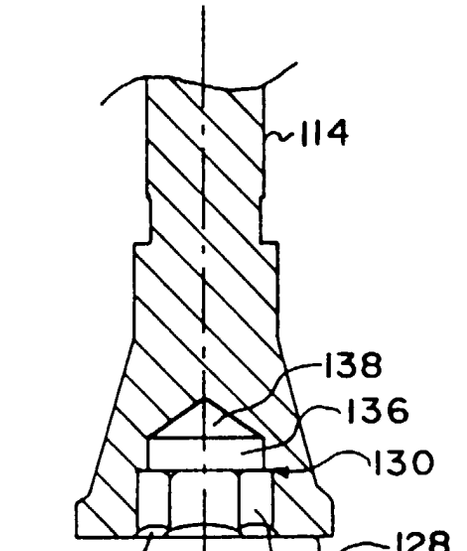


FIG. 11

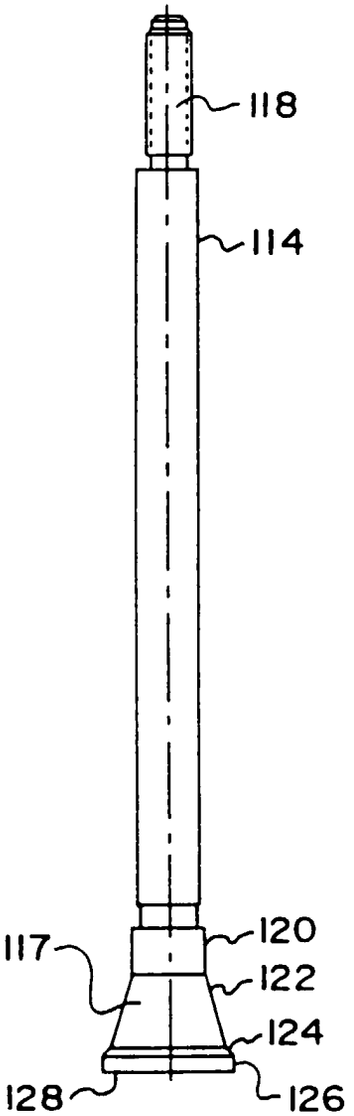


FIG. 9

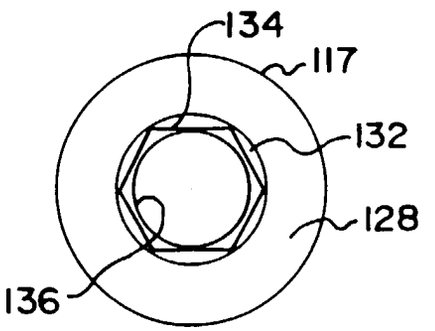


FIG. 12

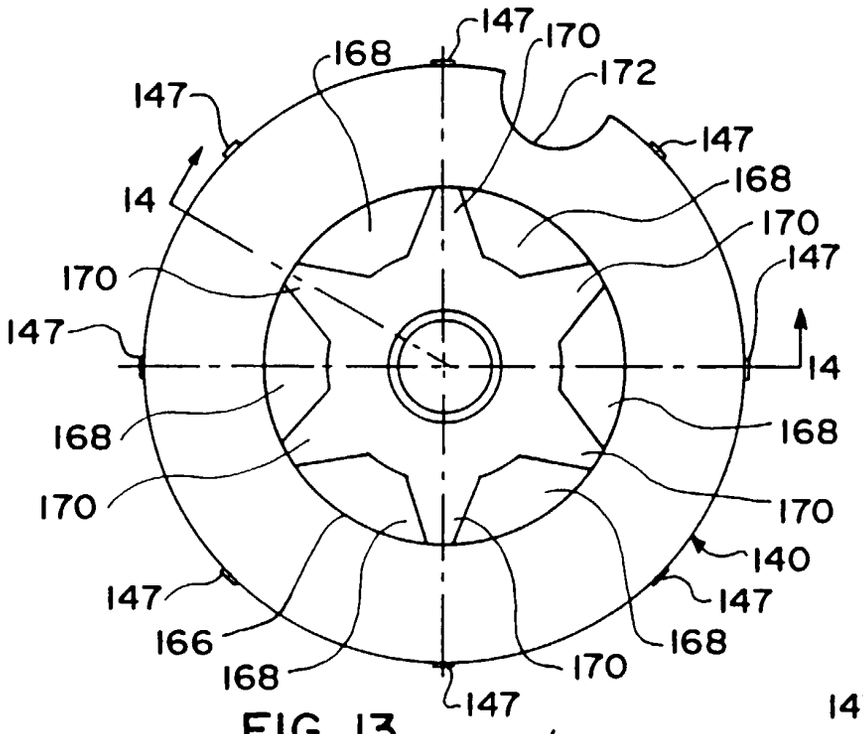


FIG. 13

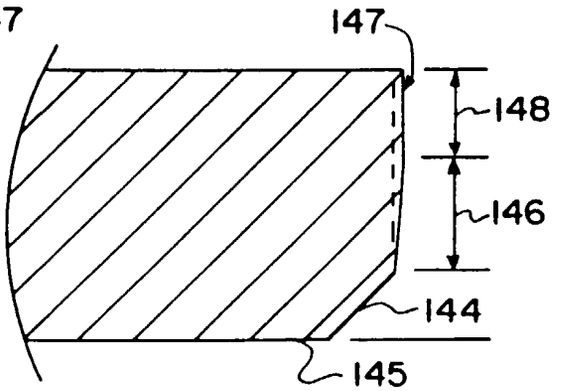


FIG. 15

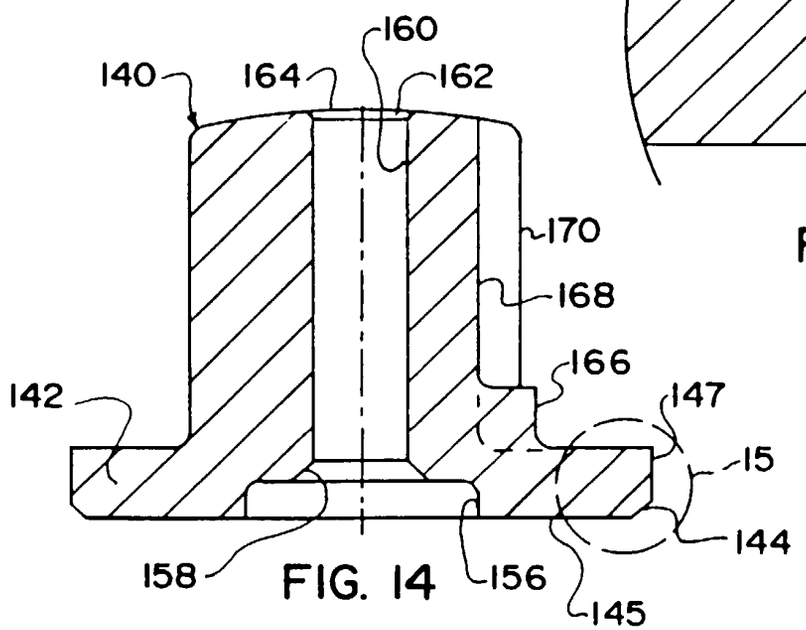


FIG. 14

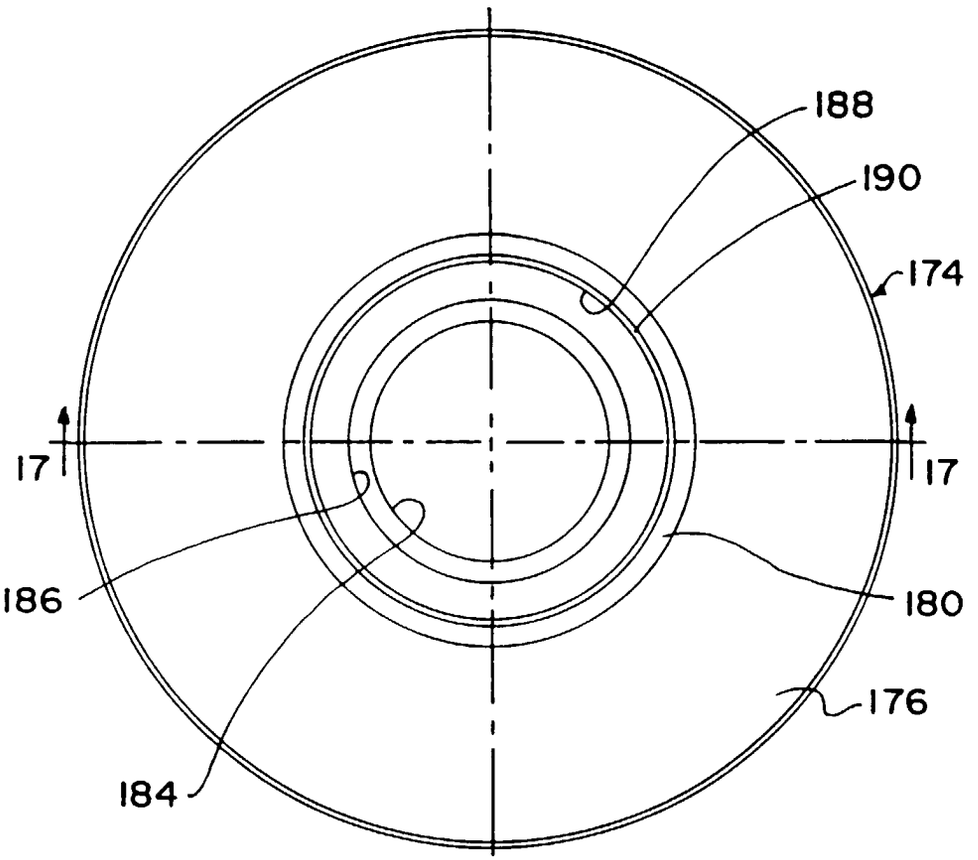

188
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174
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FIG. 16

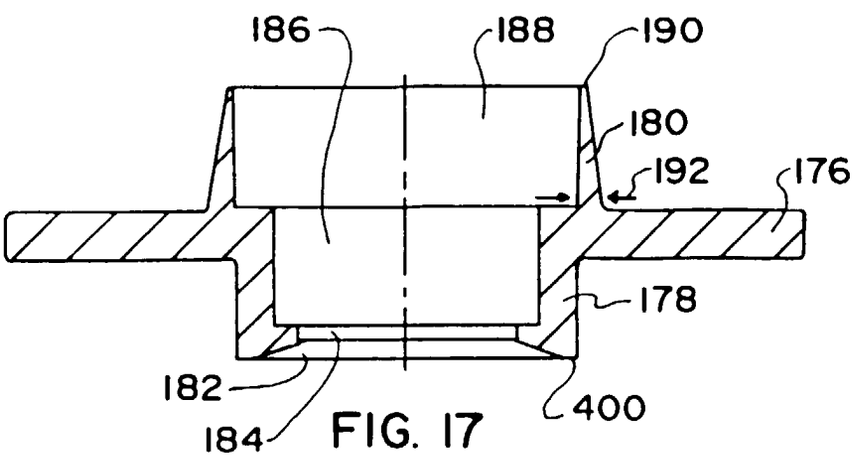

186
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182
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FIG. 17

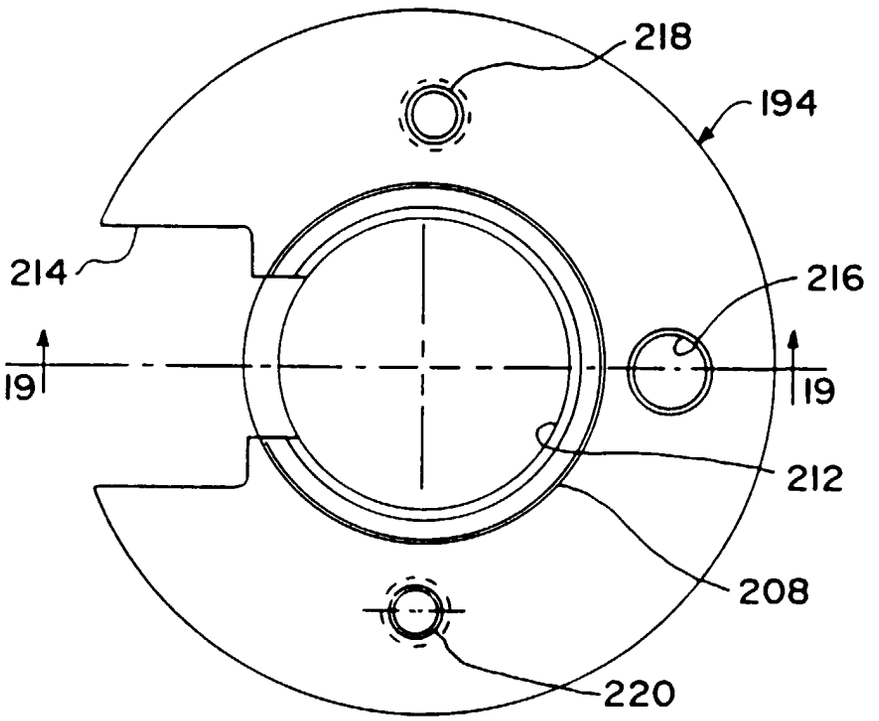


FIG. 18

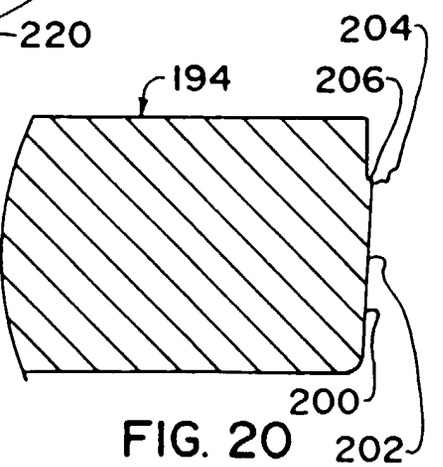


FIG. 20

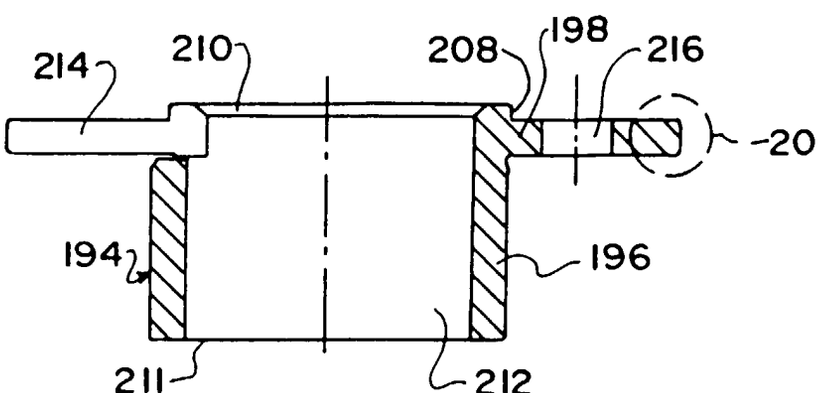


FIG. 19

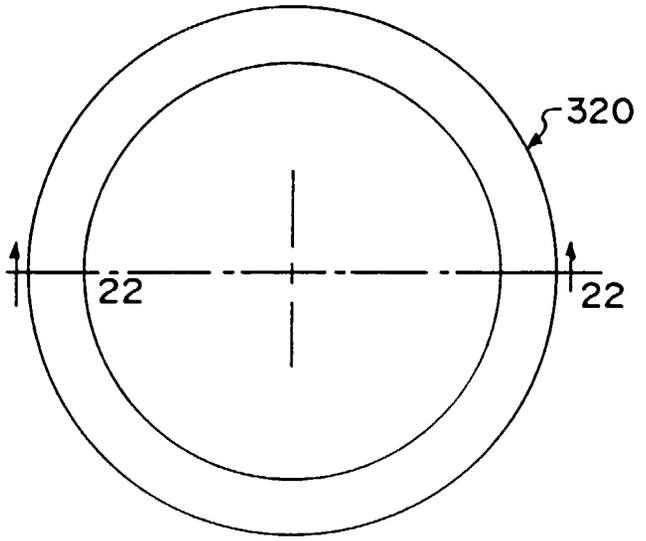


FIG. 21



FIG. 22

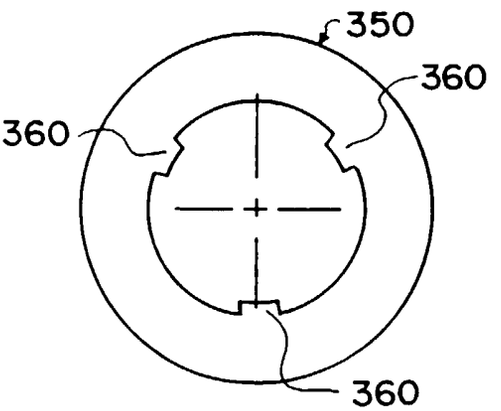


FIG. 23



FIG. 24

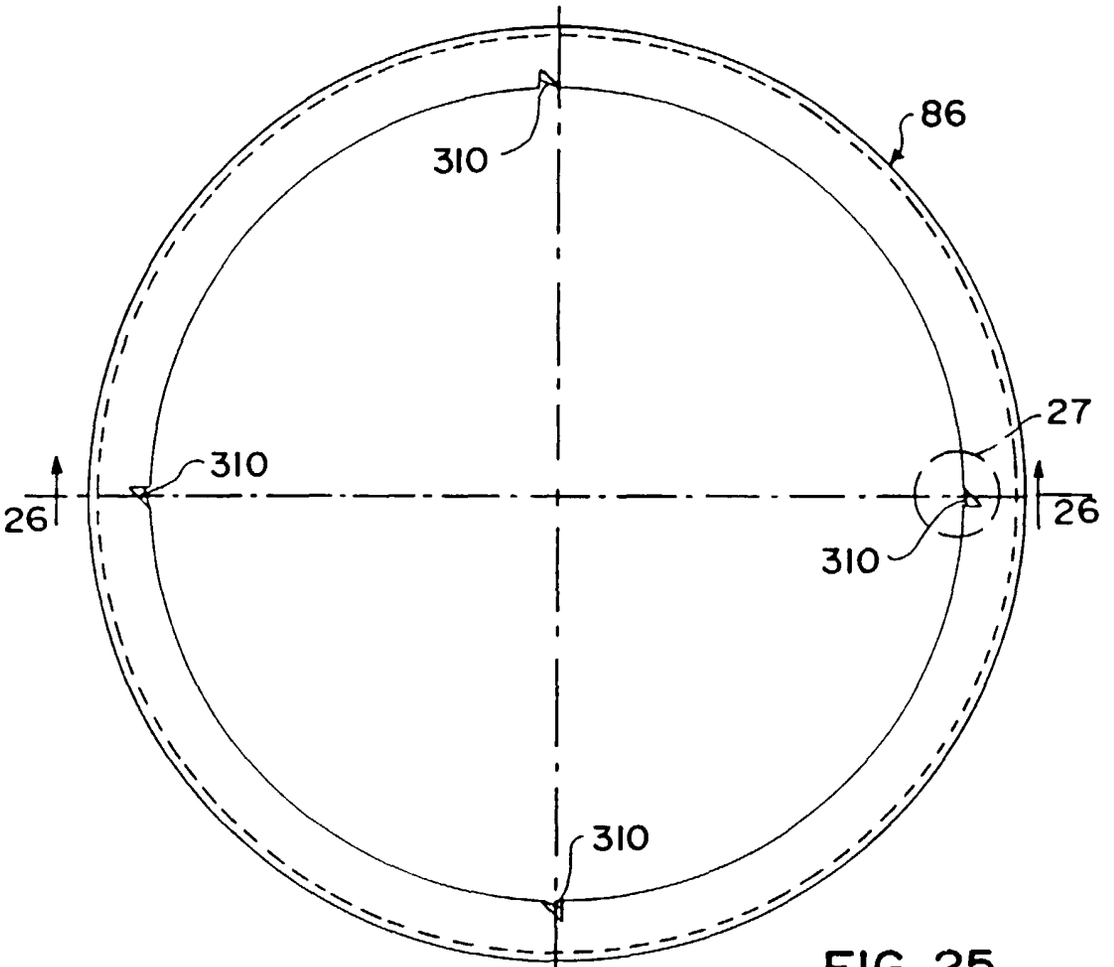


FIG. 25

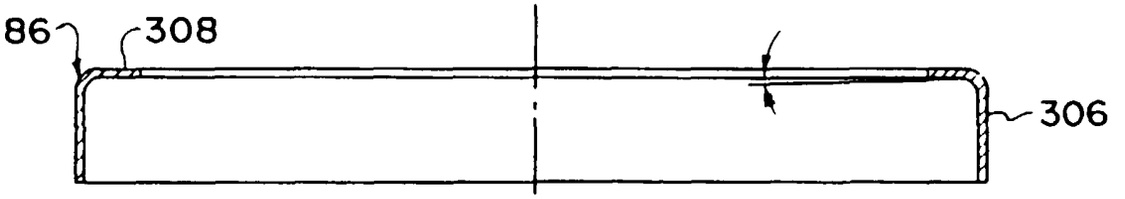


FIG. 26

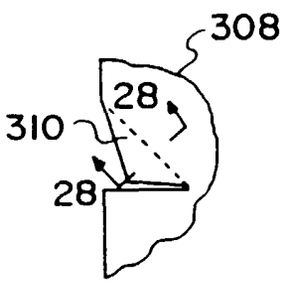


FIG. 27

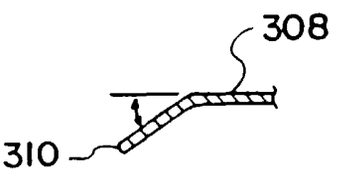


FIG. 28

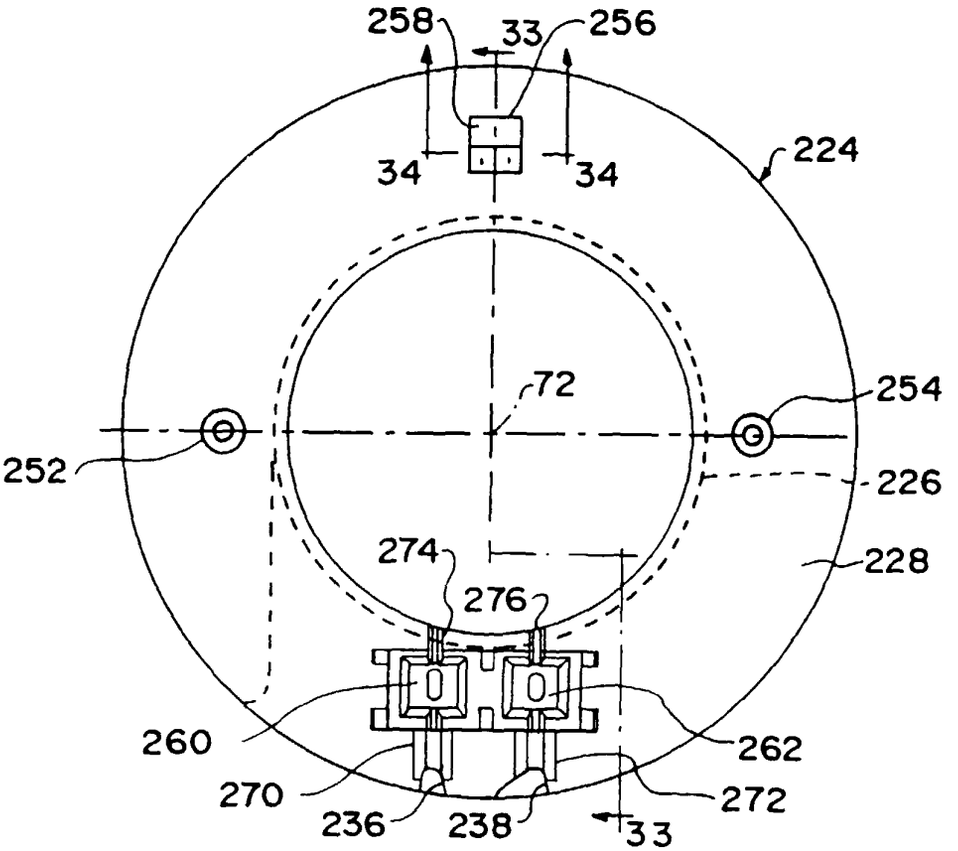

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FIG. 29

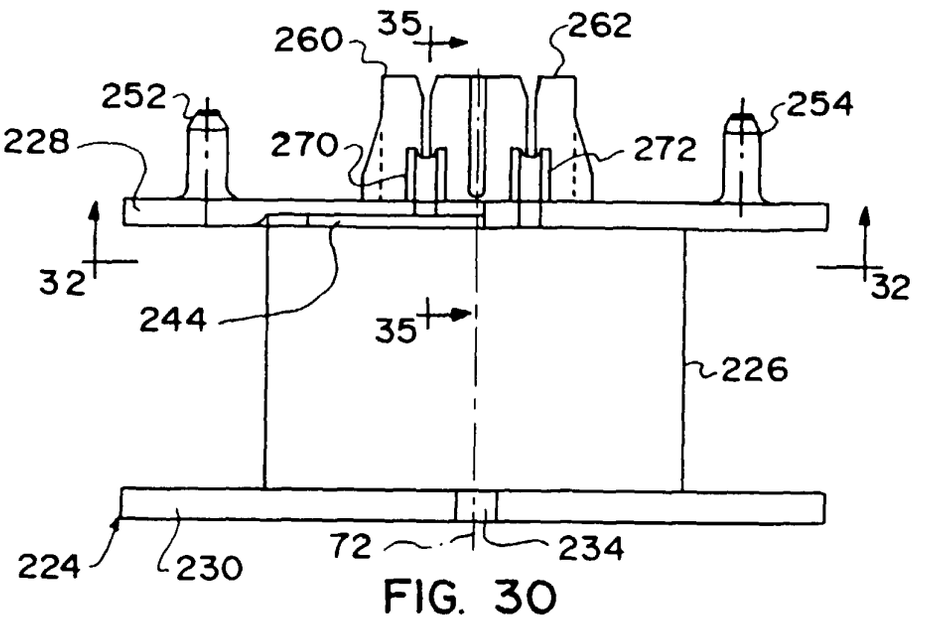

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FIG. 30

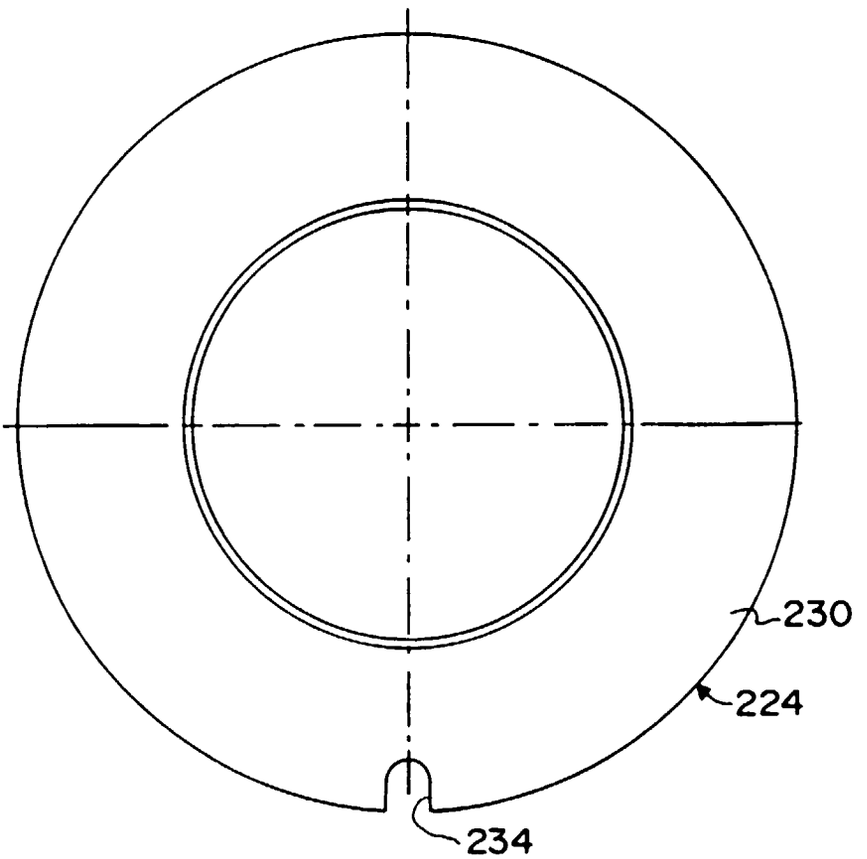


FIG. 31

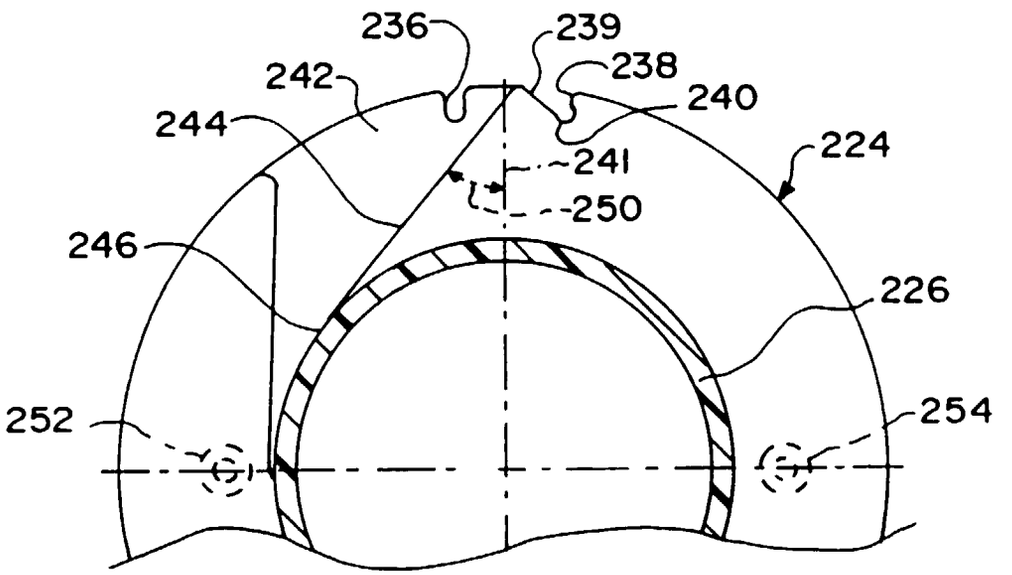


FIG. 32

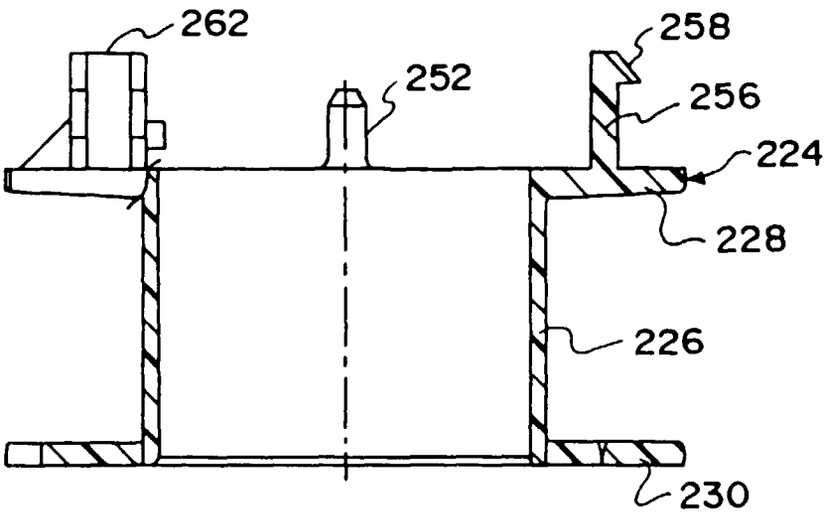


FIG. 33

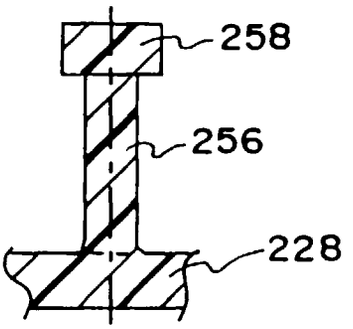


FIG. 34

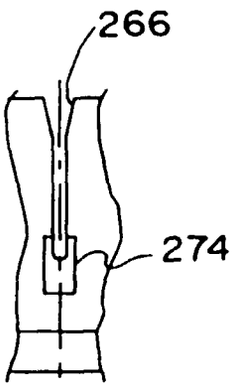


FIG. 36

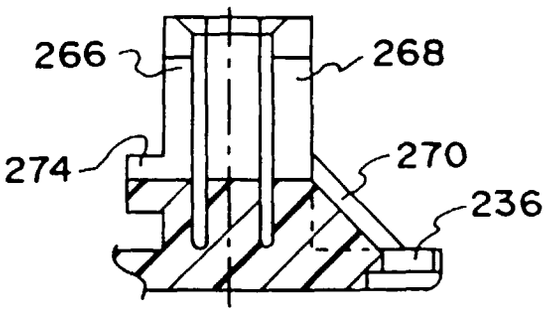


FIG. 35

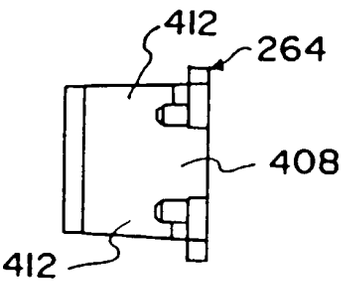


FIG. 38

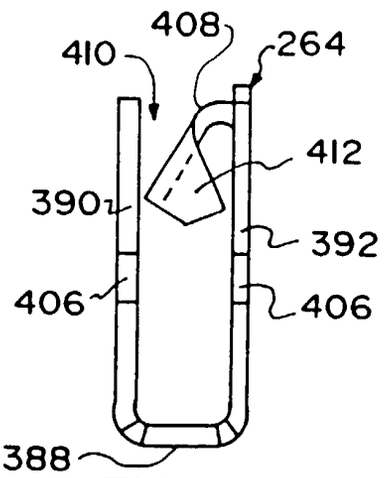


FIG. 37

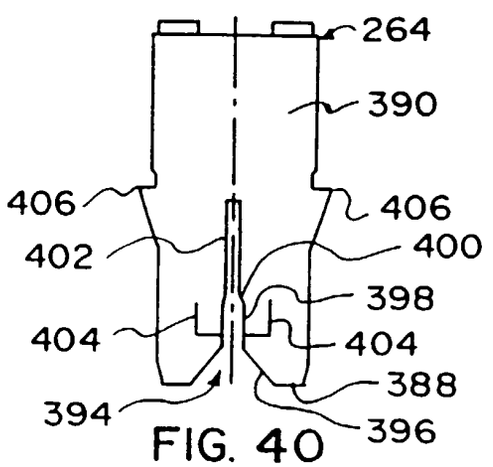


FIG. 40

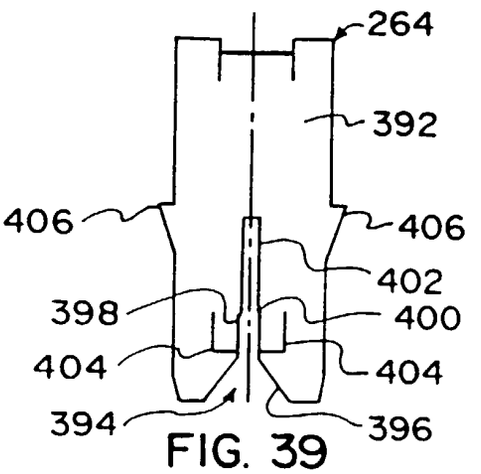


FIG. 39

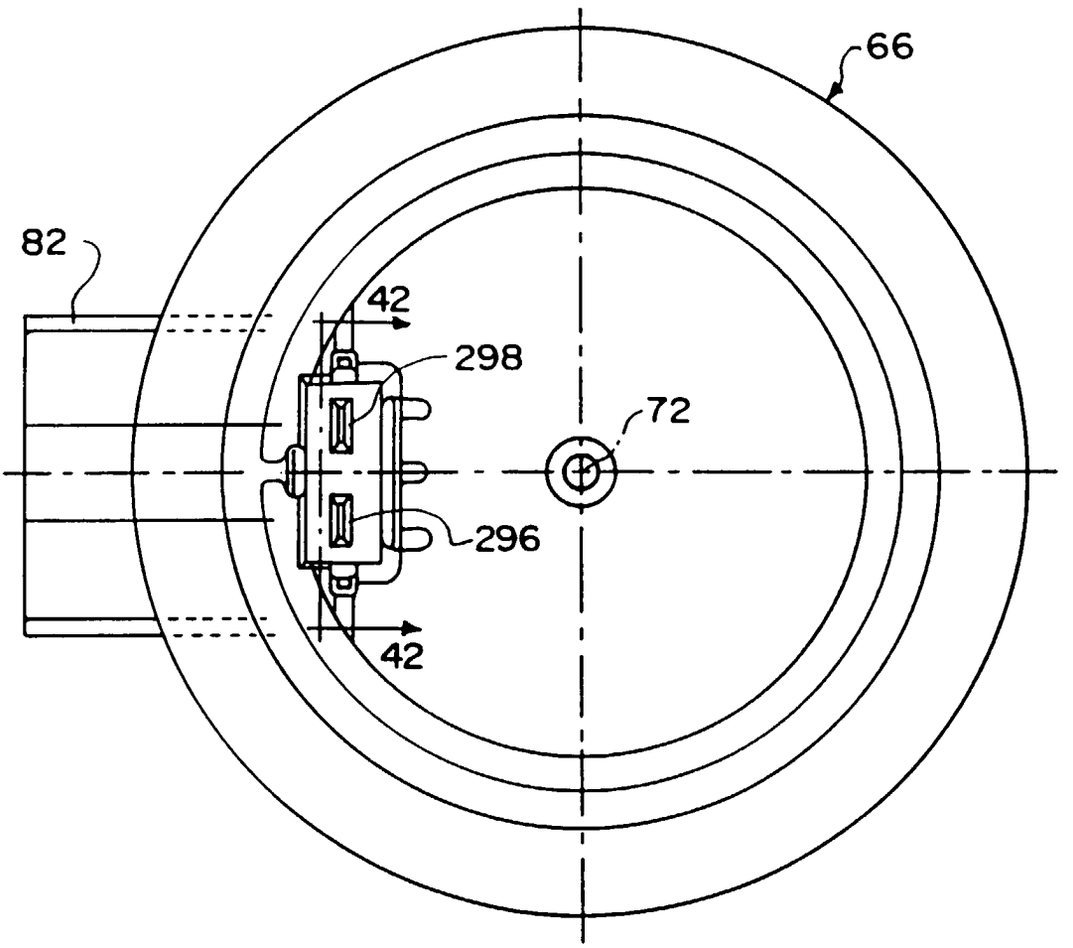


FIG. 41

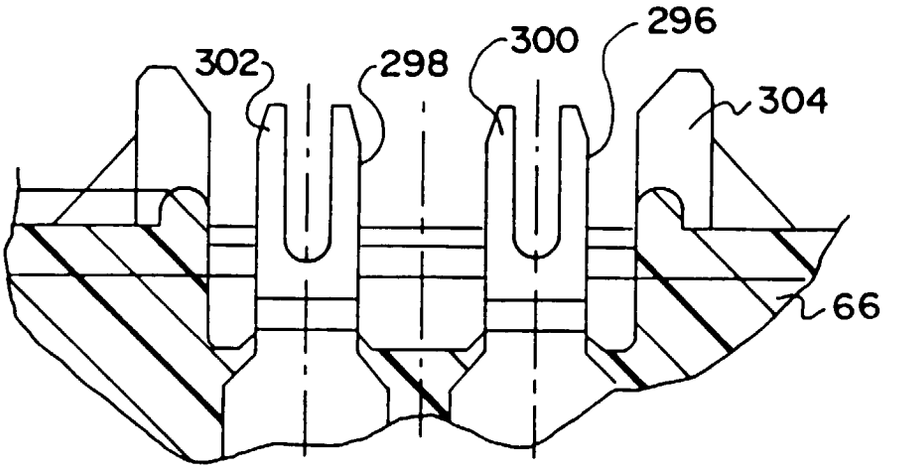


FIG. 42

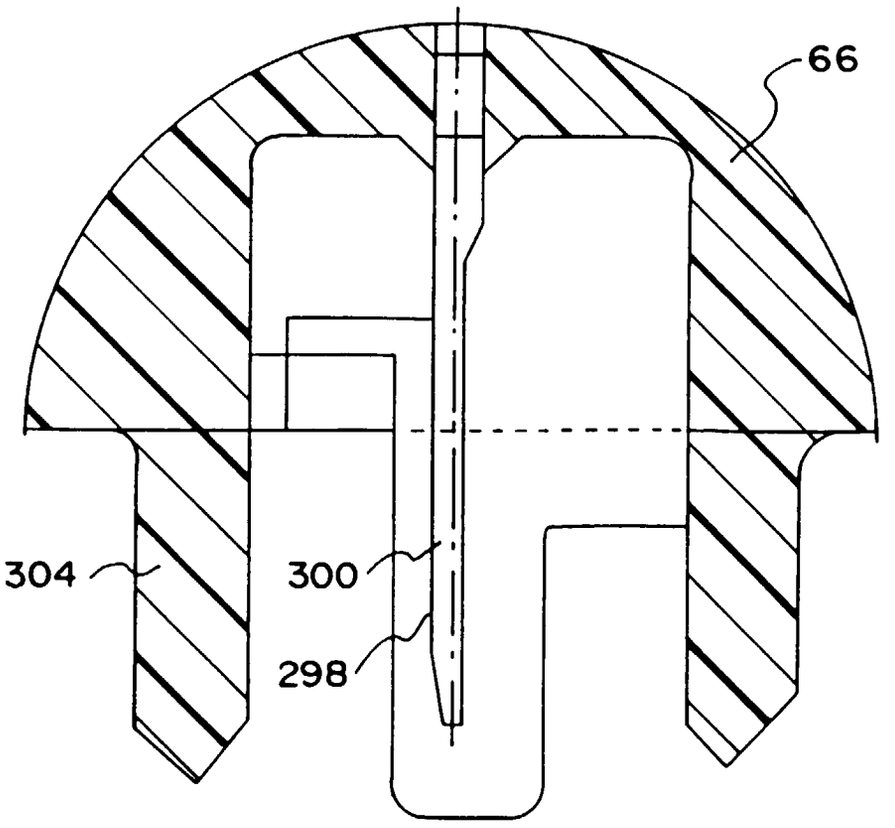


FIG. 43

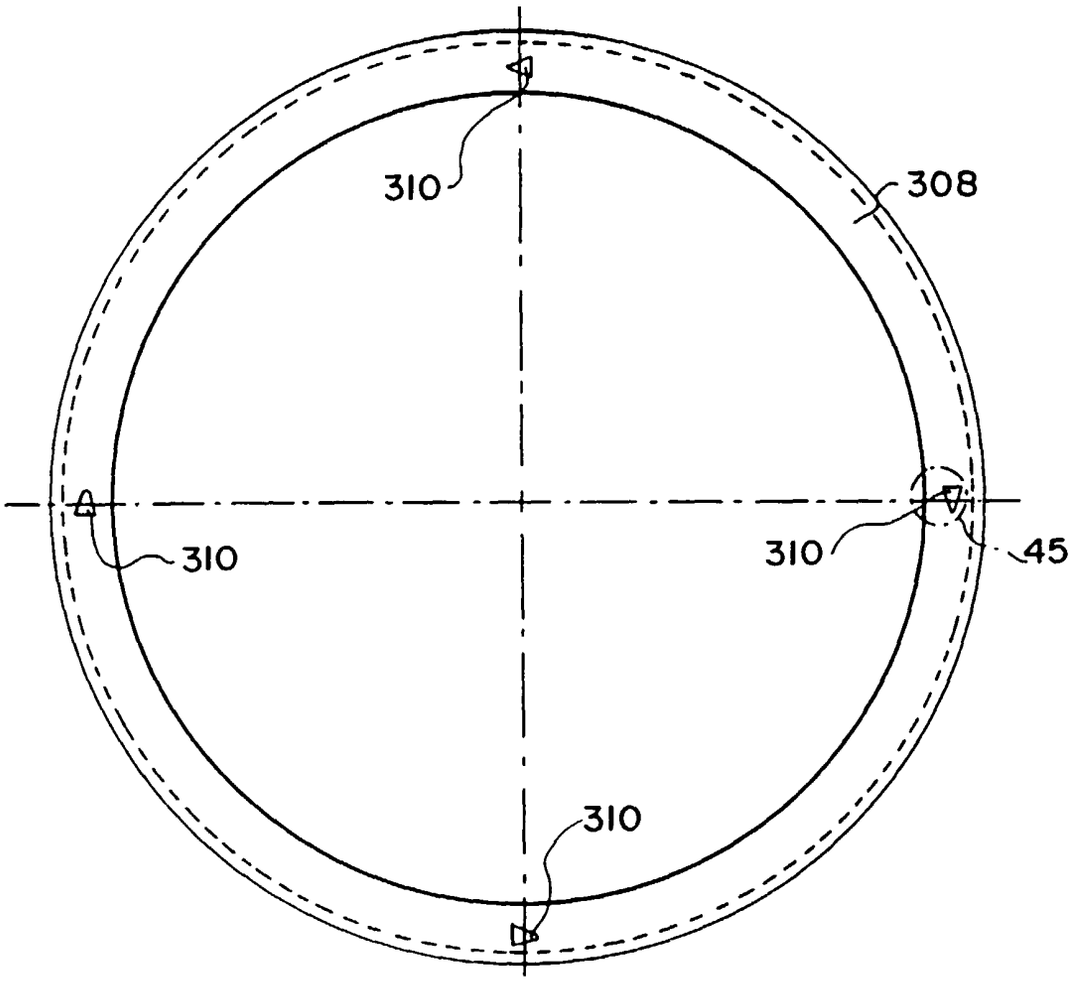


FIG. 44

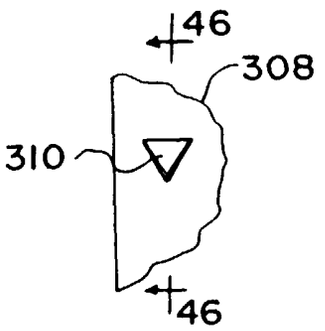


FIG. 45

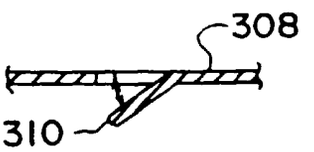


FIG. 46