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[54] **ELECTROMAGNETICALLY TRANSPARENT FLUIDIC OPERATORS FOR REMOTE OPERATION OF ELECTRIC SWITCHES AND METHOD OF ADAPTING ELECTRIC SWITCHES FOR REMOTE, FLUIDIC OPERATION**

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[51] **Int. Cl.**[7] **H01H 35/34**

[52] **U.S. Cl.** .... **200/83 R**

[58] **Field of Search** .... 307/118; 340/626; 92/5 R, 94, 96, 101, 102; 73/717, 723, 861.47; 200/81 R, 81.4, 81.5, 302.1, 330, 331, 332.1, 83 R, 83 S, 83 A, 83 B, 83 J, 83 SA

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[57] **ABSTRACT**

An electromagnetically transparent fluidic operator for adapting a conventional, mechanically operated electric switch to remote, fluidic operation includes a non-metallic housing for being rigidly attached to the electric switch with a chamber in the housing aligned with a mechanical actuator of the electric switch and a non-metallic, expandable reservoir mounted by the housing. The reservoir includes a nipple rigidly attached to the housing and a deformable diaphragm forming a seal with the nipple and being disposed in the chamber close to the mechanical actuator. The reservoir is pressurized with fluid from a remote location causing the diaphragm to deform and the reservoir to expand thereby applying a positive pressure or operating force against the mechanical actuator to operate the electric switch. A method of adapting an electric switch for remote, fluidic operation includes the steps of rigidly attaching the housing to a selected electric switch such that the chamber in the housing is aligned with the mechanical actuator, positioning the diaphragm in the chamber close to the mechanical actuator, rigidly attaching the nipple to the housing, establishing a seal between the nipple and the diaphragm to form a fluid-tight reservoir and supplying fluid to the reservoir to deform the diaphragm and apply the operating force against the mechanical actuator.

19 Claims, 4 Drawing Sheets

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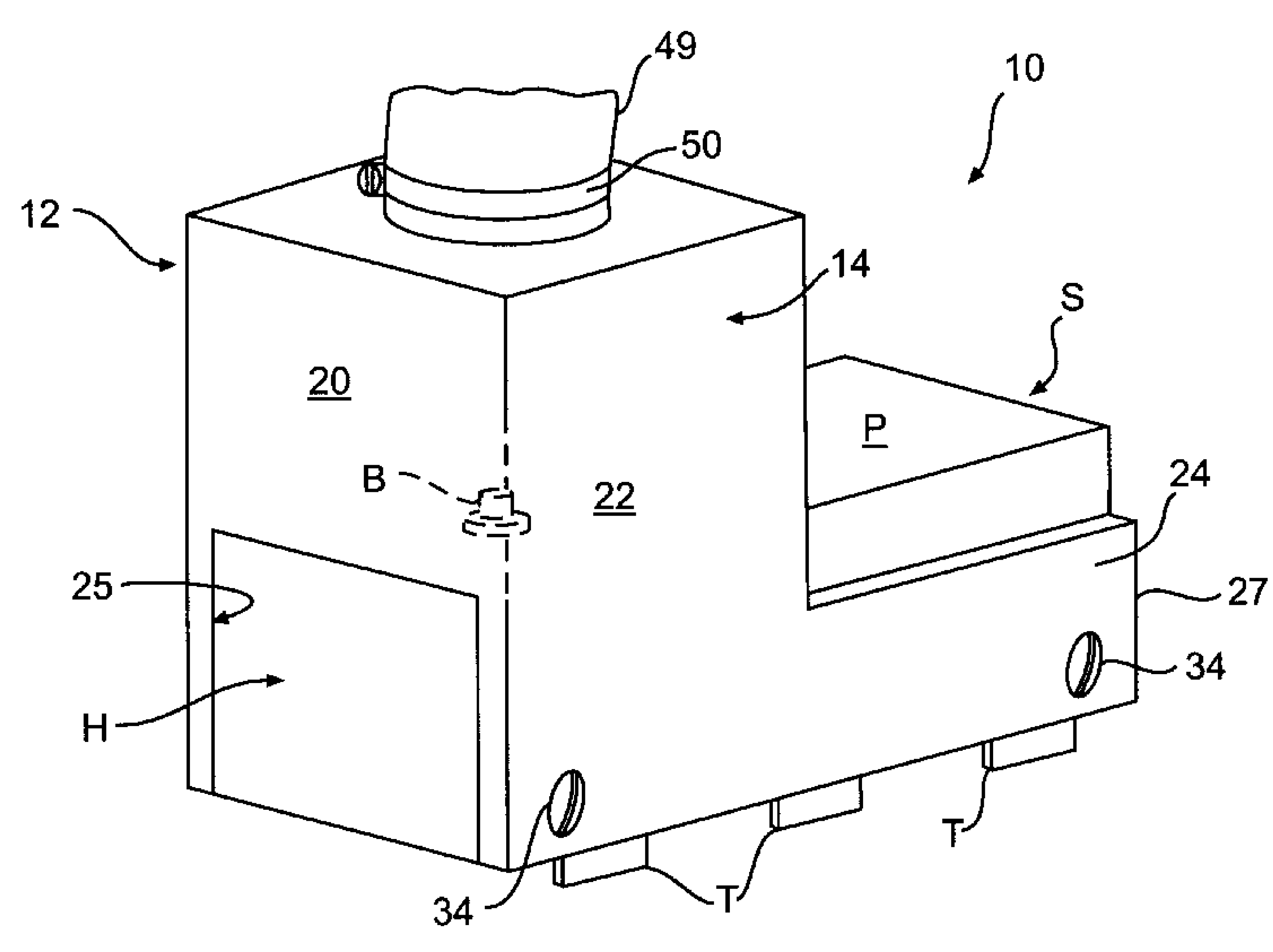


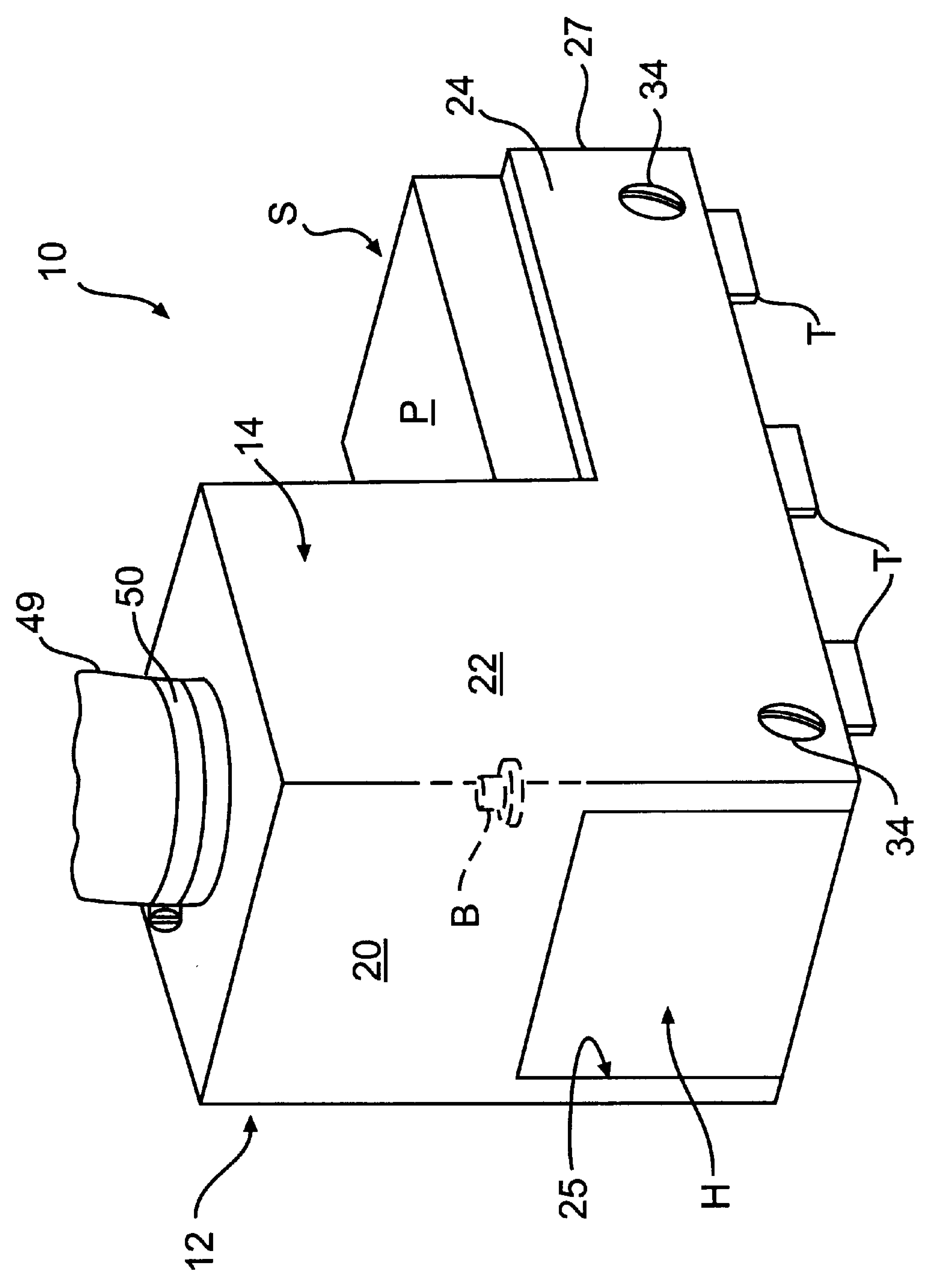
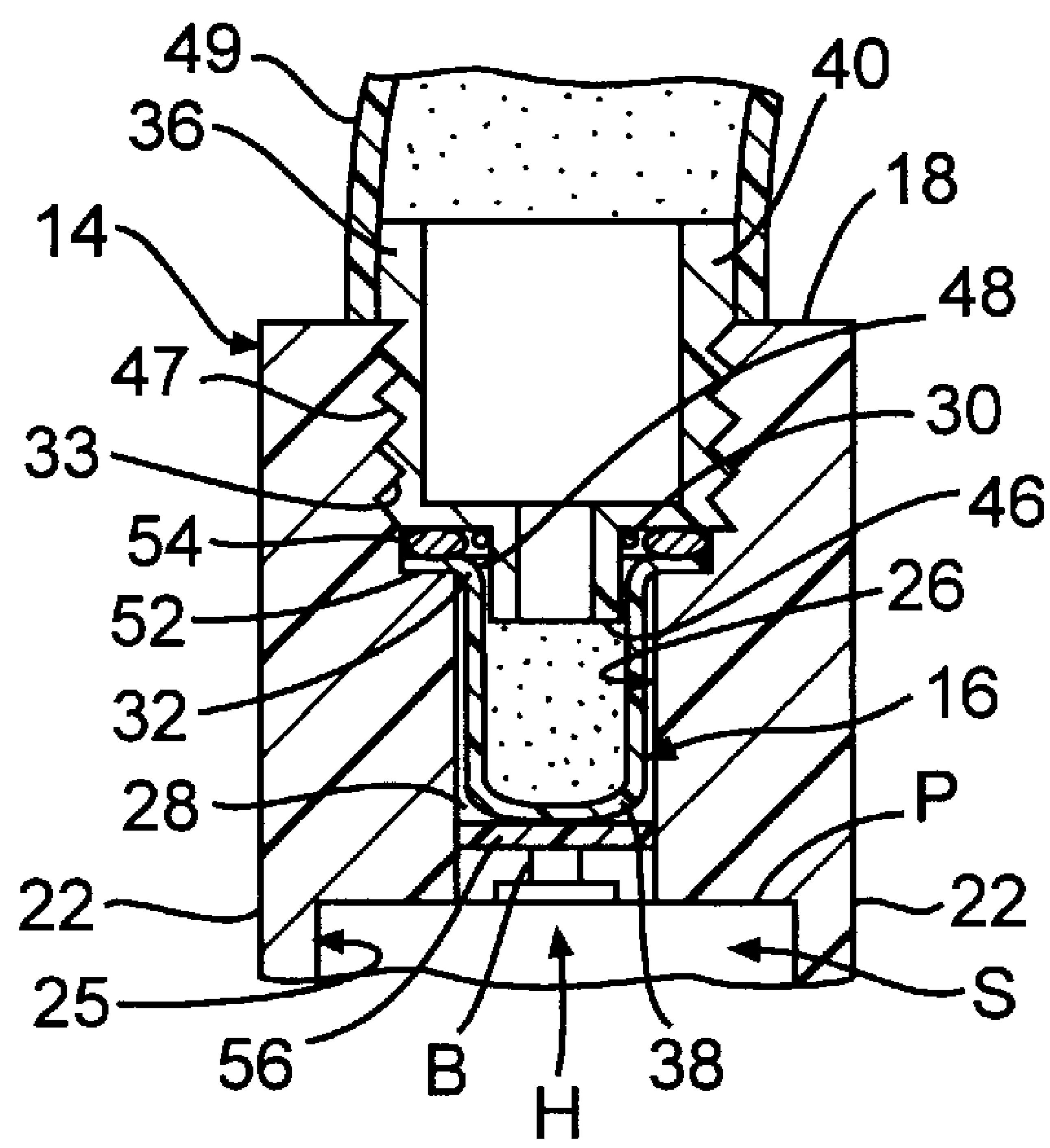


FIG. 1

FIG. 2



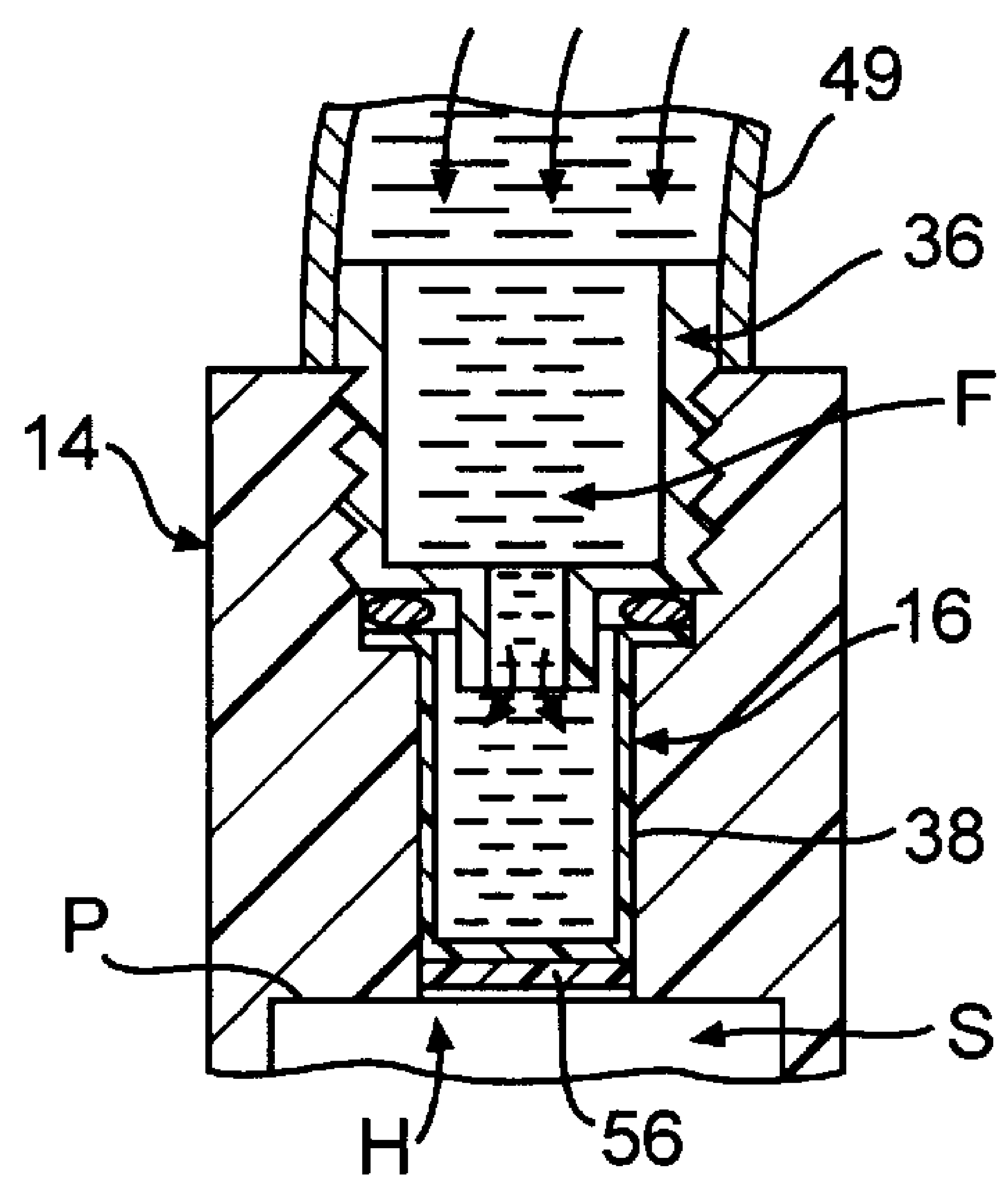
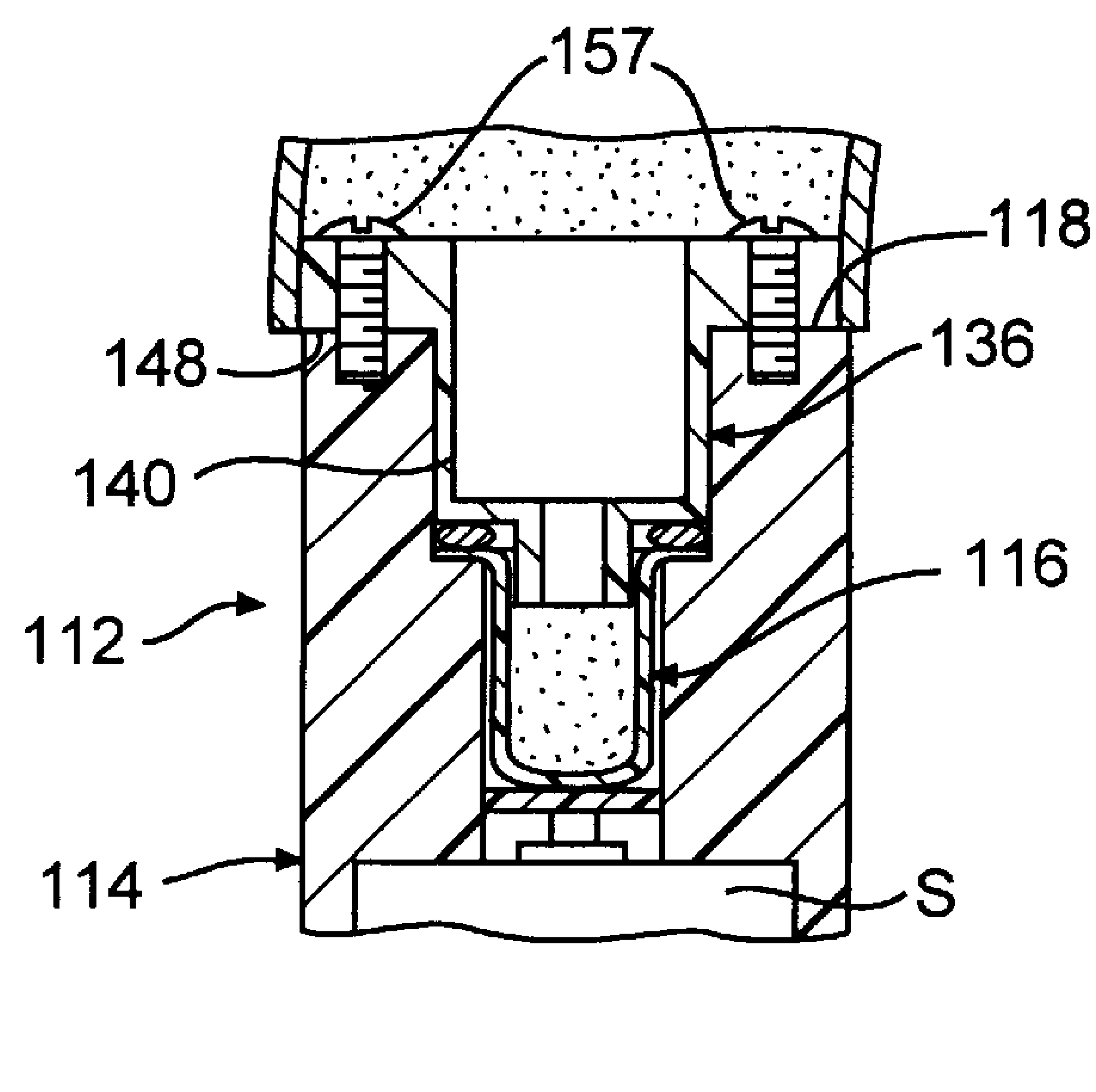


FIG. 3

FIG. 4



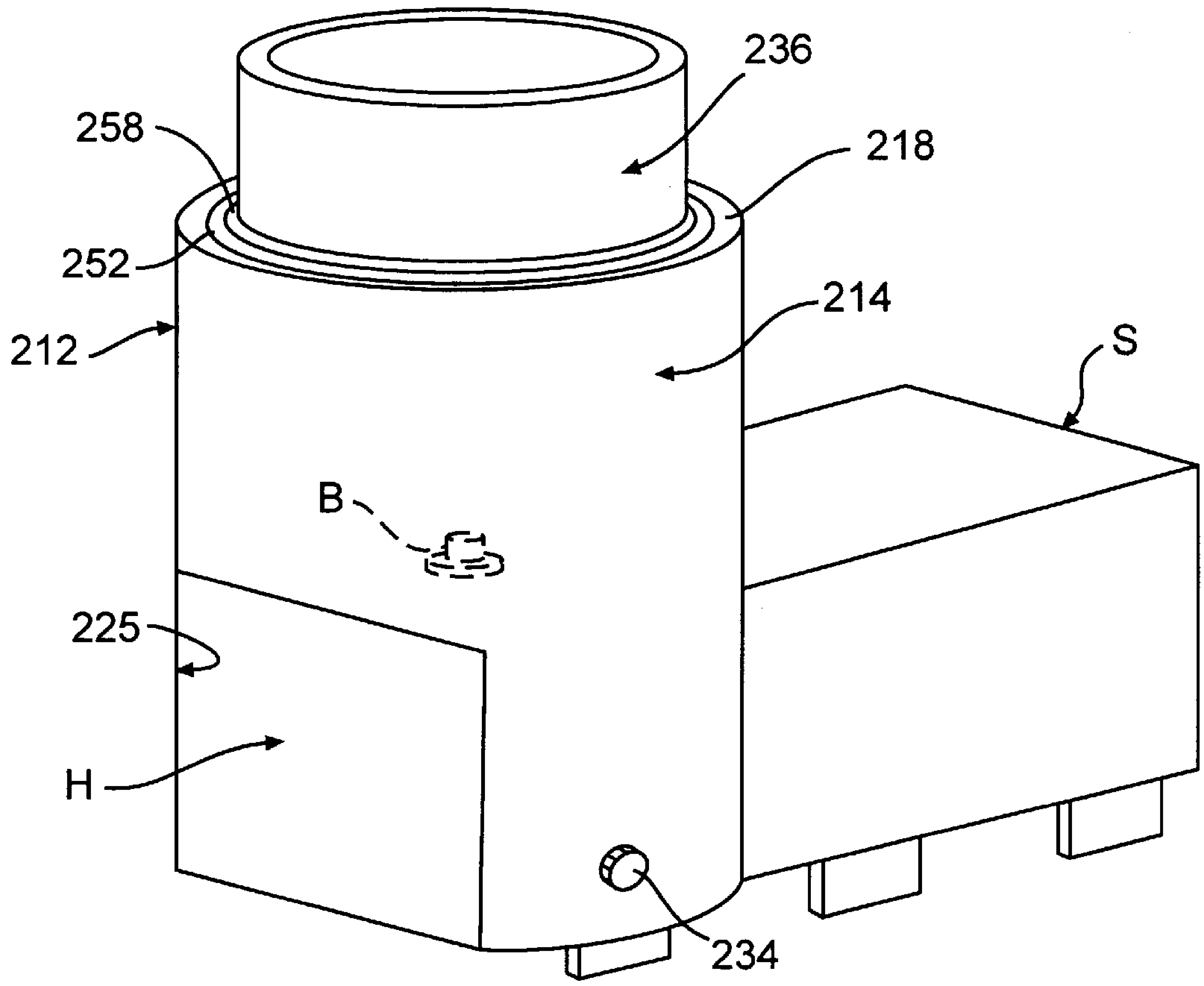


FIG. 5

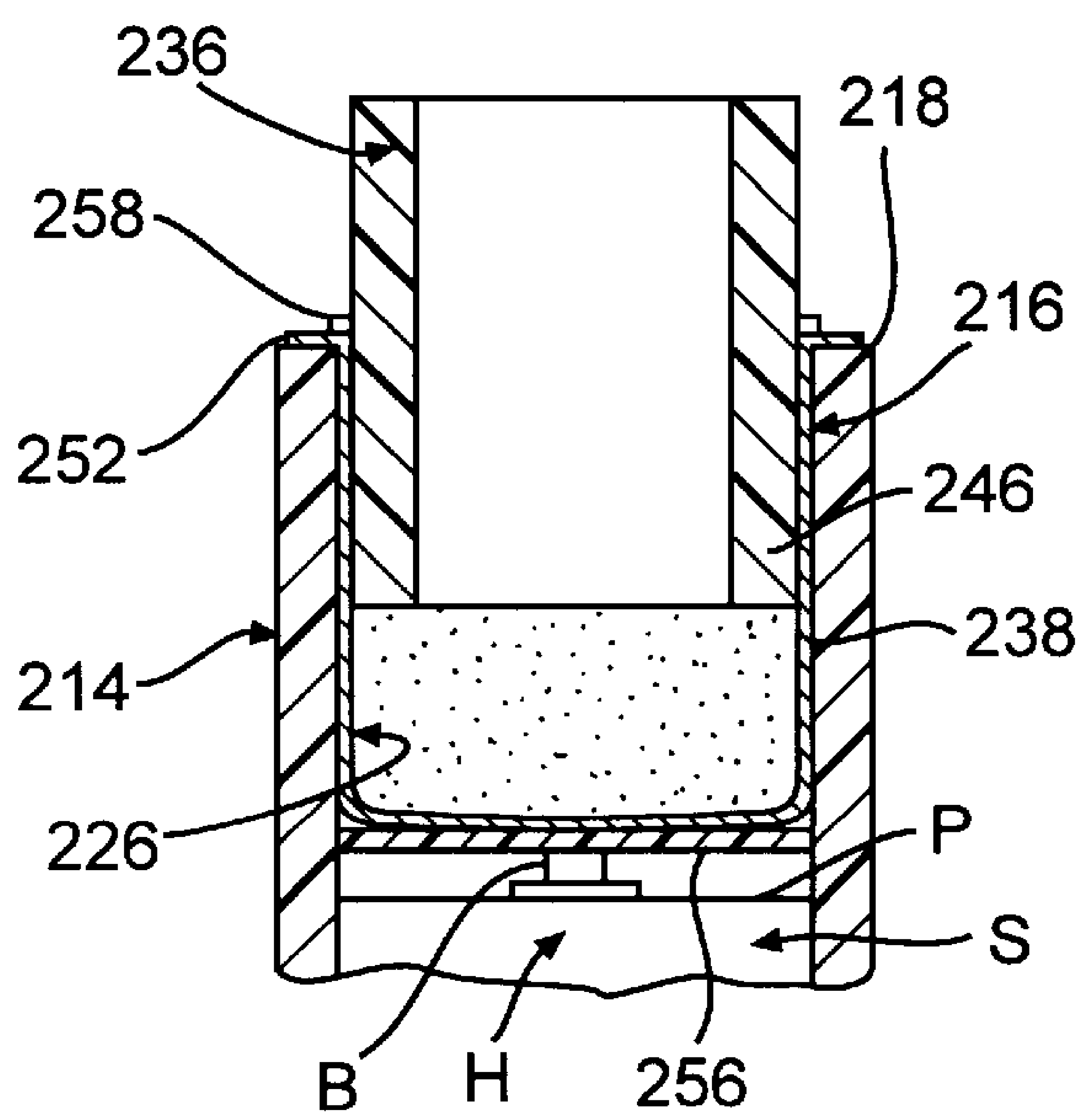


FIG. 6

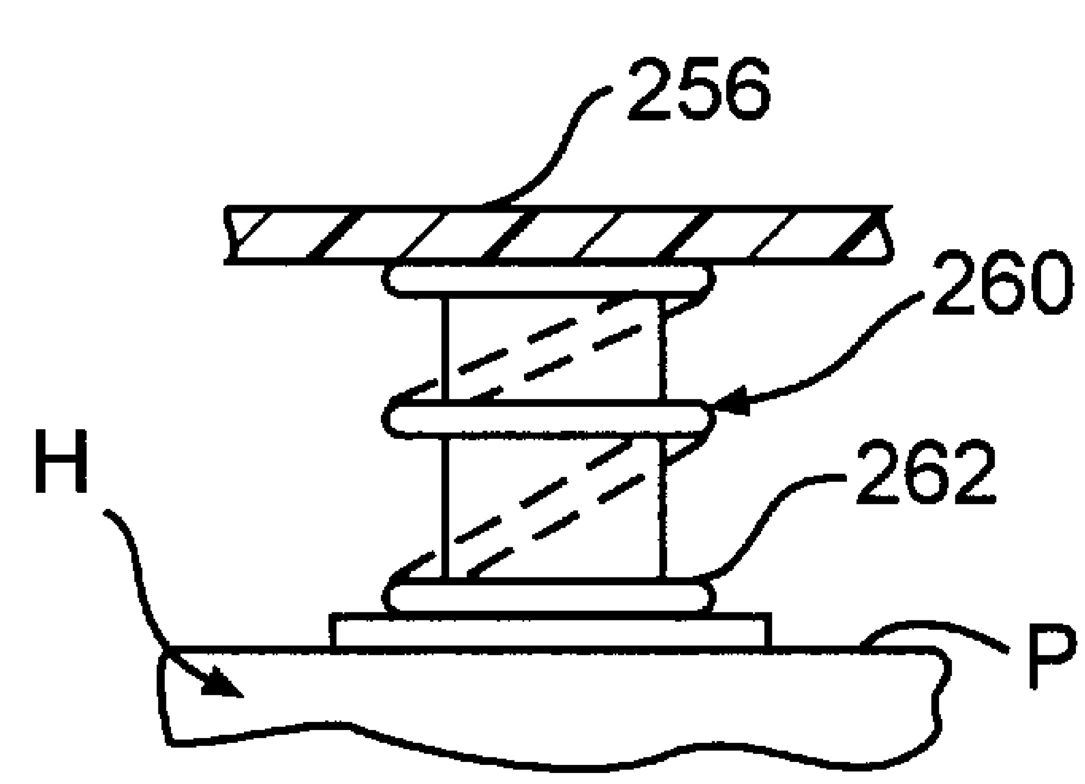


FIG. 7

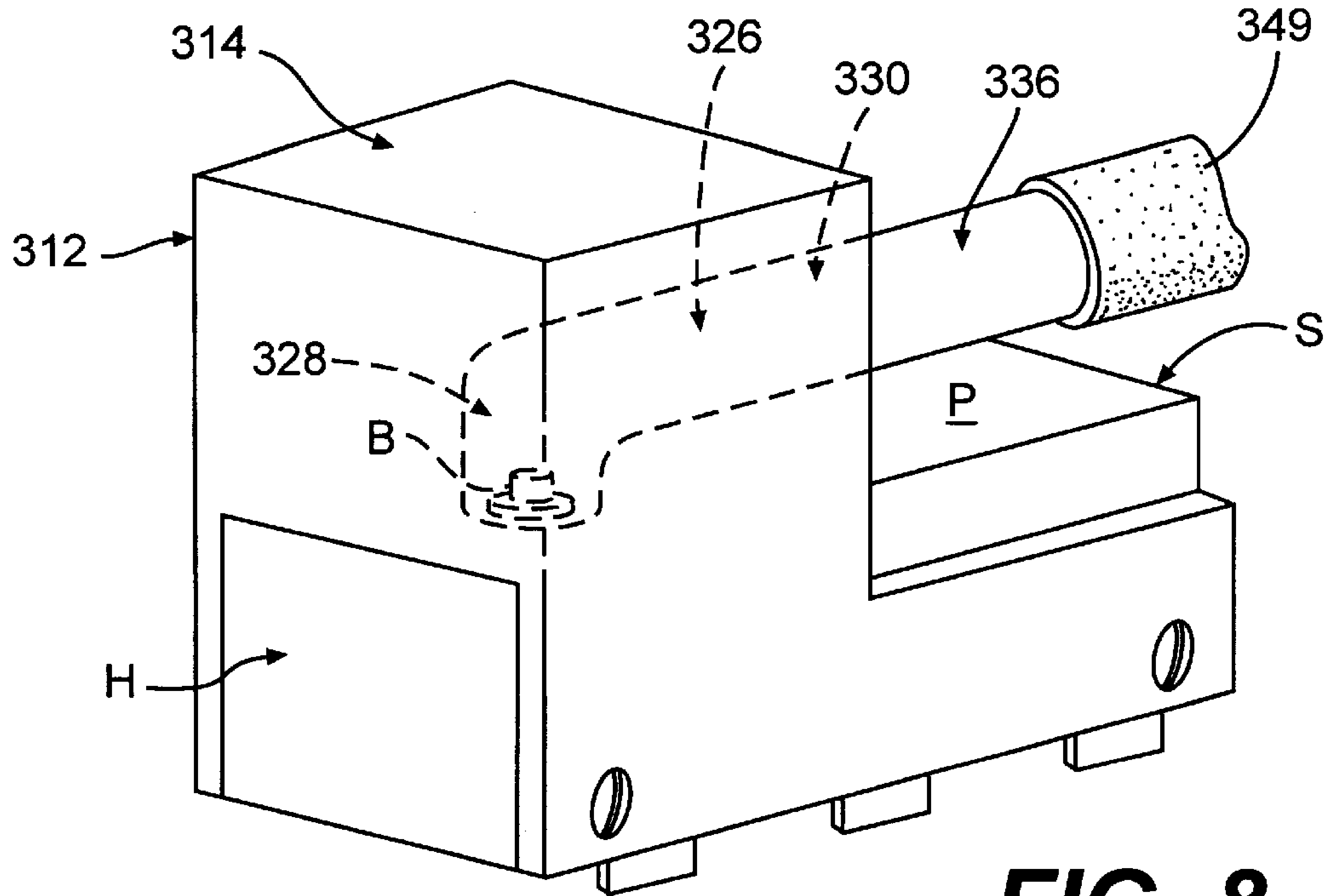


FIG. 8

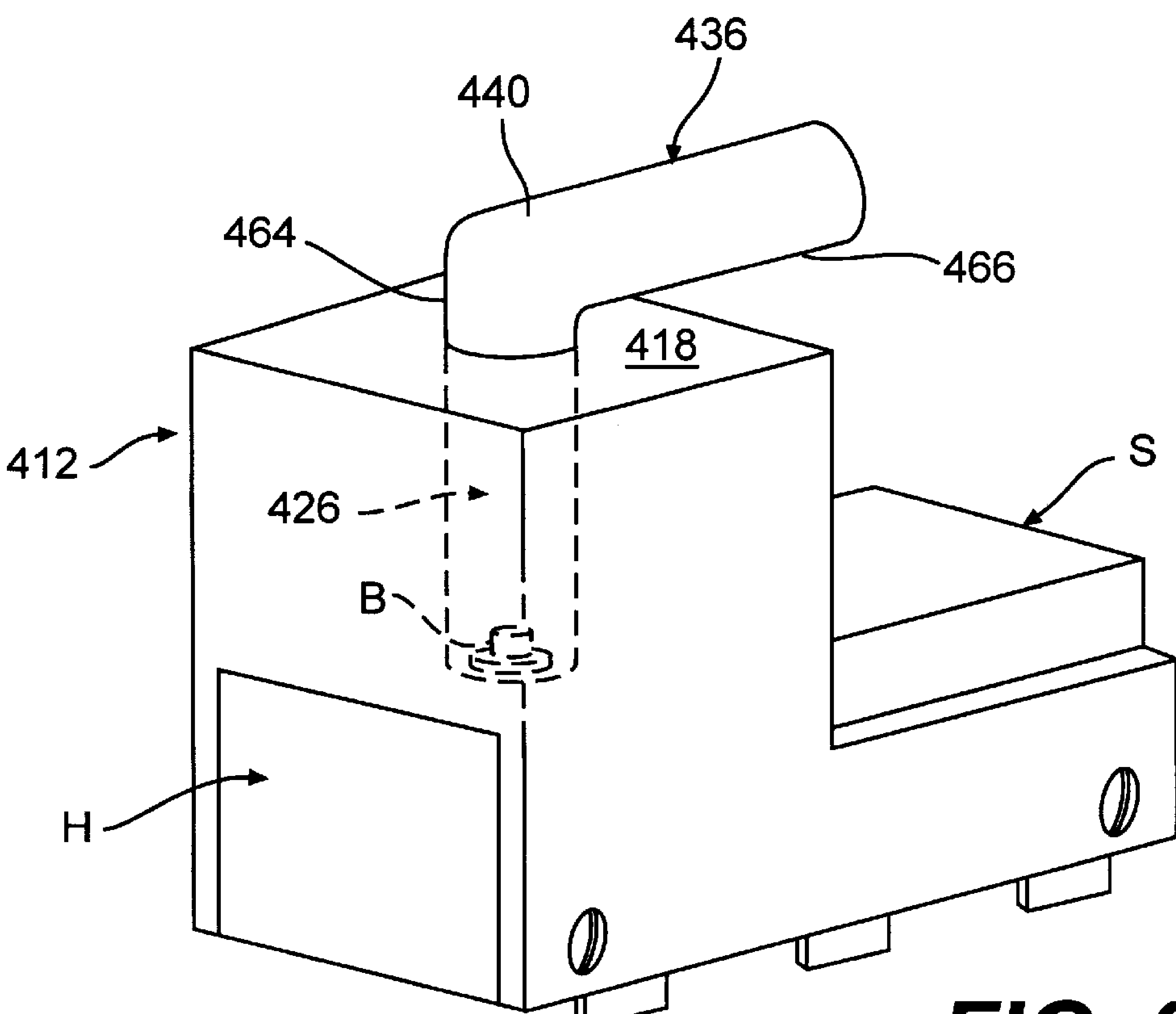


FIG. 9

ELECTROMAGNETICALLY TRANSPARENT FLUIDIC OPERATORS FOR REMOTE OPERATION OF ELECTRIC SWITCHES AND METHOD OF ADAPTING ELECTRIC SWITCHES FOR REMOTE, FLUIDIC OPERATION

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to remote, pressure operation of electric switches and, more particularly, to electromagnetically transparent fluidic operators adapted to conventional electric switches for operating the electric switches remotely and to a method of adapting electric switches for remote, fluid operation.

2. Description of the Prior Art

When testing battery operated systems to electromagnetic stimulus, such as in electromagnetic interference studies and radiated susceptibility studies, it is desirable to switch the system power "on" and "off" between test shots to conserve battery charge. It is further desirable to switch the system power "on" and "off" from a remote location to eliminate down times associated with accessing the systems directly. Attempts to modify the original power supplies for the systems to permit remote switching such as, for example, by adding at least a remotely operable switch and a remote control receiver, are usually incompatible with electromagnetic testing due to the size, configuration and cost of the modifications as well as the effect the modifications have on the electromagnetic coupling characteristics of the systems. In addition, different systems to be tested typically require different switch designs in accordance with the size, weight and power requirements of the systems. The specialized switch designs of diverse systems are often not amenable to modification for remote switching and, even where modification is possible, the modifications are often not cost-effective to undertake and/or reproduce.

Remotely operable electric switches using pressure, such as fluid pressure, radiation pressure and sound pressure, as the switching signal have been proposed for remote operation. Remote, pressure operated electric switches typically employ various mediums as control links including liquid, gas, light, electrical radiation and sound. Representative of prior art pressure operated electric switches are U.S. Pat. Nos. 5,139,357 to Rents, 4,900,883 to Brane et al, 4,855,545 to Kreuter, 4,755,638 to Geberth, 4,468,532 to Clark et al and 4,037,317 to Bauer et al as well as Models 506019, 506038 and 506039 of pressure switches manufactured by Bristol Babcock, Inc.

Conventional electric switches redesigned or modified for remote operation as well as conventional, remotely operable electric switches including those that are pressure operated are frequently not suitable for use in electromagnetic testing. Most conventional, remotely operable electric switches have a high metallic content and require expensive support hardware, such as a remote transmitter, receiver and/or communication link. Conventional electric switches having radio frequency control links are incompatible with electromagnetic testing due to possible interference of the RF switch signal and the RF test signal as are hard wired switches with metallic wires that can corrupt the electromagnetic characteristics of the associated system. Although fiber optics/light controlled switches are suitable for use in electromagnetic testing, the latter switches have the disadvantages of requiring an electronic transmitter and receiver, necessitating a specialized design depending on the power requirements of the system, and adding some amount of extraneous metal, in addition to the electric switch, to the system due to the fiber optic receiver imbedded therein. Furthermore, fiber optic transmitter circuitry within the system can be susceptible to electromagnetic test fields causing the circuitry to function improperly. Liquid pressure switches can be compatible with electromagnetic testing where the liquid is non-conductive; however, complications from leaking present an unacceptable risk. Although air-operated pressure switches are theoretically compatible with electromagnetic testing, conventional air-operated pressure switches are prohibitively large and comprise metallic components. Modifications or adaptations of conventional air operated electric switches are typically not easily applicable to different types of electric switches, for example, single pole double throw and double pole double throw electric switches. Indeed, many prior art remotely operable electric switch designs are themselves complete switches and not modifications of existing, off-the-shelf electric switches. Accordingly, the prior art has thus far been deficient in providing an electromagnetically transparent adaptation of an existing electrical switch to allow the electric switch to be operated remotely.

SUMMARY OF THE INVENTION

Accordingly, it is a primary object of the present invention to overcome the aforementioned disadvantages of the prior art.

Another object of the present invention is to provide an electromagnetically transparent, low-cost adaptation of a conventional electric switch allowing the electric switch to be operated from a remote location.

A further object of the present invention is to operate an electric switch remotely during electromagnetic experimentation to conserve the power of a system with which the electric switch is associated.

An additional object of the present invention is to apply an operating force against the mechanical actuator of a conventional electric switch utilizing a deformable, non-metallic diaphragm disposed close to the mechanical actuator and confined by a non-metallic housing mounted on the electric switch such that the diaphragm applies force against the mechanical actuator when deformed by fluidic pressure.

It is also an object of the present invention to move a mechanical actuator of a conventional electric switch utilizing an electromagnetically transparent, fluid-tight, expandable reservoir rigidly mounted in alignment with the mechanical actuator with the reservoir being expanded to move the mechanical actuator in response to fluidic pressurization of the reservoir.

Yet another object of the present invention it to selectively adjust the pressurization required in the reservoir to move the mechanical actuator.

Some of the advantages of the present invention are that battery power of systems undergoing electromagnetic experimentation is conserved between test shots, down times during electromagnetic testing are minimized, the fluidic operators can be mounted on conventional electric switches in many various ways for operation in various positions, the fluidic operators are adaptable to many different types of conventional electric switches of different sizes and configurations, the fluidic operators can be easily made or fabricated from readily available materials, the fluidic operators add nothing metallic to the associated system that would affect the electromagnetic characteristics of the system, various different types of fluids can be utilized to deform the diaphragm of the fluidic operators and operation of the electric switches can be obtained in response to predetermined pressures within the reservoirs of the fluidic operators.

These and other objects, advantages and benefits are realized with the present invention as characterized in an electromagnetically transparent fluidic operator for being mounted to a selected, conventional electric switch to form a remotely operable electric switch assembly. The electric switch includes a mechanical actuator movable to make or break an electric contact to operate the electric switch. The fluidic operator includes a non-metallic housing rigidly attached to the electric switch with a chamber in the housing aligned with the mechanical actuator. A non-metallic, fluid-tight reservoir is rigidly mounted by the housing and includes a hollow nipple rigidly attached to the housing and a deformable diaphragm disposed in the chamber and forming a fluidic seal with the nipple. The diaphragm is disposed close to the mechanical actuator of the switch; and, when the reservoir is pressurized with fluid from a remote source, the diaphragm deforms causing the reservoir to expand. The expanded, pressurized reservoir exerts an operating pressure or force against the mechanical actuator causing the mechanical actuator to move to operate the electric switch. The fluidic operator is made of electromagnetically transparent materials to be electromagnetically transparent at radio frequencies and to be electromagnetically translucent at microwave frequencies and does not add anything metallic to the electric switch. A method of adapting an electric switch for fluidic, remote operation according to the present invention includes the steps of rigidly attaching a non-metallic housing to a selected electric switch such that a chamber in the housing is aligned with the mechanical actuator of the switch, positioning a non-metallic, stretchable diaphragm in the chamber close to the mechanical actuator, rigidly attaching a non-metallic nipple to the housing, establishing a seal between the nipple and the diaphragm to form a fluid-tight reservoir, and supplying fluid to the reservoir to pressurize the reservoir and deform the diaphragm such that the fluidic pressure of the reservoir applies an operating force against the mechanical actuator to operate the electric switch.

Other objects and advantages of the present invention will become apparent from the following description of the preferred embodiments taken in conjunction with the accompanying drawings wherein like parts in each of the several figures are identified by the same reference characters.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a broken, perspective view of an electromagnetically transparent fluidic operator according to the present invention mounted to an electric switch to form a remotely operable electric switch assembly.

FIG. **2** is a broken, sectional view of the electric switch assembly of FIG. **1** showing the diaphragm of the fluidic operator in a non-deformed condition.

FIG. **3** is a broken, sectional view of the electric switch assembly of FIG. **1** showing the diaphragm in a deformed condition to operate the electric switch.

FIG. **4** is a broken, sectional view of a modification of an electromagnetically transparent fluidic operator according to the present invention mounted to an electric switch to form a remotely operable electric switch assembly.

FIG. **5** is a perspective view of another modification of an electromagnetically transparent fluidic operator according to the present invention mounted to an electric switch to form a remotely operable electric switch assembly.

FIG. **6** is a broken, sectional view of the electric switch assembly of FIG. **5** showing the diaphragm of the fluidic operator in a non-deformed condition.

FIG. **7** is a broken, fragmentary view, partly in section, of a pressure adjustment mechanism for the fluidic operators according to the present invention.

FIG. **8** is a broken, perspective view of a further modification of an electromagnetically transparent fluidic operator according to the present invention mounted to an electric switch to form a remotely operable electric switch assembly.

FIG. **9** is a broken, perspective view of an additional modification of an electromagnetically transparent fluidic operator according to the present invention mounted to an electric switch to form a remotely operable electric switch assembly.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

A remotely operable electric switch assembly **10** according to the present invention is illustrated in FIG. **1** and comprises an electric switch S and an electromagnetically transparent fluidic operator **12** for electric switch S. Electric switch S is a conventional electric switch having a mechanical actuator for making or breaking an electrical contact to actuate "on" and "off" states. In the case of electric switch assembly **10**, switch S is a momentary pushbutton electric microswitch having a rectangular housing H, mechanically operated electric contacts (not shown) within housing H, a mechanical actuator in the form of a pushbutton B and terminals T, such as normally open, normally closed and common. Pushbutton B is biased to protrude externally or outwardly from a planar, external surface P of housing H and is movable in an axial or longitudinal direction normal to the surface P to make or break an electric contact to operate switch S. For example, when pushbutton B is moved inwardly toward the surface P in response to an operating force or pressure applied thereto in the longitudinal direction, the electric contacts within housing H are closed to turn switch S "on". The switch S will remain in the "on" state as long as the operating force or pressure on pushbutton B is maintained. When the operating force or pressure on pushbutton B is removed, the pushbutton automatically moves away from the surface P in the longitudinal direction to open the electric contacts and thusly turn switch S "off". Although switch S for electric switch assembly **10** is a momentary pushbutton electric microswitch, it should be appreciated that various, diverse mechanically actuated electric switches can be utilized in the present invention.

Electromagnetically transparent fluidic operator **12** includes a housing **14** mounted to electric switch S and an expandable reservoir or bladder **16**, shown in FIG. **2**, mounted by housing **14**. As best shown in FIG. **1**, housing **14** includes a planar, external upper surface **18**, a pair of planar, external, parallel forward and rearward surfaces **20** perpendicular to upper surface **18** (only the forward surface **20** being visible in FIG. **1**), a pair of planar, external, parallel side surfaces **22** perpendicular to upper surface **18** and forward and rearward surfaces **20** (only one side surface being visible in FIG. **1**), and a pair of planar, parallel wings or extensions **24** merging with side surfaces **22** and extending rearwardly of the rear surface at a lower end of the housing **14** (only one wing being visible in FIG. **1**). The lower end of housing **14** is open with a passage **25** therethrough having a configuration in cross-section corresponding to the cross-sectional configuration of switch housing H. Accordingly, the switch housing H can be positioned to extend through the passage **25** as shown in FIG. **1** with the housing H disposed between the side surfaces **22** and the wings **24** of housing **14**, with the forward surface **20** of housing **14** aligned with a planar, external, forward surface of housing H, with a lower edge of housing **14** aligned with a lower surface of housing H from which terminals T protrude and with housing H protruding rearwardly of the rear surface of housing **14** such that a rear surface of housing H is aligned with rear edges **27** of wings **24**. As shown in FIG. **2**, an internal chamber or recess **26** is formed in an upper end of housing **14** in longitudinal or axial alignment with pushbutton B when the housing **14** is mounted to switch S. Chamber **26** includes a lower or inner, cylindrical chamber section **28** communicating with passage **25** and longitudinally or axially aligned with pushbutton B and an upper or outer, cylindrical chamber section **30** longitudinally aligned with lower chamber section **28**. Outer chamber section **30** has an opening along upper surface **18** and a cross-sectional diameter or size greater than the cross-sectional diameter or size of the inner chamber section **28** such that an inwardly protruding shoulder **32** is defined within housing **14** at the junction of the upper and lower chamber sections. An internal wall of housing **14** defining the outer chamber section **30** is provided with threads **33** therealong. The housing **14** is rigidly attached or mounted to electric switch S with securing elements such as screws **34** extending through side walls of the housing **14** and into side walls of the housing H. The housing **14** can be made of any suitable electromagnetically transparent, non-metallic material, including polyvinylchloride, plexiglassρ, and acrylic, allowing electromagnetic waves to pass therethrough unobstructed. Accordingly, as used herein "electromagnetically transparent" has the same meaning that "transparent" has relative to light. Securing elements **34** can be made of any suitable electromagnetically transparent, non-metallic material including nylon, and the material of the securing devices can be the same as or different from the material of the housing **14**.

Expandable reservoir or bladder **16** includes a hollow, rigid nipple **36** and an expandable, deformable, flexible or stretchable diaphragm **38**. Nipple **36** has an upper or outer cylindrical portion **40**, and a lower or inner cylindrical portion **46** depending from outer portion **40**. Outer portion **40** has an open, upper or outer end and a lower end carrying external threads **47** for mating with threads **33** of housing **14**. The inner portion **46** of nipple **36** has an open, inner or lower end and an external diameter or cross-sectional size smaller than the external diameter or cross-sectional size of the outer portion **40** to define an outwardly protruding shoulder **48** at the junction of the outer and inner portions. The inner portion **46** protrudes into the inner chamber section **28** of housing **14** when reservoir **16** is disposed in chamber **26**. As shown in FIG. **2**, when the nipple **36** is rigidly secured to the housing **14**, a longitudinal axis of the nipple is aligned with the longitudinal direction of movement of pushbutton B normal to the upper surface P of housing H. Nipple **36** can be made of any suitable electromagnetically transparent, non-metallic material including the same materials from which housing **14** is constructed. One end of a fluid conduit **49** is connected with the open, outer end of outer portion **40** of the nipple to communicate with the hollow interior thereof, and the conduit **49** can be secured to the nipple with a compression clamp **50** if desired. Another end of conduit **49** is connected with a remote fluid supply allowing conduit **49** to supply fluid to reservoir **16** from a remote location. The

end of conduit **49** coupled with the fluid supply can be provided with a valve such that the reservoir **16** and the lumen of the conduit **49** form a fluid or pressure tight enclosure, with the valve controlling the supply of fluid and the release of fluid from the reservoir. Although the conduit **49** is illustrated connected to the outer end of nipple **36**, it should be appreciated that the fluid conduit can be connected to other parts of the nipple. The conduit **49** is made of a non-metallic material such as plastic or rubber.

Diaphragm **38** has a closed, lower or inner end and an open, upper or outer end having a peripheral edge **52** held between the nipple **36** and the housing **14**. Diaphragm **38** is arranged in the inner chamber section **28** of housing **14** with the inner end thereof close to or adjacent pushbutton B and in alignment therewith. Peripheral edge **52** is disposed between shoulders **32** and **48**. A compressive seal, such as a rubber O-ring **54**, is disposed entirely along the peripheral edge **52** between the diaphragm **38** and the shoulder **48**; and, when the nipple **36** is screwed to the housing **14**, the seal **54** is compressed between the shoulders **32** and **48**. Accordingly, seal **54** holds the diaphragm **38** in place and creates a fluidic seal between the nipple **36** and the diaphragm **38** such that the diaphragm defines or forms a sealed fluidic barrier between the interior of reservoir **16** and the pushbutton B. An annular pressure plate **56** having an external diameter or size to be received in the inner chamber section **28** of housing **14** is interposed between the inner end of diaphragm **38** and pushbutton B. The pressure plate **56** is illustrated as being in engagement with or supported on the pushbutton B; however, the pressure plate can be spaced from and not engaged with the mechanical actuator. The pressure plate can be freely movable in chamber **26** or the pressure plate can be attached to the diaphragm or the mechanical actuator. The diaphragm **38** can be made of any suitable electromagnetically transparent, non-metallic stretchable or expandable material such as latex rubber. The diaphragm **38** an be formed from conventionally available preformed rubber products. For example, the diaphragm can be a finger tip cut from a surgical glove or the reservoir tip of a prophylactic. The pressure plate **56** can be made of any suitable smooth, electromagnetically transparent, non-metallic material. For instance, the pressure plate can be cut from a thin, smooth sheet of plastic.

In use, an electric switch S is selected for adaptation and the fluidic operator **12** is assembled to the selected electric switch S as described above and as shown in FIGS. **1** and **2** with diaphragm **38** normally in an unexpanded, non-deformed or relaxed condition close to or adjacent pushbutton B. When it is desired to operate electric switch S remotely, fluid F such as compressed air is supplied to reservoir **16** via fluid conduit **49**. Enough fluid is supplied to reservoir **16** to fluidically pressurize, expand or inflate the reservoir and because diaphragm **38** to deform, stretch or expand. As shown in FIG. **3**, diaphragm **38** will then be in an expanded, deformed or stretched condition with reservoir **16** increasing in size in the longitudinal direction due to confinement of the diaphragm by the internal wall of housing **14** defining chamber **26**. The housing **14** thusly aligns the deformation of diaphragm **38** with the mechanical actuator of the electric switch S. The sufficiently pressurized, expanded reservoir **16** will exert an operating force or positive pressure, in excess of atmospheric pressure, against pressure plate **56** to move the pressure plate **56** in the longitudinal direction normal to surface P to depress pushbutton B toward surface P as shown in FIG. **3**. Accordingly, the electrical contacts within housing H will close causing the electric switch S to switch to the "on" state. The electric switch S will remain in the "on" state as long as a constant, positive fluidic pressure sufficient to depress pushbutton B is maintained in reservoir **16**. With the switch in the "on" state, an electromagnetic experiment or test can be conducted on the system with which the switch is associated. When experimentation or testing is not being performed, the reservoir **16** is depressurized by releasing fluid via the fluid conduit **49**. The diaphragm **38** will relax or return to the non-expanded condition causing the reservoir **16** to retract in size. The positive pressure or operating force on pushbutton B will be removed or will be insufficient to maintain the "on" state causing pushbutton B to move upwardly to again protrude from surface P. Accordingly, the electric contacts within housing H will open causing the electric switch S to switch to the "off" state. The system power can thusly be conserved prior to turning the switch "on" again when experimentation or testing is resumed.

An alternate embodiment of an electromagnetically transparent fluidic operator according to the present invention is illustrated at **112** in FIG. **4** wherein the fluidic operator **112** is mounted to electric switch S to form a remotely operable electric switch assembly. Fluidic operator **112** is substantially the same as fluidic operator **12** and includes housing **114** mounted to electric switch S and expandable reservoir **116** mounted by housing **114**. Fluidic operator **112** differs from fluidic operator **12** in the manner in which nipple **136** is secured to housing **114**. The outer portion **140** of nipple **136** has a cylindrical, protruding rim **148** at the outer end thereof for engaging upper surface **118** of housing **114**. Screws **157** made of an electromagnetically transparent, non-metallic material are threaded through the protruding rim **148** and into the outer or upper end of housing **114** to rigidly secure the nipple **136** to the housing **114**. It should be appreciated that the nipples can be attached to the housings of the fluidic operators in many various ways including adhesively, with clamps or with a zero-clearance pressure fit.

Another alternative embodiment of an electromagnetically transparent fluidic operator according to the present invention is illustrated at **212** in FIG. **5** wherein the fluidic operator **212** is mounted to electric switch S to form a remotely operable electric switch assembly. Fluidic operator **212** is exemplary of a very low-cost, simplistic adaptation made from readily available conventional materials or components. The housing **214** for fluidic operator **212** is made from a short length of non-metallic tubing, such as polyvinylchloride, having opposed sections cut from the wall thereof in alignment with one another at an inner end of the housing **214** to define passage **225**. Accordingly, the housing H of electric switch S can be positioned to extend through the passage **225** with the housing **214** cradling the electric switch S and with the lumen or chamber **226** of housing **214** longitudinally or axially aligned with pushbutton B. Securing elements such as bolts **234**, only one of which is shown in FIG. **5**, extend through the sides of housing **214** at the inner end thereof and into the side walls of housing H for cooperating with nuts (not shown) to rigidly secure the fluidic operator **212** to the electric switch S. The bolts and nuts can be made of any suitable electromagnetically transparent, non-metallic material such as nylon. Nipple **236** is formed from a length of non-metallic tubing having an external diameter the same as or smaller than the internal diameter of housing **214** allowing nipple **236** to be pressed into the chamber of housing **214**. An inner portion **246** of nipple **236** is received in diaphragm **238** with the peripheral upper edge **252** of the diaphragm protruding externally from the opening of chamber **226** along upper surface **218**. An adhesive bead or seal **258** is disposed entirely around peripheral edge **252** to form a seal between the nipple **236** and the diaphragm **238**. A pressure plate **256** is disposed between the inner end of diaphragm **238** and pushbutton B. The fluidic operator **212** is assembled by positioning the diaphragm **238** in the lumen or chamber **226** of housing **214** with the peripheral edge **252** protruding externally from the opening of chamber **226** along the upper surface **218** of housing **214** and the inner end of the diaphragm close to or adjacent pushbutton B. The nipple **236** is then pressed into the open outer end of the diaphragm **238**, and the seal **258** is applied along the peripheral edge **252** such that the nipple **236** and the diaphragm **238** form the reservoir **216**. Use of fluidic operator **212** is the same as that described above in that fluid is supplied to reservoir **216** via a fluid conduit (not shown) coupled with the open end of nipple **236** protruding externally of housing **214**. The reservoir **216** is sufficiently pressurized with fluid to cause diaphragm **238** to move from a non-expanded condition to an expanded condition. The pressurized reservoir **216**, which is confined by housing **214**, will thusly expand or increase in size longitudinally to move pressure plate **256** toward the surface P of housing H to depress pushbutton B. When fluid is released from reservoir **216** via the conduit, diaphragm **238** will relax or move to the non-expanded condition causing the pushbutton B to move outwardly to again protrude from housing H.

FIG. **7** illustrates a pressure adjustment mechanism **260** for the fluidic operators according to the present invention to allow adjustment of the pressure required to operate the electric switches. The pressure adjustment mechanism **260** is illustrated in FIG. **7** incorporated in the fluidic operator **212** and includes a non-metallic spring **262**, such as a helical coil spring, disposed around pushbutton B and mounted in compression between pressure plate **256** and the surface P of housing H. Accordingly, when the resistance or force of spring **262** is greater than the resistance or force of pushbutton B, the positive pressure required to overcome the force of spring **262** in order to depress the pushbutton B will be greater than the positive pressure required to overcome the force of the pushbutton alone. By using springs of various strengths in the fluidic operators, the pressure required to operate the electric switches can be selectively controlled. In other words, the positive pressure in the reservoirs required to operate the electric switches can be varied or adjusted in accordance with the force constant of the springs, and springs having various known force constants can be selected for use in the fluidic operators to obtain operation of the switches in response to predetermined positive pressures in the reservoirs.

FIGS. **8** and **9** illustrate additional alternative embodiments of electromagnetically transparent fluidic operators according to the present invention having alternative nipple arrangements. The fluidic operator **312** illustrated in FIG. **8** is similar to the fluidic operator **12** except that nipple **336** for fluidic operator **312** protrudes from the rear surface of housing **314** parallel with surface P of switch housing H. Nipple **336**, which is angularly offset from the longitudinal or axial direction of movement of the pushbutton B normal to the surface P of housing H, is secured in a chamber **326** of housing **314**. The chamber **326** has an outer chamber section **330** receiving nipple **336** and an inner chamber section **328** disposed at an angle of 90° with outer chamber section **330**. The chamber **326** is of uniform cross-sectional diameter or size along the length thereof. The inner chamber section **328** is longitudinally aligned with pushbutton B and the diaphragm (not shown) of the fluidic operator is disposed in the chamber **326**. Accordingly, when fluid is supplied to the expandable reservoir via conduit **349**, the housing **314** confines the diaphragm and, therefore, the reservoir, to expand in the direction of movement of pushbutton B to turn the electric switch "on". The fluidic operator **412** illustrated in FIG. **9** is similar to the fluidic operator **312** except that nipple **436** of fluidic operator **412** has an angled outer portion **440** including a first segment **464** rigidly secured in a chamber **426** of housing **314** and a second segment **466** disposed at an angle of 90° with first segment **464**. Chamber **426**, which has a uniform cross-sectional diameter or size along the length thereof is longitudinally aligned with pushbutton B, and the first segment **464** of the nipple enters the chamber **426** at the opening therealong the upper surface **418** of housing **414**. Accordingly, if should be appreciated that the nipples and the chambers of the housings can have various non-straight configurations as well as straight configurations.

The fluidic operators according to the present invention represent simple, near zero-cost adaptations of conventional electric switches for operating the electric switches remotely. The fluidic operators can be adapted to a chosen electric switch for only a fractional percentage, typically less than one percent, of the cost of the electric switch itself. The fluidic operators are compatible with electromagnetic testing and experimentation and are electromagnetically transparent at radio frequencies and at least electromagnetically translucent at microwave frequencies. Although the electric switch itself may contain small metallic contacts and leads, the fluidic operators add nothing metallic that would influence the electromagnetic characteristics of the associated system. The fluidic operators can be operated in various positions other than the vertical position illustrated herein. The fluidic operators can be easily adapted to various types of off-the-shelf electric switches of different sizes and configurations. Various types of fluids can be utilized in the fluidic operators including various gases. Various pressure adjustment mechanisms can be incorporated in the fluidic operators to selectively control or adjust the positive pressures required to operate the electric switches. With the use of a pressure adjustment mechanism, operation of the electric switches can be obtained in response to predetermined positive pressures in the reservoirs of the fluidic operators.

Inasmuch as the present invention is subject to many variations, modifications and changes in detail, it is intended that all subject matter discussed above or shown in the accompanying drawings be interpreted as illustrative only and not be taken in a limiting sense.

What is claimed is:

1. An electromagnetically transparent fluidic operator for attachment to an electric switch for operating the electric switch remotely, the electric switch having a switch housing and a mechanical actuator for operating the electric switch in response to an operating force applied against the mechanical actuator, said fluidic operator comprising:

a fluidic housing made of non-metallic material for being rigidly mounted to the electric switch and having a chamber therein aligned with the mechanical actuator when said fluidic housing is mounted to the switch housing; and

an expandable reservoir made of non-metallic material rigidly mounted to said fluidic housing and including a nipple rigidly attached to said fluidic housing and a deformable diaphragm forming a seal with said nipple, said diaphragm being arranged in said chamber to be disposed close to the mechanical actuator, said nipple having an opening therein for receiving fluid from a remote location to deform said diaphragm, said diaphragm being confined by said fluidic housing such that said deformed diaphragm applies the operating force.

2. An electromagnetically transparent fluidic operator as recited in claim **1** wherein said fluidic housing has a passage therein for receiving the electric switch.

3. An electromagnetically transparent fluidic operator as recited in claim **2** wherein said diaphragm has a closed end disposed adjacent the mechanical actuator and an open end having a peripheral edge forming said seal with said nipple.

4. An electromagnetically transparent fluidic operator as recited in claim **3** wherein said diaphragm is confined by said fluidic housing to cause said reservoir to expand in the direction of movement of the mechanical actuator.

5. An electromagnetically transparent fluidic operator as recited in claim **4** and further including a non-metallic pressure plate disposed in said chamber between said diaphragm and the mechanical actuator.

6. An electromagnetically transparent fluidic operator as recited in claim **1** wherein said nipple is threadedly attached to said fluidic housing.

7. An electromagnetically transparent fluidic operator as recited in claim **1** wherein said fluidic housing comprises a first tubular member and said nipple comprises a second tubular member pressed into said first tubular member.

8. An electromagnetically transparent fluidic operator as recited in claim **7** wherein said first and second tubular members are made of polyvinylchloride.

9. An electromagnetically transparent fluidic operator as recited in claim **1** wherein said diaphragm is made of latex rubber.

10. An electromagnetically transparent fluidic operator as recited in claim **1** wherein said fluidic operator is electromagnetically transparent at radio frequencies.

11. An electromagnetically transparent fluidic operator as recited in claim **10** wherein said fluidic operator is electromagnetically translucent at microwave frequencies.

12. An electromagnetically transparent fluidic operator as recited in claim **1** and further including an adjustment mechanism disposed in said fluidic housing for selectively adjusting the operating force required to be applied by said diaphragm against the mechanical actuator to operate the electric switch.

13. A remotely operable electric switch assembly comprising:

an electric switch having a switch housing and a mechanical actuator protruding from said switch housing and being movable relative to said switch housing to operate said electric switch; and

an electromagnetically transparent fluidic operator attached to said electric switch for operating said electric switch remotely, said fluidic operator including a fluidic housing attached to said switch housing, expandable reservoir disposed in said fluidic housing and a source of fluid coupled with said reservoir for pressurizing said reservoir from a remote location, said reservoir including a nipple rigidly attached to said fluidic housing and a deformable diaphragm disposed adjacent said mechanical actuator and having a peripheral edge forming a seal with said nipple, said diaphragm being deformable to cause said reservoir to expand in response to pressurization of said reservoir with said fluid, said reservoir being confined by said fluidic housing to expand in the direction of movement of said mechanical actuator to move said mechanical actuator to open said electric switch.

14. A remotely operable electric switch assembly as recited in claim **13** wherein said electric switch is a momentary pushbutton electric microswitch and said mechanical actuator is a pushbutton.

15. A remotely operable electric switch assembly as recited in claim **14** and further including a pressure plate interposed between said diaphragm and said pushbutton.

16. A remotely operable electric switch assembly as recited in claim **15** and further including a spring mounted in compression between said pressure plate and said switch for selectively adjusting the pressure required in said reservoir to move said mechanical actuator.

17. A method of adapting an electric switch for fluidic, remote operation comprising the steps of:

selecting an electric switch to be adapted for remote operation, the switch having a switch housing and a mechanical actuator for operating the electric switch in response to an operating force applied against the mechanical actuator; and

attaching an electromagnetically transparent fluidic operator to the electric switch, the attacthing step including

rigidly attaching a non-metallic housing to the electric switch such that a chamber in the non-metallic housing is aligned with the mechanical actuator;

positioning a non-metallic, stretchable diaphragm in the chamber close to the mechanical actuator;

rigidly attaching a non-metallic nipple to the non-metallic housing;

establishing a seal between the nipple and the diaphragm to form a fluid-tight reservoir; and

supplying fluid to the reservoir from a remote location to stretch the diaphragm and pressurize the reservoir to apply an operating force against the mechanical actuator to operate the electric switch.

18. A method of adapting an electric switch for fluidic, remote operation as recited in claim **17** and further including the step of positioning a non-metallic pressure plate between the diaphragm and the mechanical actuator such that the diaphragm applies pressure against the pressure plate and the pressure plate applies pressure against the mechanical actuator to operate the electric switch.

19. A method of adapting an electric switch for fluidic, remote operation as recited in claim **18** and further including the step of positioning a non-metallic spring between the pressure plate and the electric switch to adjust the fluidic pressure required in the reservoir to operate the electric switch.

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