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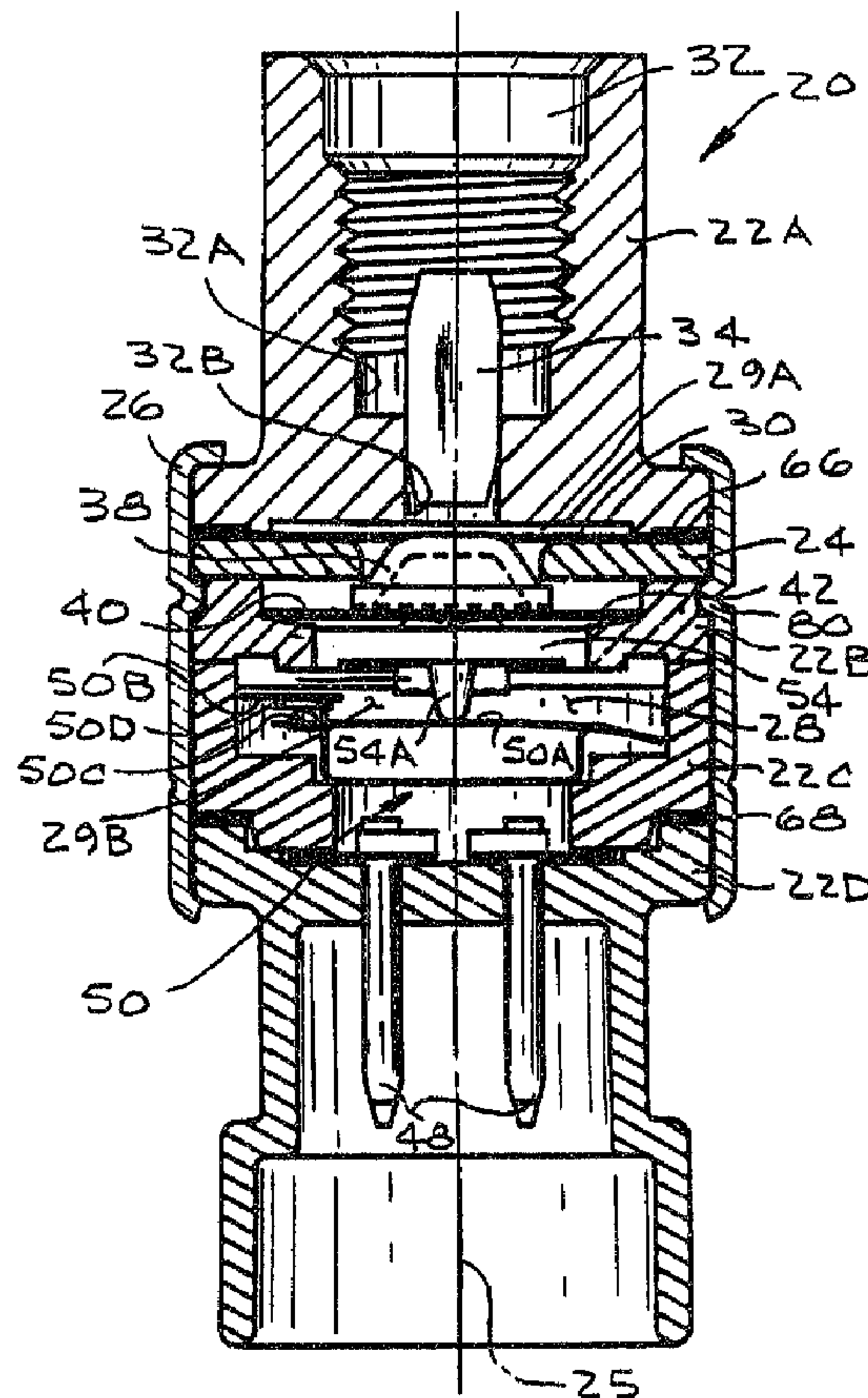
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(54) Titre : DISPOSITIF DE CONTROLE

(54) Title: CONTROL DEVICE



(57) Abrégé/Abstract:

A pressure sensitive control device having a housing made up of a plurality of housing members, a diaphragm, a bistable snap-disc, a switch and an actuator. The snap-disc moves from one configuration to another upon application of pressure over a

(57) Abrégé(suite)/Abstract(continued):

predetermined amount to drive the actuator which moves the switch from its normal operating position, which can be either closed or open, to a tripped position, which is opposite its normal operating position. Two adjacent housing members, which support the snap-disc and switch, respectively, are formed with cooperating spacers which allow the spacing of these housing members to be continuously varied over a small range of adjustment to allow the switch point of the control device to be adjusted after partial assembly of the control device. The diaphragm and some of the housing members may be subassembled for testing the components of the control device prior to complete assembly. The switch is initially formed as one piece and electrically halved after subassembly with one of the housing members. A housing member which is formed for connection to an electrical control circuit to which the control device is to be attached as modular and can be replaced with similar housing members which are configured for connection to different types of mating electrical connectors associated with different control circuits. Methods of assembly are also enclosed.

CONTROL DEVICE

Abstract of the Disclosure

A pressure sensitive control device having a housing made up of a plurality of housing members, a diaphragm, a bistable snap-disc, a switch and an actuator. The snap-disc moves from one configuration to another upon application of pressure over a predetermined amount to drive the actuator which moves the switch from its normal operating position, which can be either closed or open, to a tripped position, which is opposite its normal operating position. Two adjacent housing members, which support the snap-disc and switch, respectively, are formed with cooperating spacers which allow the spacing of these housing members to be continuously varied over a small range of adjustment to allow the switch point of the control device to be adjusted after partial assembly of the control device. The diaphragm and some of the housing members may be subassembled for testing the components of the control device prior to complete assembly. The switch is initially formed as one piece and electrically halved after subassembly with one of the housing members. A housing member which is formed for connection to an electrical control circuit to which the control device is to be attached is modular and can be replaced with similar housing members which are configured for connection to different types of mating electrical connectors associated with different control circuits.

Methods of assembly are also enclosed.

CONTROL DEVICE

Background of the Invention

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5 This invention relates generally to an electrical circuit control device and more particularly to fluid pressure actuated control device and a method of assembling such a control device.

10 Fluid pressure sensitive control devices typically include a housing having an opening for the communication of fluid pressure into the housing and a diaphragm which moves in response to the fluid pressure. A two position, bistable, snap-acting disc in the housing is movable, for example, from a generally convex configuration to a generally concave configuration upon application of sufficient pressure to the snap-disc from the diaphragm
15 for actuating a switch in the housing to open or to close an electrical circuit to which the control device is attached. The snap-disc moves back to its convex configuration when the pressure applied by the diaphragm falls below a certain predetermined value. Control devices
20 of the type to which this invention generally relates are used in automotive air conditioning systems to control the energization and deenergization of a clutch actuated compressor in response to a preselected low and high value of fluid pressure measured at a preselected point in the
25 system, such as in an accumulator in the system. Examples of control devices of the same general type as disclosed herein are disclosed in Poling, U.S. Patent No. 4,200,776, and Johnson, U.S. Patent No. 4,464,551.

30 The control device is constructed so that the switch is either opened or closed by action of the snap-disc upon the detection of a predetermined level of pressure in the fluid system. In either case, the control device should be set so that the switch point, that is, the

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instant when the switch first makes or breaks contact to shut or open the electrical circuit occurs when the snap-disc is between its convex and concave configurations. Should the switch point be too near the convex or concave configuration of the snap-disc, the switch tends to oscillate between its open and closed positions because of small movements of the snap-disc caused by a slow pressure build-up (or relief) in the control device. Most significantly, operating temperature conditions encountered by the control device and wear of parts over the life of the control device causes the switch point to drift toward the concave orientation of the snap-disc. Therefore, it is necessary to set the switch point nearer the convex position of the snap-disc to allow for this drift.

15 In production of control devices, properly setting the switch point is difficult because of the variations in component part sizes naturally arising from manufacturing tolerances for those parts. Presently, the switch point is set by attempting to hold part tolerances within limits which will result in the switch point being in one of an acceptable range of positions between the convex and concave configurations of the snap-disc. In some existing control devices, a one-way adjustment of the switch point can be made by fixing a pin in a position to engage a movable switch blade of the switch for applying a force to the switch blade in a direction opposite the force transmitted to the switch blade from the snap-disc. The application of this force by the pin adjusts the location of the switch point. Setting the switch point is a delicate procedure involving only a small range of appropriate positions of the pin. An important disadvantage of this approach is that the pin can only be moved in one direction, toward the switch blade. Thus, an overcorrection of the switch point cannot be remedied. In

addition, this approach causes the switch blade to be subject to increased stress, thereby reducing its operating life.

Control devices must have the appropriate connection to the particular electrical control circuit to which they are to be attached. While the interior workings of the control device may be the same for various types of control circuits, changing the connector portion of the device requires a considerable expenditure of time and money because the housing is formed as one piece. Moreover, prior control devices do not allow the device to be tested prior to complete assembly. Thus, a defective diaphragm is not discovered until the device has been completely assembled, requiring that the device either be disassembled or discarded in its entirety.

Further difficulties in assembly of existing control devices occur because the switch is assembled as two separate pieces, one of which is a movable switch blade and the other of which is a stationary contact support having a contact engageable by a contact on the switch blade to close the switch. Although separation of the switch blade and the contact support is necessary in the device so that completion of the electric circuit is made only when the contact on the switch blade engages the contact on the contact support, the additional separate parts complicates and slows down assembly of the control device. In addition, proper alignment of the contact on the stationary contact support and the contact on the switch blade is difficult to attain.

30 Summary of the Invention

Among the several objects and features of the present invention may be noted the provision of a control device constructed from standard components which may be

easily and precisely adjusted to vary the switch point; the provision of such a control device which can be easily reconfigured for connection to different types of electrical connectors; the provision of such a control
5 device which is readily capable of subassembly for testing component parts; the provision of such a control device which may be quickly assembled from fewer component parts; the provision of such a control device which can be easily and quickly assembled with the contacts of the switch in
10 alignment; and the provision of such a control device employing component parts which are simple in design, and economically manufactured.

Further among the several objects and features of the present invention may be noted the provision of a
15 method of assembling a control device which produces a subassembly prior to completion which can be tested; the provision of such a method of assembly which allows the control device to be configured for connection to different electrical connectors by replacement of one modular
20 component thereof; the provision of such a method of assembly which can be accomplished quickly and accurately.

In general, a control device constructed according to the principles of the present invention comprises a housing having a cavity therein and a central
25 longitudinal axis, the housing including first and second housing members having openings therein defining a portion of the cavity. The housing members are generally adjacent each other and selectively positionable relative each other generally axially of the housing at locations from a first
30 position in which the first and second housing members are closest together, to a second position in which the first and second housing members are furthest apart. A diaphragm disposed in the cavity divides the cavity into a pair of chambers, and a control port in one end of the housing

opens into one of the chambers for communicating fluid pressure into the one chamber. A snap-action member operable between a first and a second configuration is supported by the housing in the cavity, and spans at least
5 in part across the other chamber. The snap-action member is adapted movement conjointly with the first housing member. A pair of terminal means are mounted in the housing generally adjacent the end of the housing opposite the control port. Switch means is disposed in the cavity
10 and movable conjointly with the second housing member such that the selected spacing between the first and second housing members corresponds to the spacing between the switch means and the snap-action means. The switch means includes a resilient switch blade electrically connected to
15 one of the terminal means and a stationary contact support portion electrically connected to the other terminal means. The switch blade is adapted for motion between a closed position in which the switch blade engages the contact portion and an open position in which the switch
20 blade does not engage the contact portion. The switch blade is biased in a normal operating position selected from one of the closed and open positions. Interposed between the snap-action member and the switch blade and movable generally axially of the housing upon operation of
25 the snap-action member toward the second configuration is actuator means for moving the switch blade between the normal operating position in which the switch blade is in one of the open and closed positions and a trip position in which the switch blade is in the other of the open and
30 closed positions.

In another aspect of the present invention, a control device having a diaphragm, snap-action member, switch means and actuator means as described above, wherein the housing includes an input housing member disposed

generally at one end of the control device, a connector housing member disposed generally at the opposite end of the device and intermediate housing member disposed intermediate the input and connector housing members.

- 5 Holding means comprising a tubular sleeve adapted to receive the intermediate housing member and at least a portion of the housing members therein. The sleeve is made of a plastically deformable material so that the sleeve may be deformed into engagement with at least one of the
- 10 housing members after reception in the sleeve of the housing members for holding the housing members in substantially fixed relation relative one another.

Further in regard to the present invention, a control device having housing with a cavity and a central

15 longitudinal axis, and a diaphragm, snap-action member, actuator means and switch means substantially as described above. The switch means described is initially formed as one piece and comprises a frangible portion connecting the switch blade and the stationary contact support portion

20 upon formation of the switch means which is adapted to be broken after assembly of the switch means in the housing to break electrical connection between the switch blade and the contact portion.

Still further in regard to the present invention,

25 a method of assembling a pressure responsive control device including the step of providing housing including an input housing member having a control port therein adapted to transmit fluid pressure into the housing, an intermediate housing member, and an electrical connector housing member

30 adapted for connecting the control device to an electrical circuit exterior the control device. Means for holding the housing members together in a substantially fixed relationship relative each other, a diaphragm, switch means and actuating means for operating the switch means in

response to movement of the diaphragm are also provided. The input housing member, diaphragm and intermediate housing member are secured with the holding means together in sealing relation to form a subassembly which is tested
5 for leakage. To complete the assembly, the switch means, and the remaining housing members are secured with the holding means.

In yet another aspect of the present invention, a method of assembling a control device including steps of
10 providing the housing members, diaphragm, holding means, switch means and actuating means as described above. Assembly is continued by securing together the housing members except the connector housing member with the holding means, with the diaphragm, the switch means and the
15 actuating means being supported in the housing by the housing members. One electrical connector housing member is selected from a plurality of connector housing members, which connector housing member is constructed for connection to the particular control circuit. The selected
20 connector housing member is then secured by the holding means in substantially fixed relation to the other housing members.

Other objects and features of the present invention will be in part apparent and in part pointed out
25 hereinafter.

Brief Description of the Drawings

FIG. 1 is a longitudinal section of a control device of the present invention as assembled;

FIG. 2 is an exploded longitudinal section of the
30 control device illustrating its assembly;

FIG. 3 is a longitudinal section of a subassembly of the control device;

FIG. 4 is an elevation of first and second housing members of the control device;

FIG. 5 is a bottom plan of the first housing member;

5 FIG. 6 is a top plan of a switch prior to assembly in the control device;

FIG. 7 is a longitudinal section of the second housing member showing a switch of a second configuration as supported therein;

10 FIG. 8 is a bottom plan of the second housing member;

FIG. 9 is an elevation of the control device turned 90 degrees from its position in Fig. 1, with part of the device broken away to show details;

15 FIG. 10 is a fragmentary section of a connector pin in the second housing member; and

FIG. 11 is a control device of a second embodiment of the present invention for use in low pressure applications.

20 Corresponding reference characters indicate corresponding parts throughout the several views of the drawings.

Detailed Description of a Preferred Embodiment

Referring now to the drawings, and in particular to Fig. 1, a control device indicated generally at 20 is shown to include a housing formed from housing members 22A-22D and metal washer 24, and having a central longitudinal axis 25. The housing members 22A-22D and metal washer 24 are held together in substantially fixed relation relative each other in a tubular sleeve 26. More particularly, the housing members include an input nut 22A, an annular snap-disc support housing member 22B (broadly "first housing member"), a switch support housing member

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22C (broadly "second housing member"), and an electrical connector housing member 22D. As assembled, the housing members 22A-22D and washer 24 define a cavity 28 extending longitudinally between the input nut 22A and the connector housing member 22D. A diaphragm 30 comprising a circular disc of flexible material such as plastic is clamped at its peripheral edge margins between the input nut 22A and the metal washer 24. The diaphragm 30 divides the cavity 28 into two chambers, the first chamber 29A being the thin space between the diaphragm 30 and the input nut 22A and the second chamber 29B being the remaining portion of the cavity 28 below (as seen in Fig. 1) the diaphragm. The input nut 22A has been counterbored to form a control port 32 having an outer section 32A formed with threads for connection to a fluid (i.e., gas or liquid) system such as an automotive air conditioning system (not shown), and a narrow inner section 32B which opens into the first chamber 29A for communicating fluid pressure from the system to the first chamber. A valve actuator 34 held in the inner section 32B of the control port is capable of engaging and actuating a check valve (not shown) of a fluid system for opening the check valve and allowing fluid to enter the control device 20.

Communication of fluid pressure from the fluid system to the first chamber 29A results in a pressure differential between the first and second chambers 29A, 29B across the diaphragm 30 which presses against an inverted, cup-shaped force transmitting member 38 located between and engaging the diaphragm and a snap-disc 40 (broadly "snap-action member"). The snap-disc 40 is circular and supported at its peripheral edge margins by an annular ledge 42 in the snap-disc support housing member 22B such that the snap-disc spans across the second chamber 29B of the cavity. The snap-disc 40 is operable between two

configurations, a convex (or "first") configuration in which the disc bows outwardly away from the switch support housing member 22C, and a concave (or "second") configuration in which the snap-disc bows inwardly toward the switch support housing member 22C.

The snap-disc is shown in its convex configuration in Figs. 3 and 11, and in an unstable configuration intermediate its convex and concave configuration in Figs. 1 and 9. Movement of the snap-disc from the convex configuration to the concave configuration is produced by the application of pressure to the snap-disc from the diaphragm 30 through the force transmitting member 38. The metal washer 24 and force transmitting member 38 operate to proportionately reduce the force applied to the snap-disc 40 as a result of the pressure in the first chamber 29A. It is to be understood that other snap-action devices, including but not limited to an annular snap action member or Belleville spring, or a spider or spoke type snap-action member may be used and still fall within the scope of the present invention. The ledge 42 is generally frustoconically shaped, sloping toward the switch support housing member 22C away from the periphery of the ledge to facilitate the movement of the snap-disc 40 to its concave configuration. However, the control device will function with the ledge 42 having shapes other than frustoconical.

A pair of terminal pins 48 are mounted on and extend through the inner end of the electrical connector housing member 22D. The opposite end of the connector housing 22D is open for receiving an electrical connector of a control circuit of apparatus (not shown) to be controlled by the control device (e.g., the compressor of an automotive air conditioning system). The type of connector housing 22D required may differ depending upon

the specific type of electrical connector to which the control device 20 must be connected. As explained more fully below, the control device of the present invention is constructed for quick and easy changeover to accommodate
5 different types of electrical connectors. A switch 50 held in the switch support housing member 22C includes a resilient switch blade 50A and a stationary contact support portion 50B. The switch blade 50A is a cantilevered arm extending across the second chamber 29B and has a contact
10 50C at its free end aligned with a contact 50D on the stationary contact support portion 50B. The switch blade is permanently electrically connected to one of the terminal pins 48, and the contact support portion 50B is permanently electrically connected to the other terminal
15 pin. To selectively achieve electrical connection between the terminal pins 48, thereby completing the electrical circuit to which the control device is attached, the switch blade 50A is movable between an open position in which the outer end of the switch blade is spaced from the contact
20 support portion and the contacts 50C, 50D are not engaged, and a closed position in which the contact 50C of the switch blade engages the contact 50D of the contact support portion. The switch 50 has a normal operating position which is either closed (as shown in Fig. 1), or open (as
25 shown in Fig. 7). In either case, the switch blade 50A is biased by its own resiliency toward the normal operating position.

A disc-shaped actuator 54 is slidably received in the snap-disc support housing member 22B for movement
30 axially of the housing. A finger 54A of the actuator 54 projects toward and engages the switch blade 50A of the switch, and the opposite end of the actuator engages the snap-disc 40. The actuator 54 moves toward the switch upon the operation of the snap-disc to its concave

configuration, with the finger 54A pushing the switch blade 50A away from its normal operating position in which the switch 50 is either opened or closed, to a trip position in which the switch is in the opposite position. The

5 snap-disc 40 is operable to its concave configuration only when the pressure transmitted from the diaphragm 30 through the force transmitting member 38 to the snap-disc reaches or exceeds a certain predetermined value. As illustrated in Figs. 1 and 9, the snap-disc 40 is in an unstable
10 configuration corresponding to the point where the actuator 54 causes the switch blade 50A to break the engagement of the contacts 50C, 50D (i.e., the "switch point").

In the control device 20 described herein, the pressure value triggering operation of the snap-disc 40 may
15 be increased upon assembly about 2 psi to 30 psi from the natural sensitivity pressure of the snap-disc. However, the precise range of pressure sensitivity variation may be other than 2-30 psi and still fall within the scope of the present invention. Pressure sensitivity of the control
20 device may be adjusted with a spring regulator 58 (Fig. 9) including a thin, inverted V-shaped spring 58A having an opening in its center through which is received the finger 54A of the actuator 54. The spring 58A biases the actuator upwardly against the snap-disc 40 thereby increasing the
25 pressure necessary to operate the snap-disc from its convex configuration to its concave configuration. Referring to Fig. 9, the spring 58A is supported at its right end in a recess 60 formed in the switch support housing member 22C, and at its left end on a set pin 58B held by a friction fit
30 in a hole 62 through the switch support housing member. The biasing force the spring 58A exerts against the actuator 54 and hence against the snap-disc 40 may be set after assembly in the sleeve 26 by fixing the set pin 58B in the hole 62 with a selected amount of the set pin

extending inwardly into the second chamber 29B from the hole. The further the set pin 58 extends from the hole 62, the closer it is to the snap-disc 40 and the greater the force exerted by the spring 58A against the actuator 54 and the snap-disc 40.

To seal the housing, the input nut 22A, diaphragm 30 and washer 24 are sealed with each other and with the sleeve 26 by a first annular gasket 66 received in an annular rabbet in the inner end of the input nut. The first gasket 66 is squeezed between the input nut 22A, and the diaphragm 30 and washer 24, and forced outwardly against the sleeve 26. A second annular gasket 68 is located between the switch support housing member 22C and the electrical connector housing member 22D for sealing between them and also sealing with the sleeve 26. The second gasket 68 serves to keep moisture and other contaminants out of the second chamber 29B of the housing.

The control device 20 of the present invention is constructed to allow the switch point of the switch 50 to be set at one of a plurality of positions upon assembly of the control device. The switch point is determined by the separation of the snap-disc 40 from the switch blade 50A. To that end, the snap-disc support housing member 22B and the switch support housing member 22C are positionable relative each other axially of the housing. The snap-disc 40 and the switch 50 are movable conjointly with the snap-disc support housing member 22B and switch support housing member 22C, respectively. As shown in Figs. 4 and 5, the snap-disc support housing member 22B is formed with three arcuate ramps 72 (broadly "first spacer means") extending along the periphery of the of the housing member. Each ramp 72 is an arcuate, elongate strip formed as one piece with the snap-disc support housing member 22B which projects outwardly from one end 72A of the ramp where

the strip is generally flush with the peripheral edge margin of the snap-disc support housing member, to a position at an opposite end 72B of the ramp which is axially spaced from the peripheral edge margin of the housing member. In the preferred embodiment, three studs 74 (broadly "second spacer means") formed as one piece with the switch support housing member 22C are radially aligned for engagement with respective ramps 72. By changing the angular orientation of the snap-disc support housing member 22B and the switch support housing member 22C relative each other about the central longitudinal axis 25, the location of engagement of the studs 74 along the ramps 72 can be changed. As shown in Fig. 4, the housing members 22B, 22C are oriented so that the studs 74 rest on the portion of the ramp 72 furthest away from the remainder of the snap-disc support housing member so that maximum separation of the housing members is attained. The separation may be selectively reduced from that shown in Fig. 4 by turning the snap-disc support housing member 22B relative the switch support housing member 22C so that the studs 74 engage a different portion of the ramp closer to the snap-disc support housing member 22C. Minimum separation may be achieved by turning the housing members 22B, 22C so that the studs 74 engage the flat peripheral edge margins of the snap-disc support housing member 22B between the ramps 72.

It is envisioned that the means for adjusting the spacing between the snap-disc support housing member 22B and the switch support housing member 22C may take on other forms. For example, the studs 74 on the switch support housing member 22C may be replaced by ramps (not shown) similar to the ramps 72 on the snap-disc support housing member 22B. The ramps on the switch support housing member 22C would be constructed for cooperatively engaging the

ramps 72 on the snap-disc support housing member 22B so that rotation of the housing members 22B, 22C relative each other would vary the separation of the housing members, and thus the switch point.

5 Referring to Fig. 2, the control device 20 of the present invention is designed for quick and easy assembly, and changeover flexibility to produce a control device needed to fit into a particular fluid system. Moreover, the control device is assembled so that during the ordinary
10 course of assembly, a subassembly may be formed and tested prior to completion of the control device assembly. The tubular sleeve 26 is made of a ductile material, such as aluminum, so that it may be crimped to engage and hold the housing members 22A-22D together in a generally fixed
15 relation with respect to each other. In the preferred embodiment, the opening in one end of the tubular sleeve 26 is smaller than the opening in the other end. The input housing member 22A, first gasket 66, diaphragm 30 and metal washer 24 are inserted in that order through the larger
20 opening at the opposite end of the tubular sleeve 26. For the high pressure configuration of the control device 20 shown in Fig. 3, the metal washer 24 constitutes an "intermediate housing member". The end of the sleeve 26 having the smaller opening retains these control device
25 components in the sleeve with the input member 22A projecting axially out of the sleeve at the folded end. An annular crimp 80 is formed in the sleeve 26 which engages the washer 24 to form a subassembly of the input nut 22A, diaphragm 30 and washer (Fig. 4). The input nut 22A may
30 then be attached to a fluid pressure source to test the diaphragm 30 and the seal of the first gasket 66 prior to complete assembly of the control device.

After testing the subassembly, assembly of the control device 20 continues by inserting the force

transmitting member 38, snap-disc 40 and snap-disc support housing member 22B, and actuator 54 into the sleeve 26. The force transmitting member 38, snap-disc 40 and actuator 54 constitute "actuating means". These components are followed by the switch support housing member 22C preassembled with the switch 50. The switch support housing member 22C also carries the spring 58A and set pin 58B, for adjusting the pressure sensitivity of the control device upon assembly. At this time, the switch point of the control device may be set by rotating the snap-disc and switch support housing members 22B, 22C relative each other and repeatedly tripping the control device switch 50 until the switch point is appropriately set between the convex and concave configurations of the snap-disc 40. The second gasket 68 and the connector housing member 22D are then inserted into the sleeve 26. A second annular crimp 82 is formed in the sleeve 26 which engages and holds the switch support housing member 22C, and the end of the sleeve opposite the input nut is deformed against the electrical connector housing member 22D, thereby securing the housing members 22A-22D and other internal components. The precise order of many of the steps may be varied without departing from the scope of the invention.

An alternative configuration of the subassembly is shown in Fig. 11, which shows a subassembly of a control device used for low pressure (i.e., approximately less than 100 psi) applications. The control device shown in Figs. 1-10 and discussed above is used for high pressure applications and includes the metal washer 24 and the force transmitting member 38 which operate to reduce the force transmitted from the diaphragm to the snap-disc 40. In the low pressure configuration, the washer 24 and force transmitting member 38 are omitted, and, thus, the "actuating means" includes only the snap-disc 40 and the

actuator 54. The diaphragm 30 engages the snap-disc 40 so that force is transmitted directly by the diaphragm to the snap-disc. The actuator 54 is cylindrical, rather than disc-shaped as in the high pressure control device. The subassembly for testing the diaphragm 30 and first gasket seal includes the input nut 22A, the first gasket 66, the diaphragm, the snap-disc 40 and the snap-disc support housing member 22B. For the low pressure control device, the snap-disc support housing member 22B constitutes "intermediate housing member". The crimp 80 engages the snap-disc support housing member 22B in a circumferential channel 84 of the housing member to secure the subassembly shown in Fig. 11. Except for those components of the low pressure control device discussed above, the components of the low pressure control device are the same as for the high pressure device.

The electrical connector housing member 22D which is shown in the drawings is constructed to receive a particular type of electrical connector of the exterior electrical control circuit to which the control device is connected. However, different manufacturers of fluid systems frequently employ different electrical connectors. Changeover to a corresponding different electrical connector housing member (not shown) can be carried out by merely selecting the appropriate connector housing member 22D from a plurality of such connector housing members, inserting an end into the sleeve 26 and deforming the end of the sleeve against the housing member. Such changeover may be accomplished relatively inexpensively because the electrical connector housing member 22D is preassembled only with the terminal pins 48. Electrical connection of the pins 48 with the stationary contact support 50B and the switch blade 50A, respectively, is achieved upon insertion of the connector housing member 22D into the sleeve 26

through the provision of a terminal pin receptor 88 attached to the switch support housing member 22C (Fig. 8). The receptor 88 includes two electrically separate portions, each having an opposing pair of spring-acting terminal pin receiving flaps, indicated at 90A and 90B, respectively, with each terminal pin 48 being received between and contacting a pair of flaps. The terminal pin 48 pushes the flaps (90A or 90B) apart and away from their relaxed position so that the flaps are biased against the terminal pin to maintain electrical connection.

The switch 50, and receptor 88, which are formed from an electrically conductive material such as beryllium copper, are preassembled with the switch support housing member 22C prior to assembly of the control device as described. As shown in Fig. 6, the switch 50 is initially formed as one piece including the stationary contact support portion 50B and the switch blade 50A. The switch blade 50A and the contact support portion 50B each have feet indicated at 92 and 94, respectively, which are connected by narrow frangible portions 96. The feet 92, 94 each have an opening 98 which is aligned with a corresponding opening 100 in the switch support housing member 22C upon assembly (Fig. 7) of the switch 50 with the housing member. The receptor 88 is also formed as a single piece with its two sections 88A, 88B connected by narrow frangible portions 102 (shown only after broken in Fig. 8). Openings 104 in the receptor 88 are capable of alignment with the openings 100 in the switch support housing member 22C. The switch 50 and receptor 88 are mounted on the switch support housing member 22C and electrically connected to each other by four pins 108 (one of which is shown in Fig. 10) received in the openings 100 in the switch support housing member. The ends of the pins 108 are tubular and may be crimped over against the switch

50 and receptor 88, respectively, to attach them to the switch support housing member 22C. This much of the preassembly is carried out with the switch 50 and receptor 88 still configured in single pieces. The frangible portions 96, 102 of the switch 50 and receptor 88 are then broken to break electrical connection between the switch blade 50A and contact support portion 50B of the switch, and the sections 88A, 88B of the receptor. Thus, preassembly of the switch 50, receptor 88 and switch support housing member 22C may be carried out with a lesser number of pieces. Formation of the switch 50 as a single piece helps to accurately locate the switch blade 50A and contact support member 50B relative each other so that proper alignment of the contacts 50C and 50D is achieved and maintained.

The effective length of the switch blade 50A is increased by the integral feet 92, which remain attached to the switch blade after the frangible portions 96 are broken. Therefore, the stress experienced by the switch blade 50A in operation is reduced over construction in which the switch blade is attached to a separate piece of rigid material (e.g., a brass post).

In view of the above, it will be seen that the several objects of the invention are achieved and other advantageous results attained.

As various changes could be made in the above constructions without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

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1. A control device comprising:

5 a housing having a cavity therein and a central longitudinal axis, the housing including first and second housing members having openings therein defining a portion of the cavity, said housing members being generally adjacent each other and selectively positionable relative each other generally axially of the housing at locations from a first position wherein said first and second housing members are closest together, to a second position in which said first and second housing members are furthest apart;

15 said first housing member including first spacer means and said second housing member including second spacer means, said first spacer means engaging said second spacer means at a location on said second spacer means selected from a range of possible locations of engagement, said first and second spacer means being constructed and arranged such that said selected location of engagement of said first spacer means with said second spacer means determines the axial position of the first and second housing members relative one another;

25 a diaphragm disposed in the cavity and dividing the cavity into a pair of chambers;

30 a control port in one end of the housing opening into one of said chambers, said control port being adapted for the communication of fluid pressure into said one chamber;

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a bistable snap-action member operable
between a first configuration and a second
configuration supported by the housing in the
cavity, and spanning at least in part across said
5 other chamber, said snap-action member being adapted
for movement conjointly with said first housing
member;

a pair of terminal means mounted in the
housing generally adjacent the end of the housing
10 opposite the control port;

switch means disposed in the cavity and
movable conjointly with said second housing member
such that the selected spacing between said first
and second housing members corresponds to the
15 spacing between said snap-action means and said
switch means, said switch means including a
resilient switch blade electrically connected to one
of said terminal means and a stationary contact
support portion electrically connected to the other
20 terminal means, said switch blade being adapted for
motion between a closed position in which the switch
blade engages said stationary contact support
portion and an open position in which the switch
blade does not engage said stationary contact
25 support portion, said switch blade being biased in a
normal operating position selected from one of said
closed and open positions;

actuator means interposed between said snap-
action member and the switch blade and movable
30 generally axially of the housing upon operation of
said snap-action member toward said second
configuration for moving the switch blade between

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said normal operating position in which the switch blade is in one of said open and closed positions and a trip position in which the switch blade is in the other of said open and closed positions.

5 2. A control device as set forth in claim 1 wherein said first spacer means comprises at least one ramp connected to the first housing member, the axial spacing between said first housing member and said second housing member being determined by the
10 angular orientation relative to one another of said first and second housing members about the central longitudinal axis of the housing.

 3. A control device comprising:
 a housing having a cavity therein and a
15 central longitudinal axis, the housing including first and second housing members having openings therein defining a portion of the cavity, said housing members being generally adjacent each other and selectively positionable relative each other
20 generally axially of the housing at locations from a first position wherein said first and second housing members are closest together, to a second position in which said first and second housing members are furthest apart;

25 a diaphragm disposed in the cavity and dividing the cavity into a pair of chambers;

 a control port in one end of the housing opening into one of said chambers, said control port being adapted for the communication of fluid
30 pressure into said one chamber;

 a bistable snap-action member operable

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between a first configuration and a second configuration supported by the housing in the cavity, and spanning at least in part across said other chamber, said snap-action member being adapted for movement conjointly with said first housing member;

a pair of terminal means mounted in the housing generally adjacent the end of the housing opposite the control port;

switch means disposed in the cavity and movable conjointly with said second housing member such that the selected spacing between said first and second housing members corresponds to the spacing between said snap-action means and said switch means, said switch means including a resilient switch blade electrically connected to one of said terminal means and a stationary contact support portion electrically connected to the other terminal means, said switch blade being adapted for motion between a closed position in which the switch blade engages said stationary contact support portion and an open position in which the switch blade does not engage said stationary contact support portion, said switch blade being biased in a normal operating position selected from one of said closed and open positions;

actuator means interposed between said snap-action member and the switch blade and movable generally axially of the housing upon operation of said snap-action member toward said second configuration for moving the switch blade between said normal operating position in which the switch

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blade is in one of said open and closed positions and a trip position in which the switch blade is in the other of said open and closed positions;

5 said first housing member including first
spacer means, and said second housing member
including second spacer means, said first spacer
means being engageable with said second spacer means
for positioning said first and second housing
members at a predetermined axial spacing, the
10 spacing between said first housing member and said
second housing member being determined by the
angular orientation of said first and second housing
members about the central longitudinal axis of the
housing relative to one another;

15 said first and second housing members being
generally annular, and wherein said first spacer
means comprises at least one arcuate ramp formed as
one piece with said first housing member and
extending along the periphery of said first housing
20 member.

4. A control device as set forth in claim 3
wherein said second spacer means comprises at least
one stud formed as one piece with said second
housing member and projecting axially outwardly from
25 said second housing member, the stud being disposed
generally at the periphery of said second housing
member and engageable with the ramp, the spacing of
said first and second housing members depending on
the location of the stud on the ramp.

30 5. A control device as set forth in claim 3
comprising at least two of the ramps

circumferentially spaced along the periphery of said first housing member by flat portions of said first housing member, each ramp comprising an elongate, arcuate strip extending outwardly from a position generally flush with said first housing member to a position axially spaced from said first housing member.

6. A control device as set forth in claim 1 wherein the housing further comprises a connector housing member having said terminal means mounted therein and being adapted for connecting the control device to an electrical circuit exterior of the control device, the control device further comprising means for holding said housing members together in a substantially fixed relation relative each other.

7. A control device as set forth in claim 6 wherein said holding means comprises a tubular sleeve adapted to receive at least a portion of said housing members therein, the sleeve being made of a plastically deformable material whereby the sleeve may be deformed into engagement with at least one of said housing members after reception in the sleeve of said housing members for holding said housing members in substantially fixed relation relative one another.

8. A control device as set forth in claim 1 wherein the housing further comprises an input housing member having the control port therein, the input housing member and said diaphragm being

adapted to be held in the sleeve in a sealing, fixed relation relative each other, the input housing member and diaphragm subassembly thereby constructed being adapted for leak testing prior to completion of the assembly of the control device.

9. A control device comprising:

a housing having a cavity therein and a central longitudinal axis, the housing comprising a plurality of housing members including at least an input housing member disposed generally at one end of the control device, a connector housing member disposed generally at the opposite end of the device and an intermediate housing member disposed intermediate said input and connector housing members;

holding means comprising a tubular sleeve adapted to receive at least a portion of all of said housing members therein, the sleeve being made of a plastically deformable material and being deformed into engagement with at least one of said housing members after reception in the sleeve of said housing members for holding said housing members in substantially fixed relation relative one another;

a diaphragm disposed in the cavity and dividing the cavity into a pair of chambers;

the sleeve being deformed to hold the input housing member and diaphragm in sealing relation with each other separate and apart from the other housing members thereby forming a subassembly adapted for leak testing prior to completion of the assembly of the control device;



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a control port in said input housing member opening into one of said chambers, said control port being adapted for the communication of fluid pressure into said one chamber;

5 a snap-action member operable between a first and a second configuration supported by the housing in the cavity, and spanning at least in part across said other chamber;

10 a pair of terminal means mounted in said connector housing member;

switch means disposed in the cavity, said switch means including a resilient switch blade electrically connected to one of said terminal means and a stationary contact support portion
15 electrically connected to the other terminal means, said switch blade being adapted for motion between a closed position in which the switch blade engages said stationary contact support portion and an open position in which the switch blade does not engage
20 said stationary contact support portion, said switch blade being biased in a normal operating position selected from one of said closed and open positions;

actuator means interposed between said snap-action member and the switch blade and movable
25 generally axially of the housing upon operation of said snap-action member toward said second configuration for moving the switch blade between said normal operating position in which the switch blade is in one of said open and closed positions
30 and a trip position in which the switch blade is in the other of said open and closed positions.

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10. A control device as set forth in claim 9 wherein said housing comprises first and second housing members, said first housing member including first spacer means, and said second housing member including second spacer means, said first spacer means engaging said second spacer means at a location on said second spacer means selected from a range of possible locations of engagement, said first and second spacer means being constructed and arranged such that said selected location of engagement of said first spacer means with said second spacer means determines the axial spacing of the first and second housing members relative to one another, the spacing between said first housing member and said second housing member being determined by the angular orientation relative to one another of said first and second housing members about the central longitudinal axis of the housing, and wherein the snap-action member is movable conjointly with said first housing member and said switch means is movable conjointly with said second housing member such that the spacing between said first and second housing members corresponds to the spacing between the snap-action member and said switch means.

11. A control device comprising:
a housing having a cavity therein and a central longitudinal axis, the housing including at least an input housing member disposed generally at one end of the control device, a connector housing member disposed generally at the opposite end of the

device and an intermediate housing member disposed intermediate said input and connector housing members;

5 holding means comprising a tubular sleeve adapted to receive at least a portion of said housing members therein, the sleeve being made of a plastically deformable material whereby the sleeve may be deformed into engagement with at least one of said housing members after reception in the sleeve
10 of said housing members for holding said housing members in substantially fixed relation relative one another;

a diaphragm disposed in the cavity and dividing the cavity into a pair of chambers;

15 a control port in said input housing member opening into one of said chambers, said control port being adapted for the communication of fluid pressure into said one chamber;

a snap-action member operable between a
20 first and a second configuration supported by the housing in the cavity, and spanning at least in part across said other chamber;

a pair of terminal means mounted in said connector housing member;

25 switch means disposed in the cavity, said switch means including a resilient switch blade electrically connected to one of said terminal means and a stationary contact support portion electrically connected to the other terminal means,
30 said switch blade being adapted for motion between a closed position in which the switch blade engages said stationary contact support portion and an open

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position in which the switch blade does not engage
said stationary contact support portion, said switch
blade being biased in a normal operating position
selected from one of said closed and open positions;

5 actuator means interposed between said snap-
action member and the switch blade and movable
generally axially of the housing upon operation of
said snap-action member toward said second
configuration for moving the switch blade between
10 said normal operating position in which the switch
blade is in one of said open and closed positions
and a trip position in which the switch blade is in
the other of said open and closed positions;

 said housing comprising first and second
15 housing members, said first housing member including
first spacer means, and said second housing member
including second spacer means, said first spacer
means engaging said second spacer means for
positioning said first and second housing members at
20 a predetermined axial spacing, the spacing between
said first housing member and said second housing
member being determined by the angular orientation
relative to one another of said first and second
housing members about the central longitudinal axis
25 of the housing, and wherein the snap-action member
is movable conjointly with said first housing member
and said switch means is movable conjointly with
said second housing member such that the spacing
between said first and second housing members
30 corresponds to the spacing between the snap-action
member and said switch means;

 said first housing member and said second

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housing member being generally annular, and wherein
said first spacer means comprises at least one
arcuate ramp formed as one piece with said first
housing member and extending along the periphery of
5 said first housing member, said second spacer means
comprising at least one stud formed as one piece
with said second housing member and projecting
axially outwardly from said second housing member,
the stud being disposed generally at the periphery
10 of said second housing member and engageable with
the ramp, the spacing of said first and second
housing members depending on the location on the
stud on the ramp.

12. A control device as set forth in claim
15 11 comprising at least two of the ramps
circumferentially spaced along the periphery of said
first housing member by flat portions of said first
housing member, each ramp comprising an elongate,
arcuate strip extending outwardly from a position
20 generally flush with said first housing member to a
position axially spaced from said first housing
member.

13. A control device comprising:
a housing having a cavity therein and a
25 central longitudinal axis, the housing comprising a
plurality of housing members including at least an
input housing member disposed generally at one end
of the control device, a connector housing member
disposed generally at the opposite end of the device
30 and a switch housing member disposed between said
input and connector housing members and being

separate from said connector housing member;

holding means comprising a tubular sleeve adapted to receive at least a portion of all of said housing members therein, the sleeve being made of a plastically deformable material and being deformed into engagement with at least one of said housing members after reception in the sleeve of said housing members for holding said housing members in substantially fixed relation relative one another;

a diaphragm disposed in the cavity and dividing the cavity into a pair of chambers;

a control port in said input housing member opening into one of said chambers, said control port being adapted for the communication of fluid pressure into said one chamber;

a snap-action member operable between a first and a second configuration supported by the housing in the cavity, and spanning at least in part across said other chamber;

at least two terminals mounted in said connector housing member;

switch means disposed in the cavity and supported by said switch housing member, said switch means including a resilient switch blade

electrically connected to one of the terminals and a stationary contact support portion electrically connected to the other terminal, said switch blade being adapted for motion between a closed position in which the switch blade engages said stationary contact support portion and an open position in which the switch blade does not engage said stationary contact support portion, said switch

blade being biased in a normal operating position selected from one of said closed and open positions;

5 a receptor mounted on the switch housing and electrically connected to said switch means, the receptor having an opening therein receiving upper portions of the terminals therein and including resilient contact means engaged by the terminals and deflected from a relaxed position such that said resilient contact means bears against the upper portions of the terminals;

10 actuator means interposed between said snap-action member and the switch blade and movable generally axially of the housing upon operation of said snap-action member toward said second configuration for moving the switch blade between said normal operating position in which the switch blade is in one of said open and closed positions and a trip position in which the switch blade is in the other of said open and closed positions;

20 the sleeve being deformed to hold the input housing member, diaphragm, actuator means, said switch means, receptor and switch housing together in fixed relation relative to each other separate and apart from the connector housing member.

25 14. A control device as set forth in claim 13 wherein the sleeve is deformed to hold the input housing member and diaphragm in sealing relation with each other separate and apart from the other housing members thereby forming a subassembly which may be separately tested for leaks.

30 15. A control device as set forth in claim

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13 wherein said receptor means comprises resilient
flap means engaging the terminals, said flap means
being displaced from its relaxed position by the
terminals whereby said flap means is biased against
5 the terminals for maintaining engagement with the
terminals.

16. A control device as set forth in claim
15 wherein said flap means comprises first and
second pairs of flaps formed integrally with the
10 receptor, the first pair of flaps being in opposing
relation and receiving one of the terminals between
them with each flap engaging said one terminal.

17. A control device subassembly comprising:
a housing having a cavity therein and a
15 central longitudinal axis, the housing comprising a
plurality of housing members including at least an
input housing member disposed generally at one end
of the control device, and a switch housing member;

holding means comprising a tubular sleeve
20 adapted to receive at least a portion of said
housing members therein, the sleeve being made of a
plastically deformable material and being deformed
into engagement with at least one of said housing
members after reception in the sleeve of said
25 housing members for holding said housing members in
substantially fixed relation relative one another;

a diaphragm disposed in the cavity and
dividing the cavity into a pair of chambers;

a control port in said input housing member
30 opening into one of said chambers, said control port
being adapted for the communication of fluid

pressure into said one chamber;

5 a snap-action member operable between a first and a second configuration supported by the housing in the cavity, and spanning at least in part across said other chamber;

10 switch means supported by the switch housing member in the cavity, said switch means including a resilient switch blade electrically connected to one of said terminal means and a stationary contact support portion electrically connected to the other terminal means, said switch blade being adapted for motion between a closed position in which the switch blade engages said stationary contact support portion and an open position in which the switch blade does not engage said stationary contact support portion, said switch blade being biased in a normal operating position selected from one of said closed and open positions;

20 actuator means interposed between said snap-action member and the switch blade and movable generally axially of the housing upon operation of said snap-action member toward said second configuration for moving the switch blade between said normal operating position in which the switch blade is in one of said open and closed positions and a trip position in which the switch blade is in the other of said open and closed positions

30 the sleeve being deformed to hold the input housing and switch housing in the sleeve in a substantially fixed relationship relative to one another, the sleeve being adapted to receive a connector housing member including terminals for

connecting the control device into a circuit to be controlled, the connector housing member not forming part of the subassembly, the sleeve being adapted to be deformed to hold the connector housing members in fixed relation to the input and switch housing members.

18. A switch subassembly of the type used in a pressure responsive control device comprising a housing having a cavity therein and a central longitudinal axis, a diaphragm disposed in the cavity and dividing the cavity into a pair of chambers, a control port in one end of the housing opening into one of said chambers, said control port being adapted for the communication of fluid pressure into said one chamber, a snap-action member operable between a first and a second configuration supported by the housing in the cavity, and spanning at least in part across said other chamber, a pair of terminal means mounted in the housing generally adjacent the end of the housing opposite the control port, switch means disposed in the cavity, said switch means being operable between a closed position and an open position, said switch means being biased in a normal operating position selected from one of said closed and open positions, and actuator means interposed between said snap-action member and said switch means and movable generally axially of the housing upon operation of said snap-action member toward said second configuration for operating said switch means between said normal operating position in which said switch means is in

one of said open and closed positions and a trip position in which said switch means is in the other of said open and closed positions, said switch subassembly comprising:

5 a switch lead frame formed as one piece from electrically conductive material, said switch lead frame comprising a switch blade, a stationary contact support portion and a frangible portion connecting the switch blade and said stationary
10 contact support portion upon formation of said switch lead frame;

 means for electrically connecting said switch lead frame to said terminal means of the control device; and

15 means for supporting said switch lead frame and said electrical connecting means;

 the frangible portion of said switch lead frame being adapted to be broken after assembly of the switch subassembly to break electrical
20 connection between the switch blade and said stationary contact support portion thereby to form said switch means;

 said switch lead frame further comprising a first foot portion connected to the switch blade at
25 a proximal end thereof and extending generally toward the stationary contact support portion from the proximal end of the switch blade and a second foot portion connected to the stationary contact support portion generally along an edge of the
30 stationary contact support portion and extending toward the proximal end of the switch blade from the edge of the stationary contact support portion, the

first and second foot portions being interconnected by the frangible portion, the frangible portion being substantially narrower in width than the first and second foot portions thereby facilitating breakage of the frangible portion.

19. A switch subassembly of the type used in a pressure responsive control device comprising a housing having a cavity therein and a central longitudinal axis, a diaphragm disposed in the cavity and dividing the cavity into a pair of chambers, a control port in one end of the housing opening into one of said chambers, said control port being adapted for the communication of fluid pressure into said one chamber, a snap-action member operable between a first and a second configuration supported by the housing in the cavity, and spanning at least in part across said other chamber, a pair of terminal means mounted in the housing generally adjacent the end of the housing opposite the control port, switch means disposed in the cavity, said switch means being operable between a closed position and an open position, said switch means being biased in a normal operating position selected from one of said closed and open positions, and actuator means interposed between said snap-action member and said switch means and movable generally axially of the housing upon operation of said snap-action member toward said second configuration for operating said switch means between said normal operating position in which said switch means is in one of said open and closed positions and a trip

position in which said switch means is in the other of said open and closed positions, said switch subassembly comprising:

5 a switch lead frame formed as one piece from electrically conductive material, said switch lead frame comprising a switch blade, a stationary contact support portion and a frangible portion connecting the switch blade and said stationary contact support portion upon formation of the switch means;

means for electrically connecting said switch lead frame to said terminal means of the control device; and

15 means for supporting said switch lead frame and said electrical connecting means;

the frangible portion of said switch lead frame being adapted to be broken after assembly of the switch assembly to break electrical connection between the switch blade and said stationary contact support portion thereby to form said switch means;

20 said electrical connection means comprising a receptor formed as one piece from electrically conductive material, the receptor comprising a first section and a second section and a frangible portion connecting the first and second sections, the frangible portion being adapted to be broken after assembly of the switch subassembly to break electrical connection between the first section and the second section.

30 20. A switch subassembly as set forth in claim 18 wherein said support means comprises a

rigid member having surface means engaging and supporting the first and second foot portions, and an opening, the frangible portion being generally in registration with the opening thereby facilitating breakage of the frangible portion into the opening.

21. A switch subassembly as set forth in claim 18 wherein said electrical connection means comprises a receptor formed as one piece from electrically conductive material, the receptor comprising a first section and a second section and a frangible portion connecting the first and second sections, the frangible portion being adapted to be broken after assembly of the switch subassembly to break electrical connection between the first section and the second section.

22. A switch subassembly as set forth in claim 21 further comprising linking means for electrically connecting the receptor to said switch lead frame, said linking means mounting said switch lead frame and the receptor on said support means.

23. A switch subassembly as set forth in claim 22, wherein said linking means comprises a plurality of pins, said switch lead frame, the receptor and said support means having aligned openings therein receiving at least a portion of the pins, each pin having a deformable portion at each end thereof, each deformable portion being deformed against one of said switch lead frame and the receptor thereby making electrical contact with one of said switch lead frame and the receptor and

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securing one of said switch lead frame and the
receptor to the support means.

24. A switch lead frame such as for a switch
of the type used with a pressure responsive control
5 device including the switch and a pressure
responsive mechanism for actuating said switch
between a closed position in which the switch
completes an electrical circuit and an open position
in which the electrical circuit including the switch
10 is broken, the switch lead frame comprising;

a switch blade portion including a switch
blade having a contact mounted thereon;

a stationary contact support portion having
a stationary contact mounted thereon, the switch
15 blade and stationary contact support portion being
formed as one piece from electrically conductive
material;

a frangible portion connecting the switch
blade portion and the stationary contact portion,
20 the frangible portion being adapted to be broken to
break electrical connection between the switch blade
and said stationary contact support portion thereby
to form the switch;

a first foot portion connected to the switch
25 blade at a proximal end thereof and extending
generally toward the stationary contact support
portion from the proximal end of the switch blade;
and

a second foot portion connected to the
30 stationary contact support portion generally along
an edge of the stationary contact support portion

and extending generally toward the proximal end of the switch blade from the edge of the stationary contact support portion, the first and second foot portions being interconnected by the frangible
5 portion, the frangible portion being substantially narrower in width than the first and second foot portions thereby facilitating breakage of the frangible portion.

25. A switch subassembly as set forth in
10 claim 19 further comprising linking means for electrically connecting the receptor to said switch lead frame, said linking means mounting said switch lead frame and the receptor on said support means.

26. A switch subassembly as set forth in
15 claim 25 wherein said linking means comprises a plurality of pins, said switch lead frame, the receptor and said support means having aligned openings therein receiving at least a portion of the pins, each pin having a deformable portion at each
20 end thereof, each deformable portion being deformed against one of said switch lead frame and the receptor thereby making electrical contact with one of said switch lead frame and the receptor and
25 securing one of said switch lead frame and the receptor to the support means.

FIG. 1

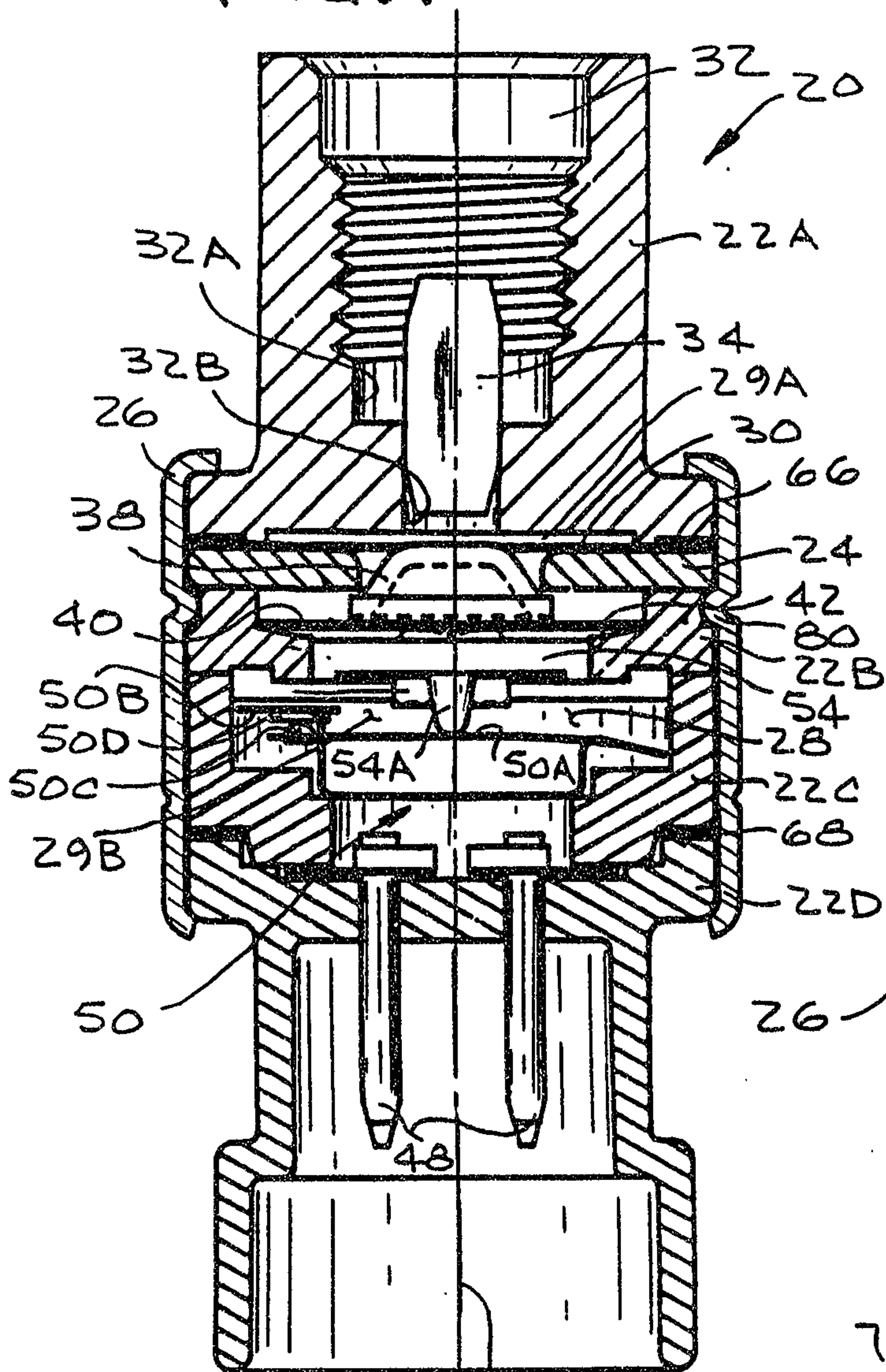


FIG. 3

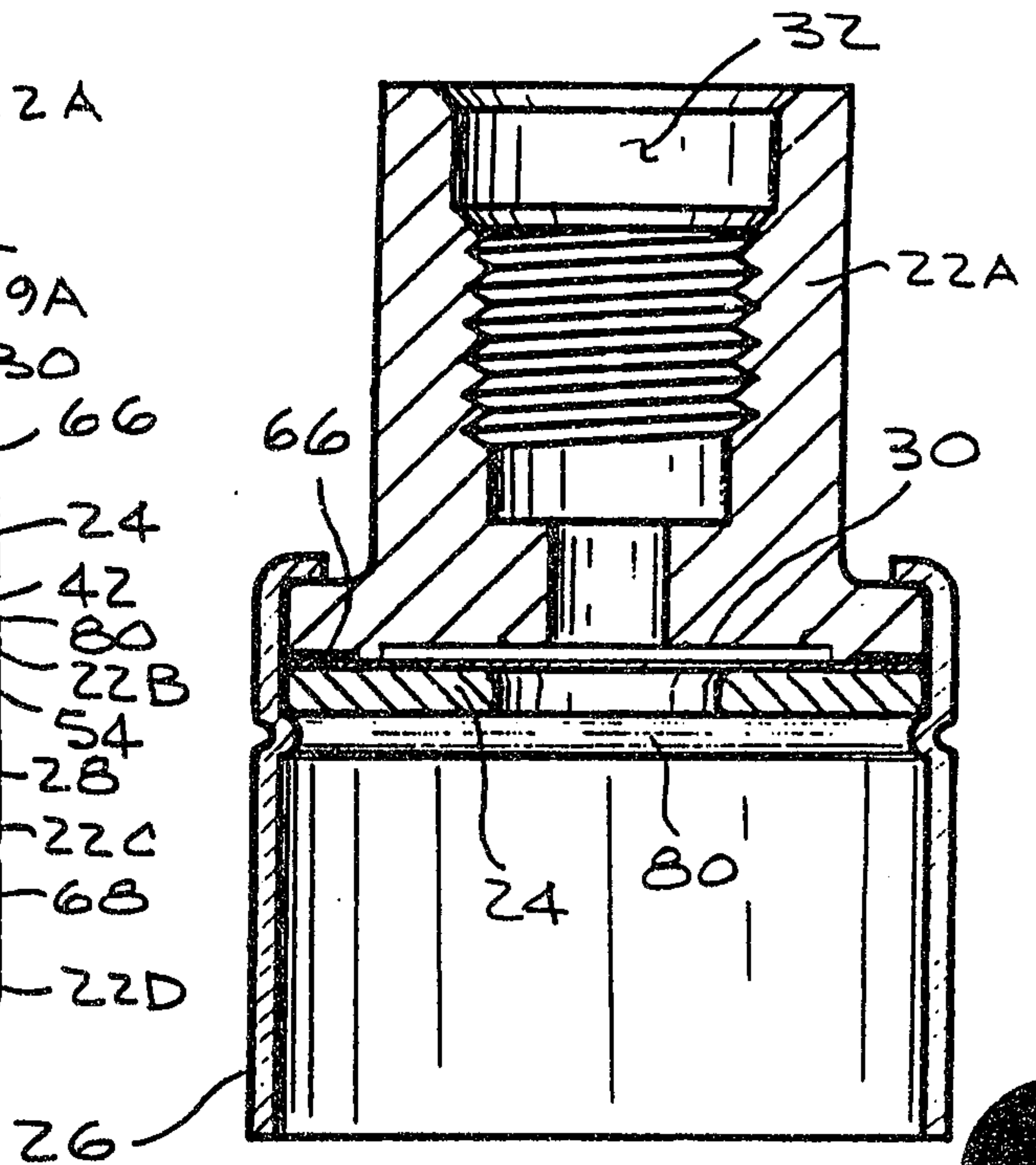


FIG. 4

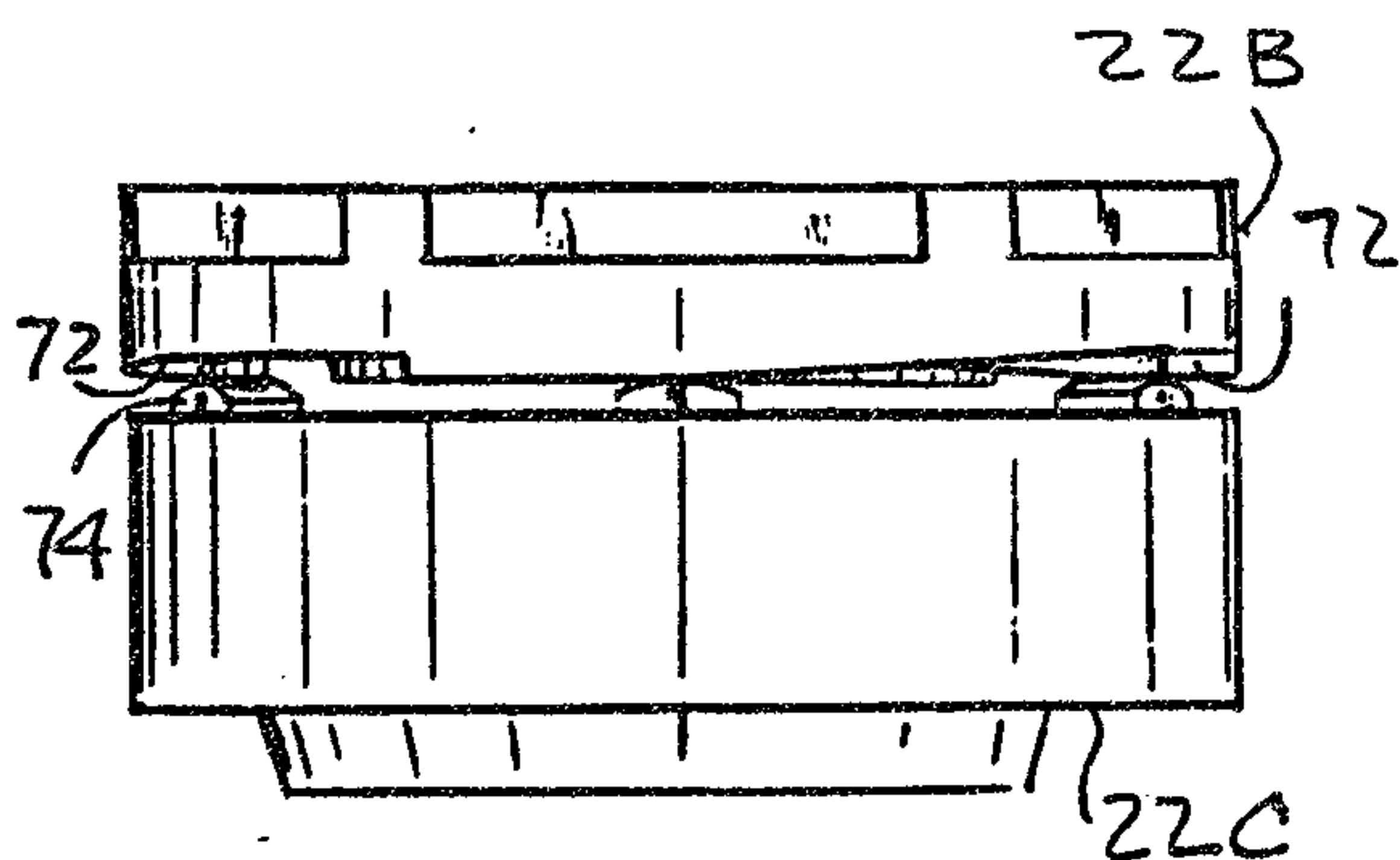
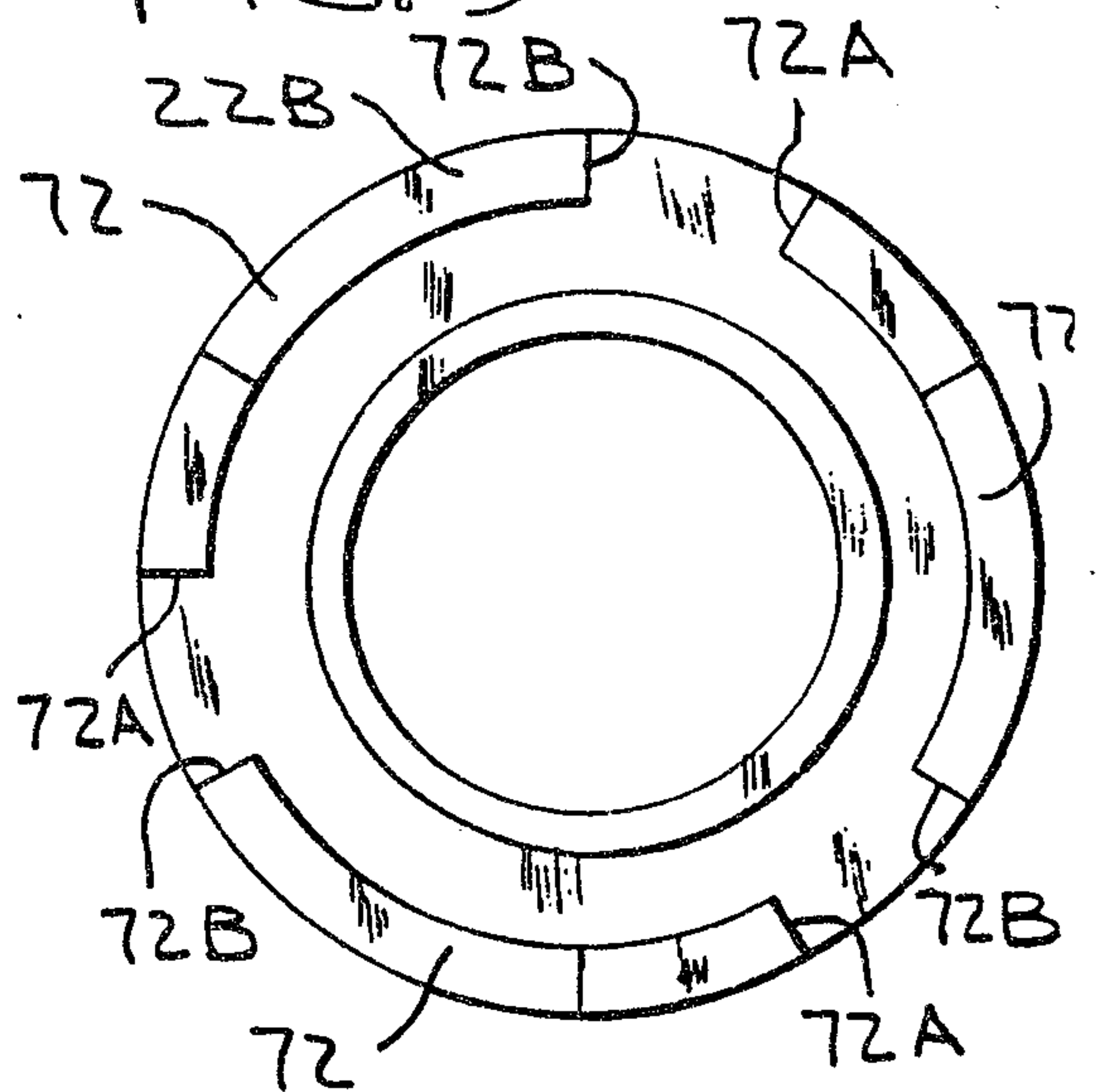
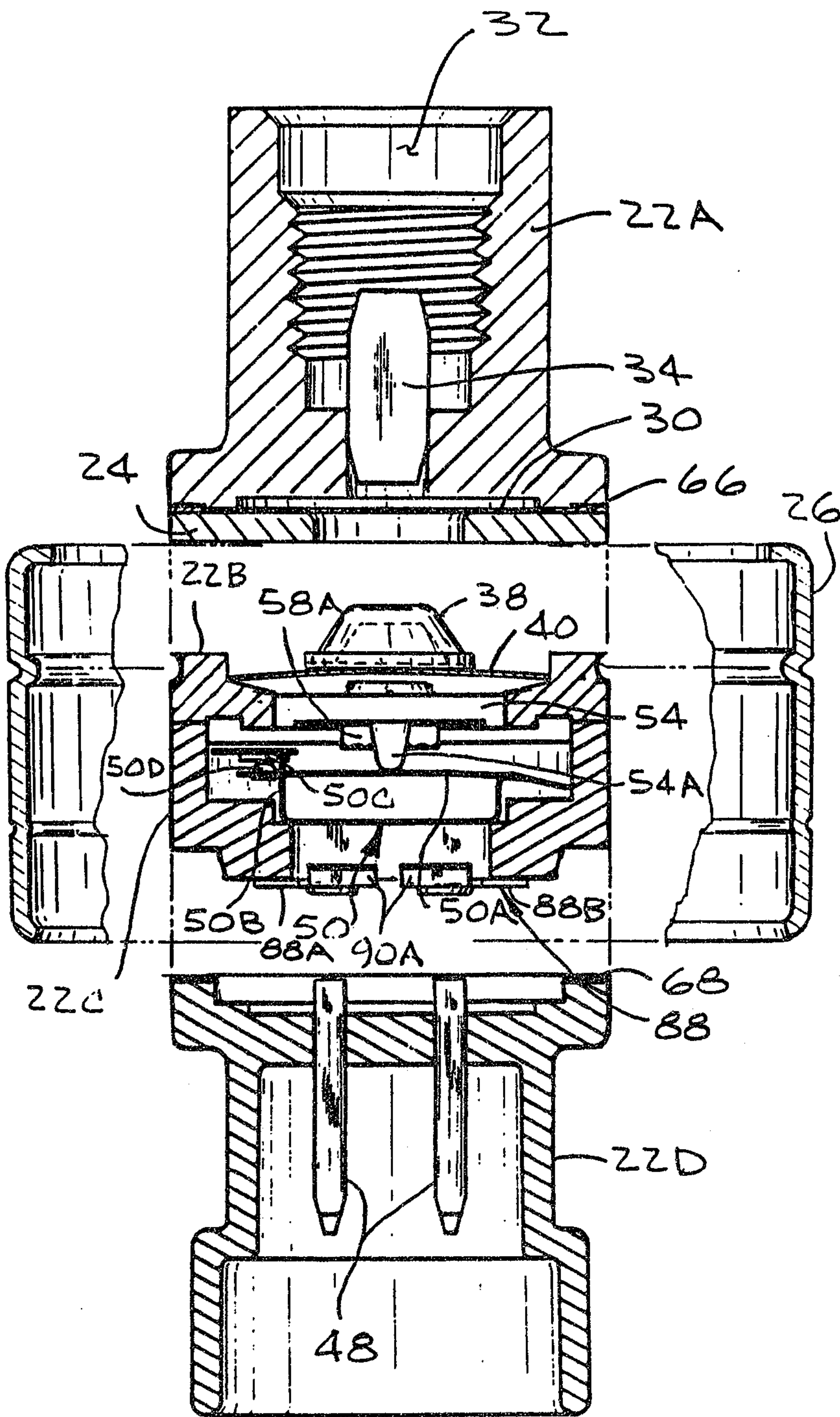


FIG. 5



Olthoff and Wilke

FIG. 2



O'Kham and Wicks

FIG. 6

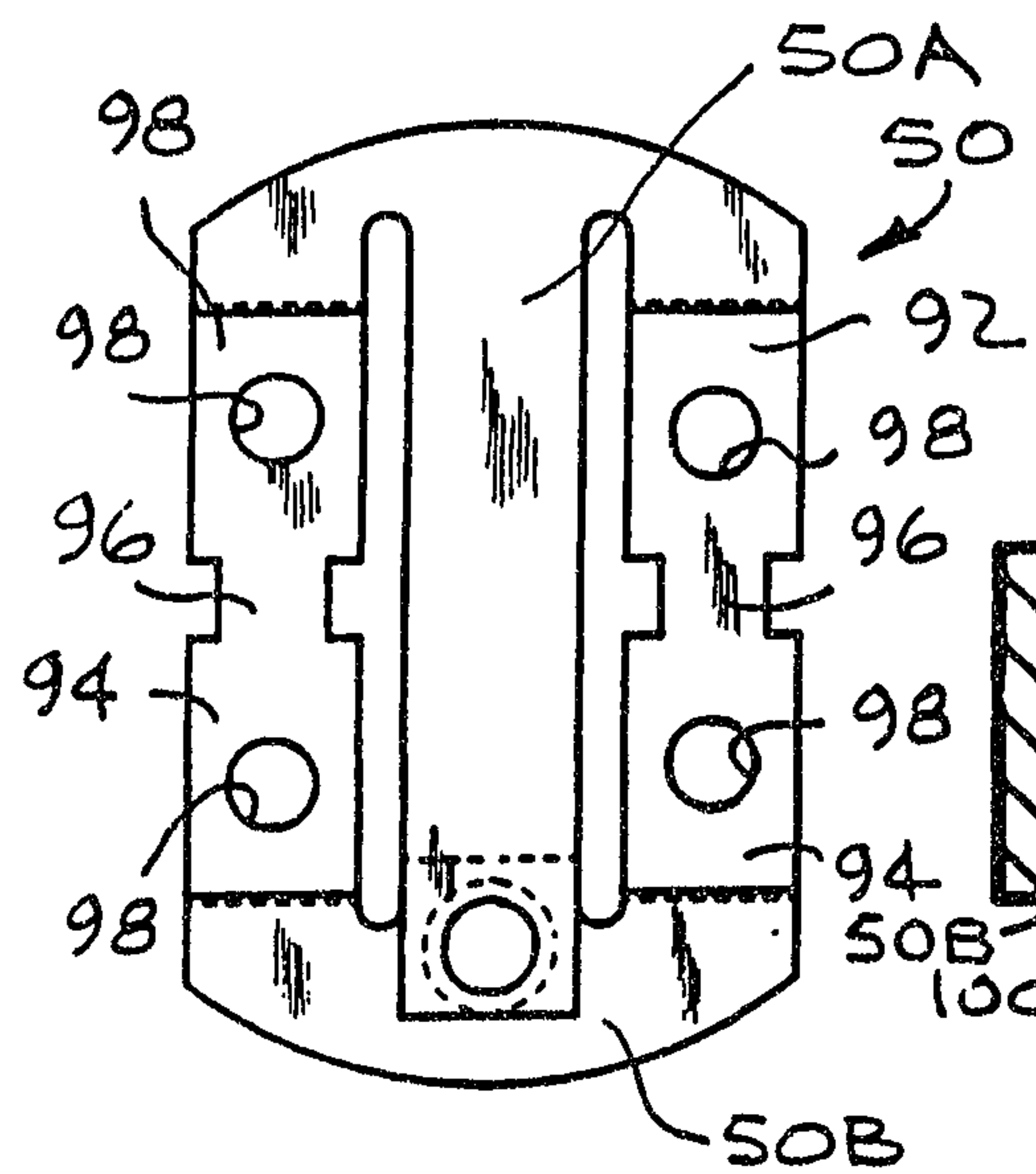


FIG. 7

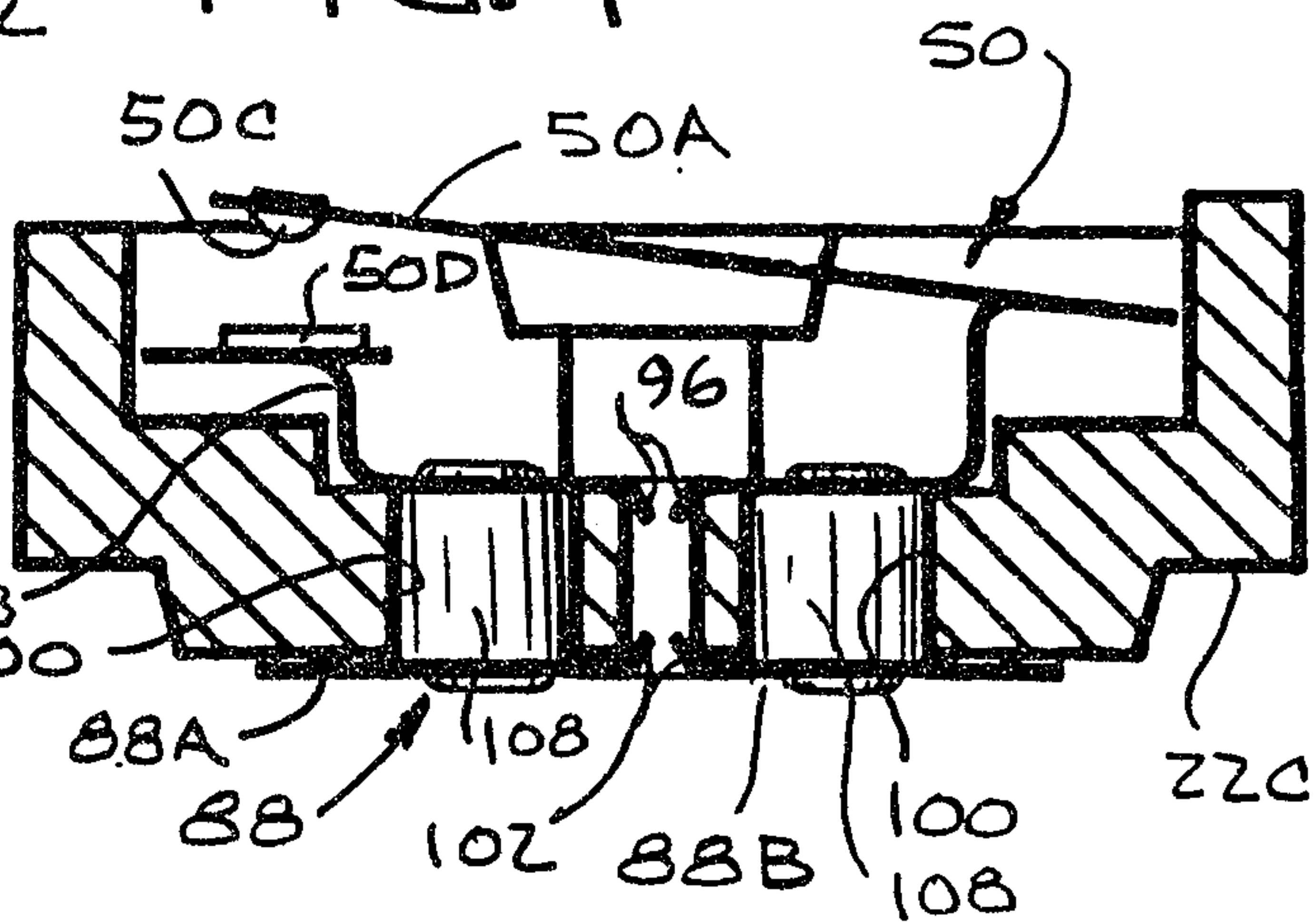
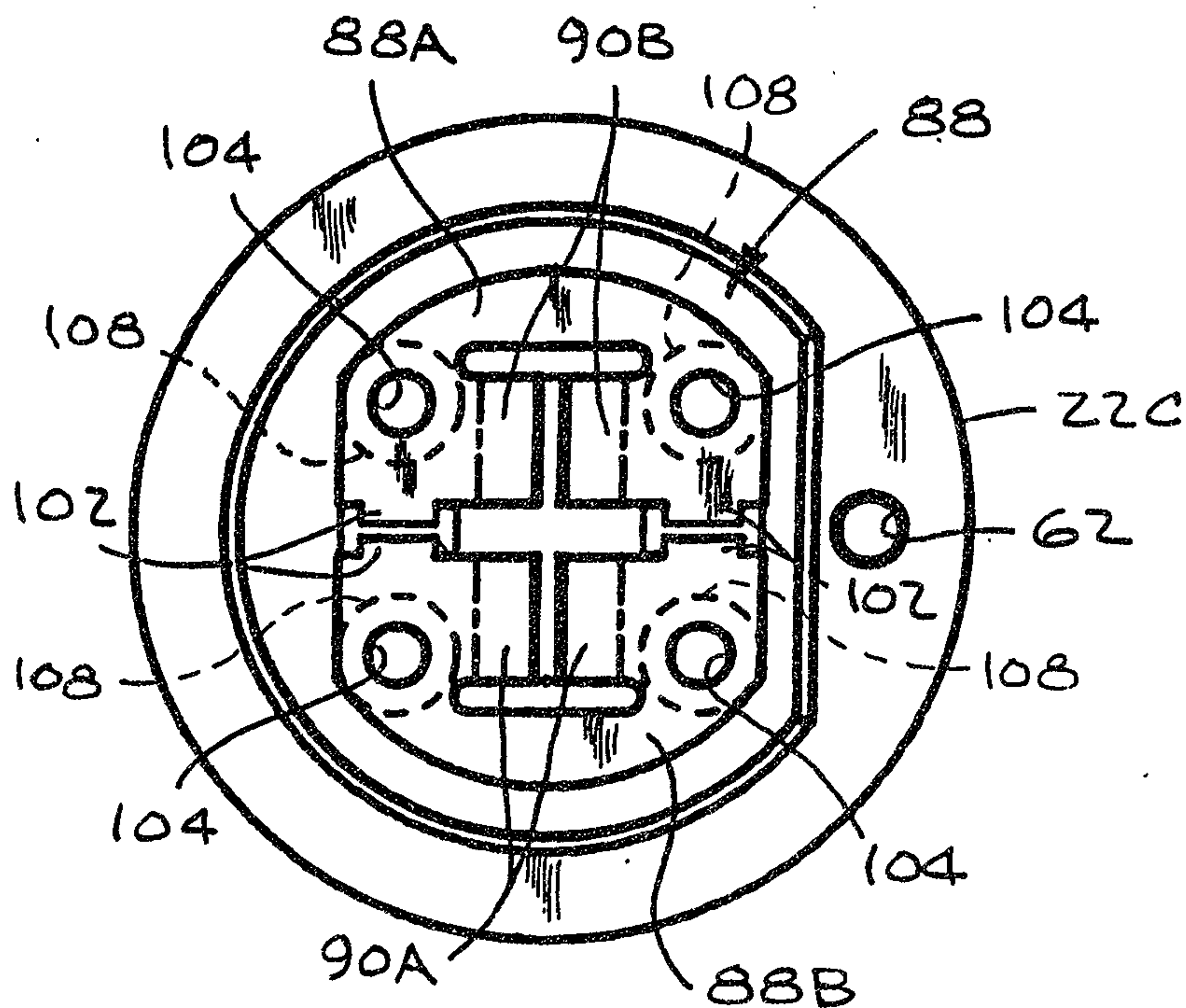


FIG. 8



Oelham and Wils

FIG. 9

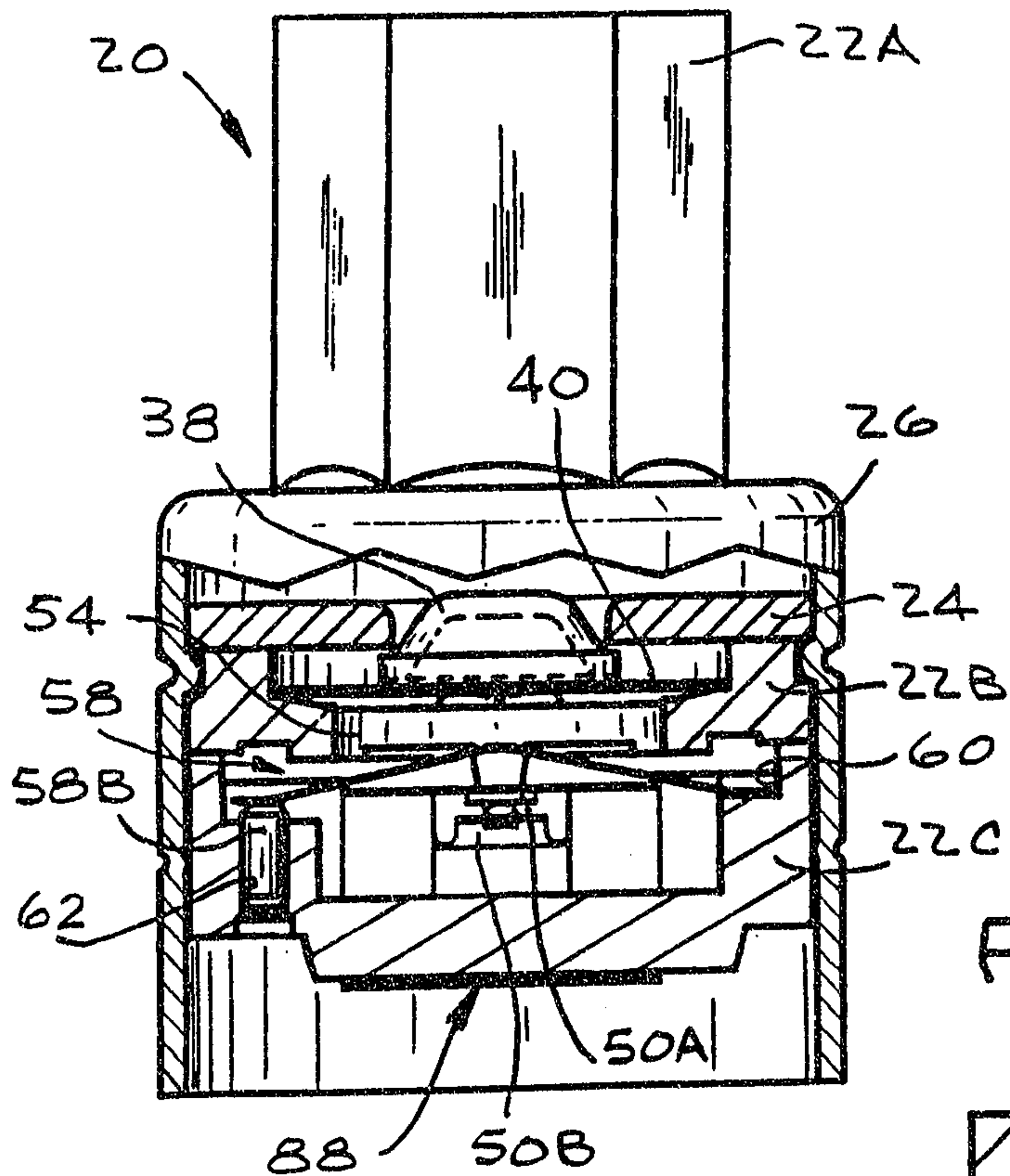


FIG. 10

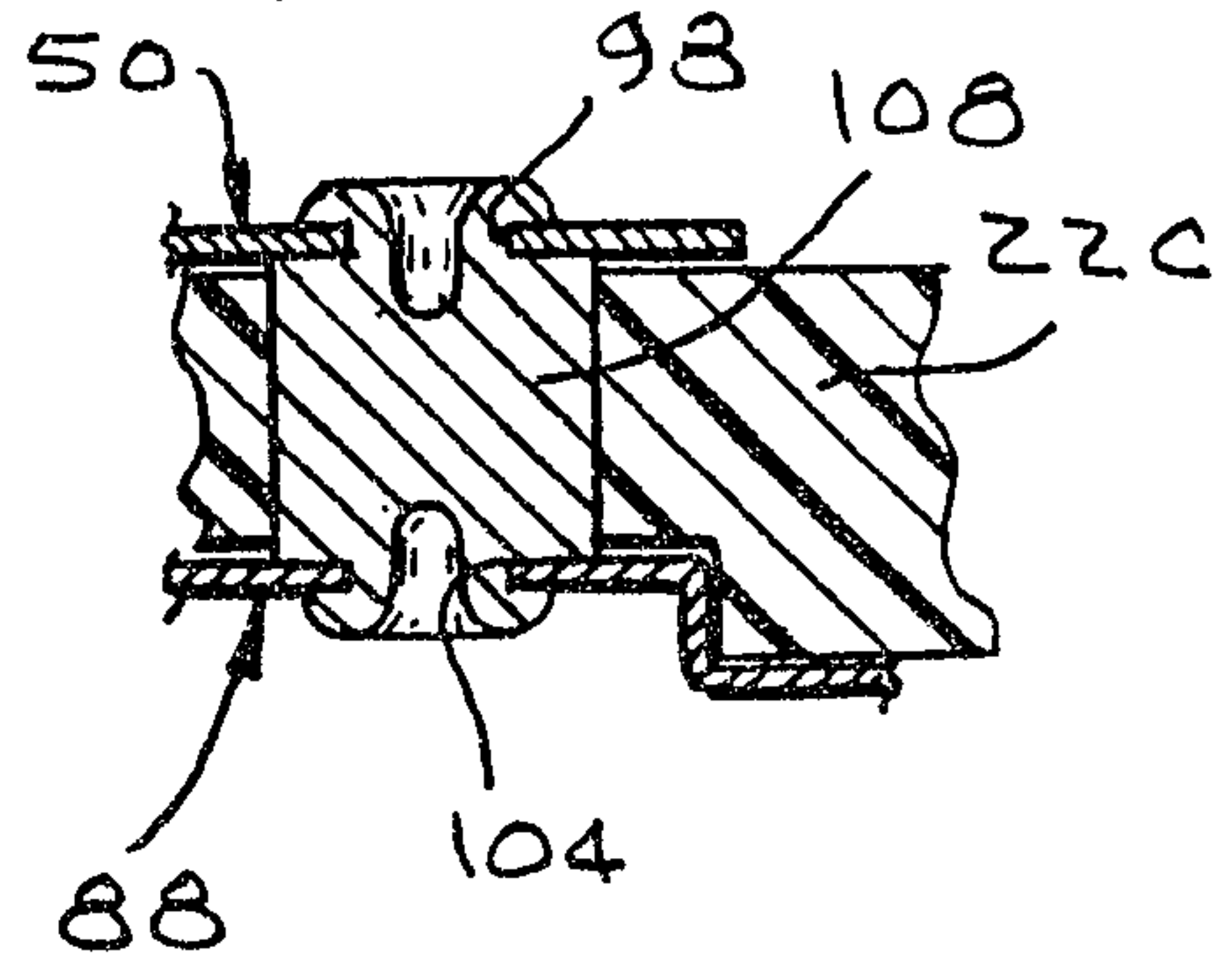
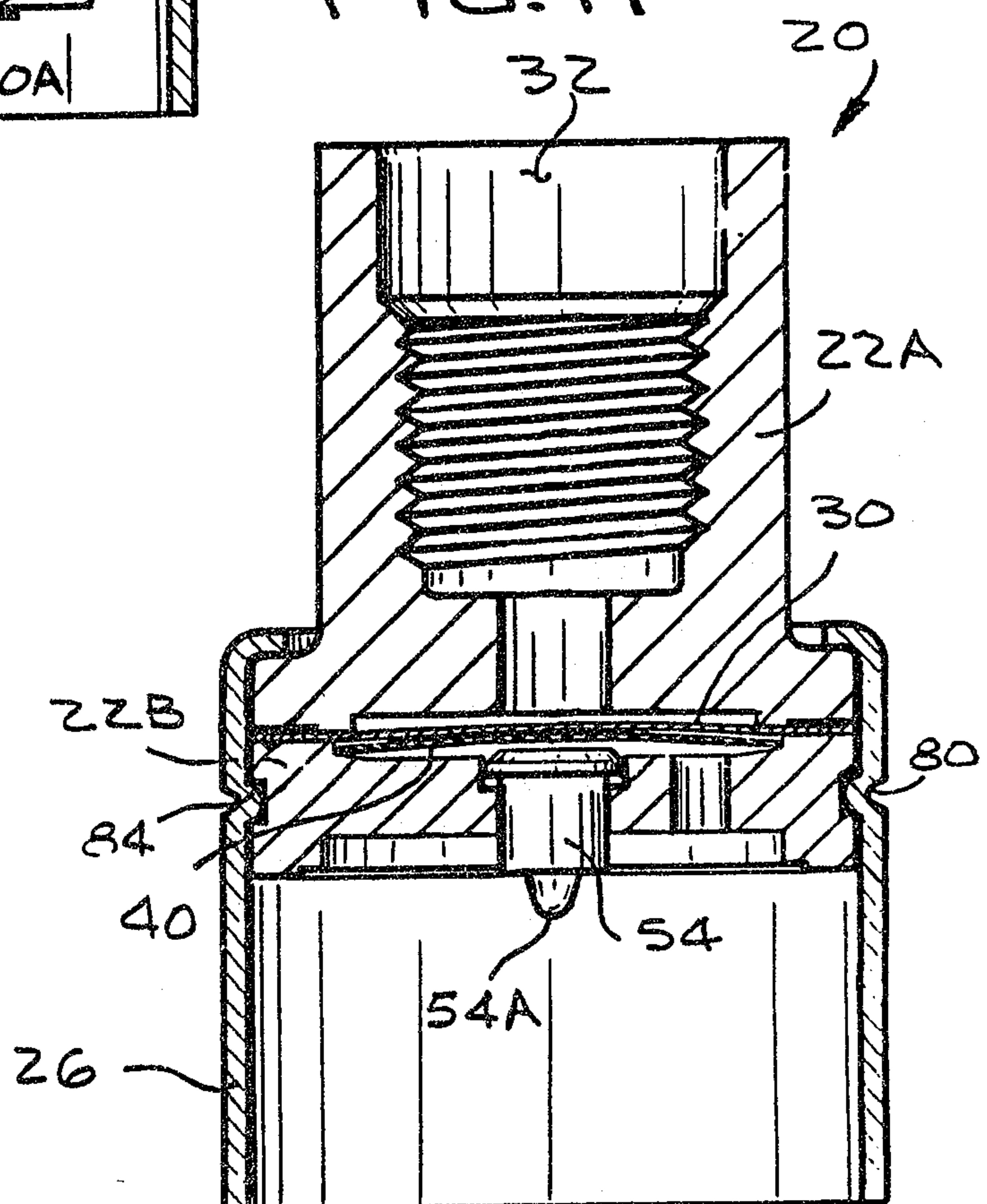


FIG. 11



Oldham and Webb

