United States Patent

[11] **3,564,175**

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[54] **MAGNETIC DIFFERENTIAL PRESSURE-RESPONSIVE MEANS**
25 Claims, 4 Drawing Figs.

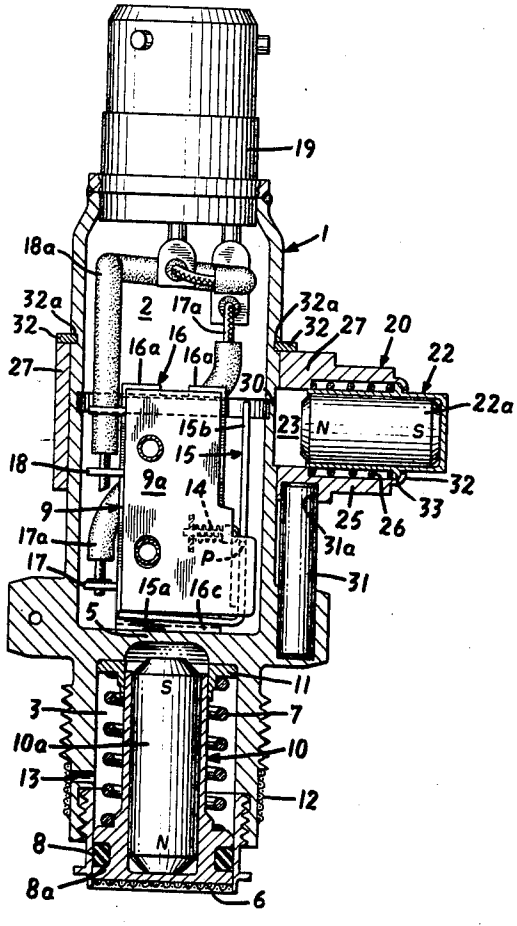
[52] **U.S. Cl.** **200/82,** 200/153
[51] **Int. Cl.** **H01h 35/38**
[50] **Field of Search** ..... 200/81.9 (M), 82 (Digest), 83.1, 83.6, 153.19

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ABSTRACT: A magnetic pressure-responsive switch is provided, having a magnetic piston that is movable toward and away from a partition in a housing in response to a predetermined pressure differential between two passages. An electrical switch positioned on the other side of a partition from the piston has a pivoted generally L-shaped magnetic lever arm. When the magnetic piston moves into actuating position the lever arm is correspondingly moved into a second position to operate the switch.



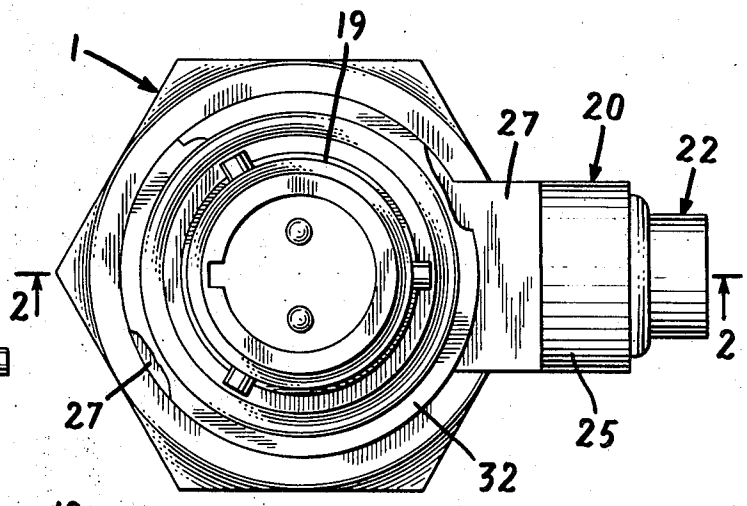

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2
2
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25
32

FIG. 1

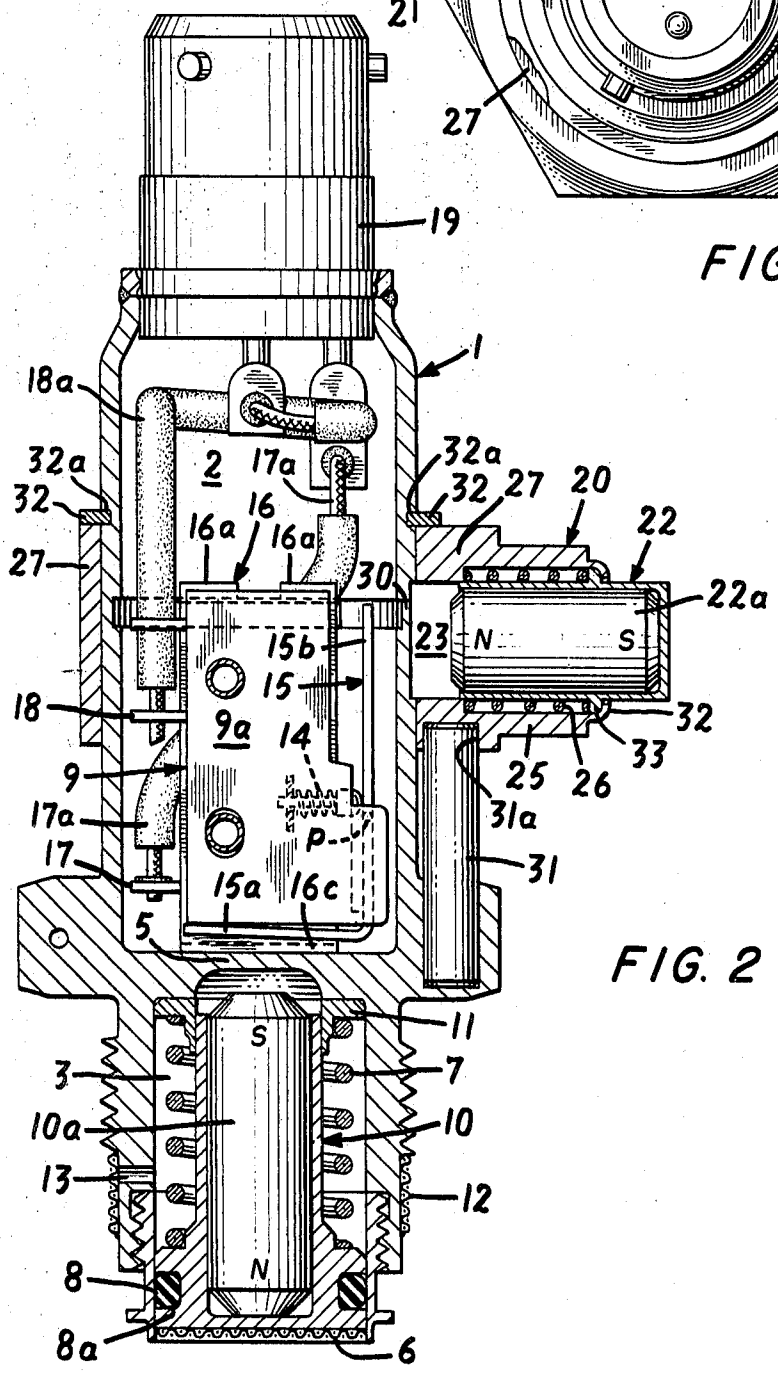

19
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18a
32a
32
27
2
17a
16
16a
16a
32a
32
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22
30
22a
23
N
S
15b
15
18
9a
14
32
33
25
26
9
31a
17a
P
17
15a
16c
31
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11
S
3
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10a
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13
12
8
N
8a
6

FIG. 2

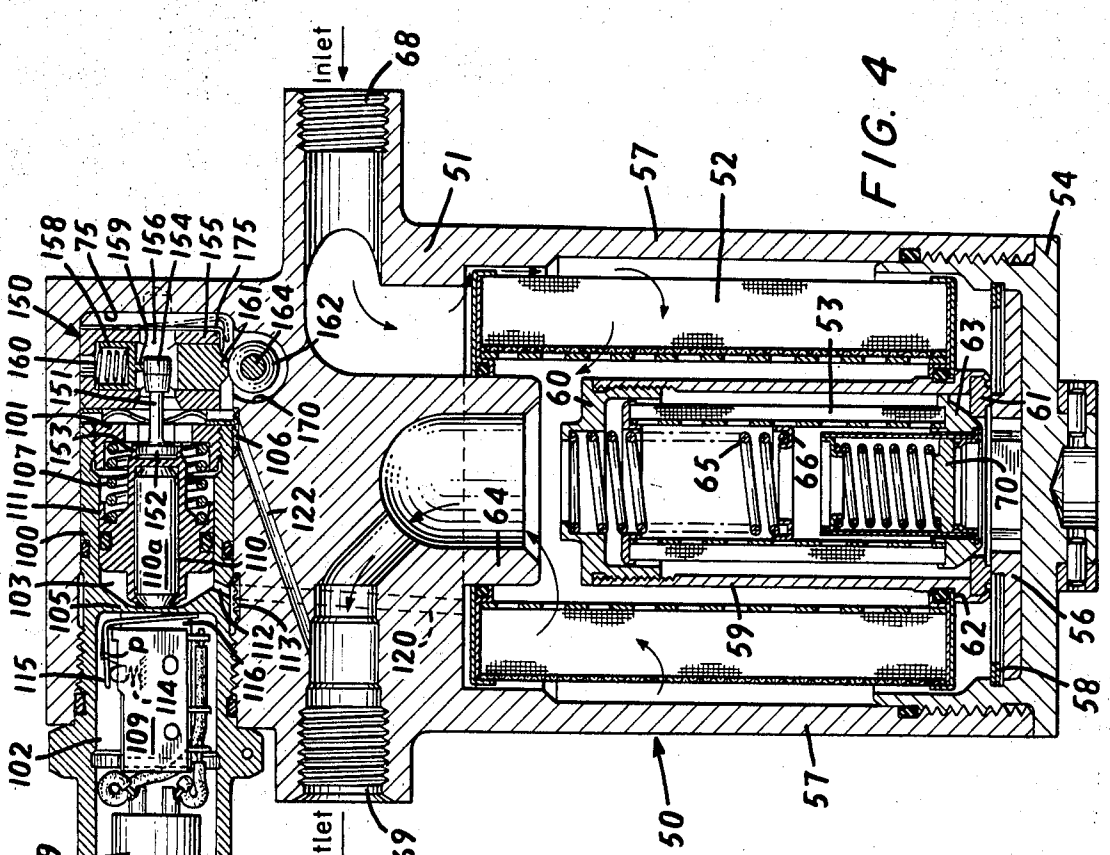

Inlet
Outlet
68
69
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110a
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122
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112
113
116
120
109
114

FIG. 4

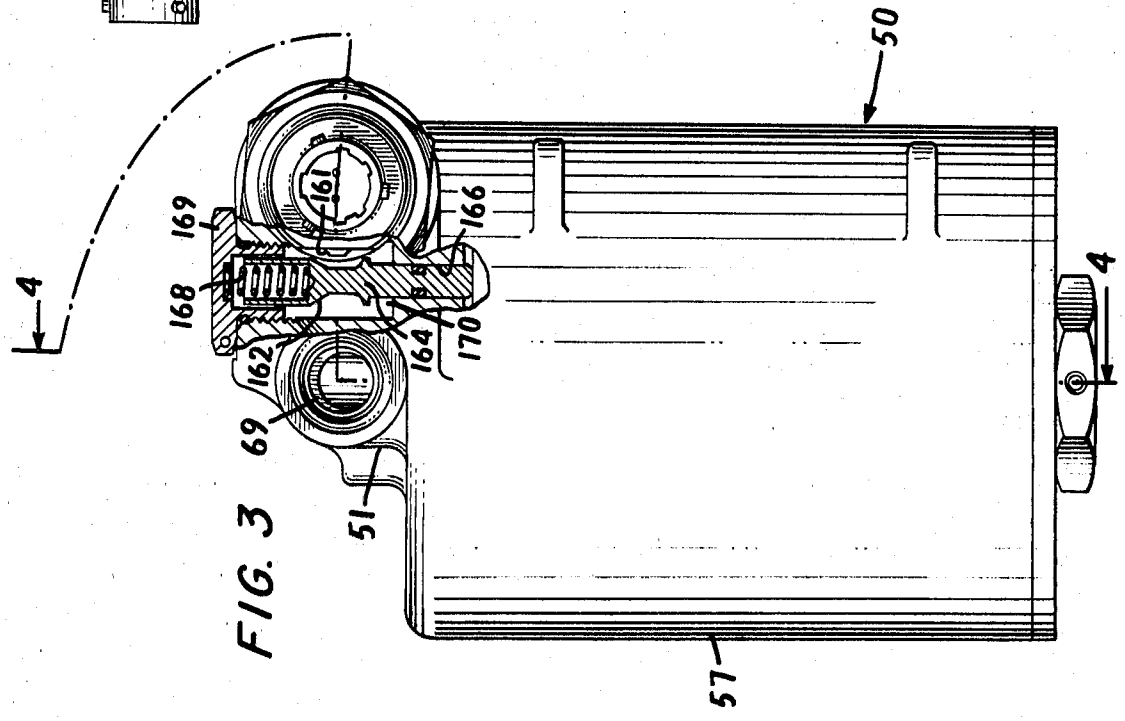

50
4
4
161
169
166
168
170
164
162
69
51
57

FIG. 3

MAGNETIC DIFFERENTIAL PRESSURE-RESPONSIVE MEANS

This invention relates to a magnetic switch and more particularly it relates to a pressure-responsive magnetic switch which is extremely compact, simple in structure, and inexpensive.

In hydraulic systems wherein fluids such as lubricating oil, coolants, or fuel, are passed through a filter to remove contaminants in the fluid, it is frequently desirable to provide a signalling mechanism to indicate when the filter is clogged, or is about to become clogged, so that the filter can be cleaned or replaced before the mechanical components are starved for lack of fluid flow, or the operation of the system halts.

As the filter becomes obstructed with contaminants, the pressure differential across it increases. Consequently, magnetic indicators and switches which are responsive to a predetermined pressure differential across the filter have been provided, to detect the occurrence of the predetermined pressure differential, and signal in response thereto that the filter is clogged and should be serviced. A magnetic switch suitable for such use is shown in U.S. Pat. No. 3,077,854 to Pall. Other magnetic differential pressure switches are shown in U.S. Pat. No. 3,342,959 to Breunich, and British Patent Specification No. 1,057,855.

Devices of the general type shown in these patents employ a magnetic pressure responsive piston which is exposed to the pressure differential across the filter. In response to the occurrence of a predetermined pressure differential, the piston moves either toward or away from a partition, on the other side of which an electrical switch is positioned. The movement of the magnetic piston causes the switch to be actuated, either by magnetic force directly, or by a mechanical linkage which is actuated by movement of the magnetic piston. Upon actuation, the switch contacts are closed, actuating a signal, such as a light or buzzer, which indicates that the filter is or is about to become clogged. Devices of this type have been widely used, and have proved in general to operate satisfactorily.

In many systems, however, magnetic switches of the type referred to above are too large, too expensive, and have too many moving parts. Two systems presenting this problem are of particular note.

In industrial machine tool operations, such as milling, and turning, where fluids are used to cool and lubricate the cutting tools, such fluids become heavily and rapidly contaminated with metal cuttings and chips. A filter is employed to remove these contaminants, and often the filter becomes very rapidly clogged. In such systems, it is extremely important to provide a convenient and reliable mechanism for automatically and immediately shutting off the apparatus, and/or indicating by means of a light or buzzer when the filter is clogged. If this is not done, the tools can overheat, and severe damage to the apparatus can rapidly result.

The magnetic pressure switches heretofore employed although providing one possible mechanism for coping with this problem have not been a complete answer. This is due to the fact that the switches heretofore provided were relatively expensive, and large, and did not always fit into the limited space available in the existing industrial equipment. Due to the expense of such switches, if for some reason the pressure differential switch failed to operate, it is necessary to remove the switch from the system and send it back to the manufacturer for repairs, since it was not generally economically feasible to discard the switch.

Moreover, the known switches had a relatively large number of moving parts and were somewhat intricate in structure. Due to this fact, such switches were not always rugged enough to withstand, for extended periods, the high vibration levels and high impact stresses to which the switches are subjected in industrial equipment.

In addition, the operating mechanism of such switches was not fully protected from being fouled by the contaminants in the system, and could fail to operate as a result. Therefore, the magnetic switches heretofore provided were not fully satisfactory.

In aerospace systems, a similar problem is also presented. The magnetic pressure switches heretofore used on aircraft and spacecraft were not as compact and not as light as desired. Furthermore, it is desirable in aerospace components to have as few moving parts as possible, to minimize the possibility of breakdown. As indicated above, the magnetic pressure switches heretofore provided often had a relatively large number of moving parts.

The instant invention provides a pressure-responsive magnetic switch which solves the problems presented both in industrial and aerospace systems by providing an extremely compact, light, simple, and rugged magnetic switch. The magnetic switch of the invention is inexpensive to make, and can be sold for a low enough price so that it is economically feasible for the switch to be discarded rather than repaired, should failure occur.

The switch of the invention comprises, in combination, a housing, a partition in the housing dividing the housing into noncommunicating first and second chambers; first and second fluid passages communicating the first chamber with first and second sources of fluid pressure; a magnetic piston movably mounted in the first chamber, so positioned between the first and second fluid passages as to be exposed to pressure in both said passages, and arranged to move in said first chamber toward and away from the partition between first and second positions, in response to a predetermined pressure differential between the two passages; an electrical switch mounted in the second chamber, said switch having a pivoted, generally L-shaped magnetic lever arm for operating the switch by movement between first and second positions; one portion of the lever arm being disposed adjacent to the partition, so as to be magnetically attracted to the magnetic piston on the opposite side of the partition, the other portion of said lever arm being disposed generally perpendicularly to said partition; bias means engaging said other portion of the lever arm and urging said lever arm into a first position, whereby when the magnetic piston moves from the first to the second position, the lever arm on the opposite side of the partition is correspondingly moved from the first to the second position to operate said switch.

The term "magnetic" as used herein generically encompasses materials susceptible to being magnetized or which are magnets either permanently or temporarily as in the case of an electromagnet. The term "magnetized" is used herein to denote a temporary magnet, whose magnetic properties arise in a magnetic field or are only temporarily retained. "Magnetizable" is used herein to refer to materials susceptible to being magnetized.

As indicated above, the switch assembly of the invention is extremely compact and inexpensive. This is in part due to the fact that the electrical switch employed can be a small, standard-size commercially-available microswitch. Such a switch can be used in the assembly of the invention with only little modification. Microswitches have lever arms which open and close the contacts of the switch. The lever arm of such switches is normally made of a magnetizable material such as a ferrous metal e.g. cold-rolled steel, and thus the switch arm itself serves as the magnetically attracted component, that is drawn into and/or out of operating position by the magnetic piston of the assembly. Moreover, microswitches can and often do have an internal spring which holds the switch in an actuated or unactuated position, according to the positioning of the contacts. Thus, no room outside of the switch body is needed to accommodate a spring for holding the switch arm in position. Microswitches are also preferred since they are readily available and since they have a pivoted lever arm that can easily be bent or otherwise formed into an L-shape. Other switches can be used, but in all cases the switch must have, or be adapted to have, a pivoted L-shaped magnetic lever arm for opening and closing the switch.

The magnetic lever arm can be made from a magnetizable material as indicated above or it can itself be a magnet. If it is a magnet the magnetic piston need not be a magnet but could merely be made of a magnetizable material. All that is

required is that either the lever arm or the piston be a magnet, although both can be. If both the lever arm and the piston are magnets the switch can employ magnetic repulsion rather than magnetic attraction for moving the lever arm into operating position.

The term "L-shaped" has been adopted for convenience as the description of the shape of the lever arm. However, other shapes such as a U-shape, a C-shape and a 7-shape can be used for the lever arm and such shapes or equivalent shapes are encompassed by the term "L-shaped" in the claims. The legs of the L are normally at a 90° angle to each other. The legs, however, can, if desired, be positioned relative to each other at any angle other than a 90° angle, but the legs of the L should be at an angle within the range of from about 45° to about 135° to each other. The 90° angle is preferred for reasons that will be a pparent from the following discussion.

The L-shaped configuration of the switch lever arm makes it possible to fit the switch in a small space and yet actuate the switch with only a very small magnetic force, and with a minimum of movement of the magnetic piston and the switch arm. The L-shape of the arm follows the generally rectangular boxlike shape of the switch body, and thus, although the lever arm may be relatively long to provide a high mechanical advantage, very little extra room is required to accommodate the long lever arm, since it follows the contour of the switch. Moreover, since the L-shaped arm is a pivoted lever arm, a high mechanical advantage of at least 3 to 1 and preferably 5—10 to 1 is obtained. This of course depends upon where the pivot of the arm is, in relation to where the force is applied. One of the portions of the L-shaped switch arm is positioned so that it lies against or is adjacent to the partition in the housing separating the piston chamber and the switch chamber. This portion of the switch arm is magnetically attracted by the magnetic piston on the opposite side of the partition, so that it swings toward or away from the partition to operate the switch. The other portion of the switch arm extends along the side of the switch, generally perpendicularly relative to the partition. This portion of the switch is acted on by the switch spring, which urges that portion of the lever arm in a direction which is opposite to the direction in which the force exerted by the magnetic piston acts.

If a microswitch is used, the spring is normally a helical compression or extension spring incorporated within the switch body itself. However, if another type of switch is used, the spring can be positioned outside of the switch body. Of course, less space is required inside of the housing if the spring is within the switch body and the housing therefore can be smaller than it otherwise might be. Any type of spring could be used such as a helical compression spring or extension spring, a leaf spring, a sear spring, and the like. Due to the L-shape of the switch arm, and the positioning of the spring, no axial space need be provided to accommodate the switch spring, thereby reducing the overall size of the assembly. In fact, very little space in the housing is required for the switch and switch arm other than the space required for the switch to move. The switch lever arm can be biased by the spring either normally toward or away from the partition, whichever is desired.

The fulcrum of the lever arm is preferably located as close to the spring as possible, to provide the maximum mechanical advantage, so that a low magnetic force can be used to overcome a spring force which is two to three times as great as the magnetic force. Normally, the switch arm is pivoted at some point on the portion of the lever arm which is perpendicular to the partition. A relatively strong spring in relation to the magnetic force (two to three times as great) is desirable, since a strong spring provides a precise point of actuation for the switch, and provides a reliable mechanism for automatically resetting the switch. A strong spring also makes it possible to build the switch with a close tolerance between open and closed positions of the switch. In fact, only a small fraction of an inch (0.040 inch) of lever arm travel is required to actuate the switch. This arm travel can be effected with only 0.050 inch movement of the magnetic piston using an Alnico V magnet and a lever arm having a mechanical advantage of 4 to 1. These features combined make it possible to provide an extremely compact, reliable and inexpensive magnetic switch.

As noted above, only small movements of the magnetic piston and magnetic lever arm are contemplated in accordance with this invention. Therefore, it can be appreciated that the spacing of the switch body and the lever arm from the partition is extremely important. It is also important that little or no external vibration or shock be transmitted to the lever arm of the switch, since this could cause false actuation of the switch. Both of these problems are solved in the instant invention by providing a plastic-mounting block which is fixed to the switch body and which has a spacing shoulder which abuts the partition in the housing, and spaces the switch the desired distance from the partition. In this way, correct spacing of the magnetic lever arm from the partition is accurately obtained without the necessity for measuring the precise distance for each switch. In addition, the plastic-mounting block acts as shock mounting to keep any vibration or shock from moving the magnetic lever arm.

The housing is composed of a nonmagnetic material such as aluminum, or austenitic stainless steel and has two, normally cylindrical chambers separated by a relatively thin partition. The housing can have external threads or other coupling means for mounting it in or on a filter housing or receptacle associated with the filter.

The magnetic piston assembly is positioned on the opposite side of the partition in the housing from the switch. As indicated above the piston can be a magnet but can alternatively merely be made of a magnetizable material if the lever arm is a magnet. The piston can be biased either against or away from the partition such as by a spring surrounding the piston or on one side of the piston in the manner shown in U.S. Pat. No. 3,077,854. Normally, when the magnetic lever arm is biased away from the partition, the magnetic piston is also biased away from the partition such that when an increase in pressure differential across the piston occurs, the piston moves toward the partition to attract the lever arm toward the partition. It is also possible, however, to have the piston biased against the partition, such that it holds the lever arm by magnetic attraction against the partition. In this case, when the piston, in the response to a predetermined pressure differential, moves away from the partition, the magnetic lever arm is moved away from the partition by the spring. The remaining details of the housing, and the magnetic piston assembly are more particularly described in connection with the drawings.

By carefully adjusting the magnetic force applied to the switch lever arm in relation to the spring force acting on it, and by adjusting the distance the switch arm is moved by the piston to operate the switch, it is possible to make the switch self-resetting. That is, when the pressure differential across the piston diminishes and the piston returns to its normal position, the switch shuts itself off. However, in certain instances, it is desirable not to permit the indicator to be reset unless it is reset manually. This helps ensure that the signal is noticed and the clogged filter is serviced. One way of doing this, in accordance with the instant invention, is to employ a manual magnetic reset mechanism positioned on the side of the switch housing in a location to attract one portion of the L-shaped lever arm and move it back into its normal position. It is also possible to provide a system whereby automatic reset of the switch is prevented by a locking mechanism which holds the magnetic piston (and thereby the switch arm) in its actuated position until the filter element is replaced, whereupon the locking mechanism is automatically released. The structure of both the manual magnetic reset, and the piston-locking mechanism, are more particularly described in connection with the drawings, in which:

FIG. 1 is a top plan view of the magnetic switch in accordance with this invention.

FIG. 2 is a sectional view taken along the line 2–2 of FIG. 1.

FIG. 3 is a plan view, partially broken away, and partially in cross section, of a filter assembly incorporating a switch of the invention having a piston locking mechanism.

FIG. 4 is a section taken along the line 4–4 of FIG. 3.

The magnetic switch shown in FIGS. 1 and 2 comprises an anodized aluminum housing 1 divided into two chambers 2 and 3 by a partition 5. A magnetic piston assembly 10 is located on one side of the partition 5 in the chamber 3. The piston has an Alnico V magnet 10*a* mounted therein. The piston is biased away from the partition 5 by a helical spring 7. The piston is held in the chamber 3 by a filter disc 6 of woven wire mesh made in accordance with U.S. Pat. Nos. 2,925,650 and 3,049,796. The disc 6 is swaged into the housing at the end of the chamber 3. The mesh openings of the disc are 10μ in diameter. The piston 10 is exposed to upstream pressure via the filter 6. The downstream pressure is communicated to the other side of the piston via a port 13 in the sidewall of the chamber 3.

An O-ring 8 is fitted in a groove 8*a* in the piston. The O-ring 8 seals against the walls of the chamber 3 and prevents communication between the upstream and downstream sides of the piston. A centering piece 11 captured between the spring 7 and the partition 5 guides the piston in its movement toward and away from the partition, in response to a pressure differential between the upstream and downstream sides of the piston.

A further feature of the invention is that both the upstream and downstream ports which communicate pressure to the opposite sides of the magnetic piston are provided with filters to protect both the upstream and downstream sides of the piston. Wire mesh filters having pores of 5 to 20 microns in diameter are suitable for this purpose. The provision of filters on both upstream and downstream ports is important. This is due to the fact that many filter assemblies have bypass valves to permit fluid to bypass the filter when the filter is clogged. When the bypass valve is open, the fluid on the downstream side of the filter is unfiltered. Thus, to prevent contamination of the piston with contaminants in the fluid, both upstream and downstream ports are protected by filters.

A band 12 of filter sheet material is positioned across the port 13. The filters 6 and 12 prevent any contaminants in the fluid from entering the chamber 3.

A microswitch 9 is located on the opposite side of the partition 5 in the chamber 2, and in line with the magnetic piston 10 in the chamber 3. The switch 9 has a boxlike body 9*a* on which a pivoted L-shaped lever arm 15 made of magnetizable steel is mounted. The lever arm 15 is pivoted at P. One portion 15*a* of the L is normally positioned along the partition 5 and at a slight angle thereto. The other portion 15*b* of the arm 15 is normally positioned generally perpendicularly to the partition 5. The lever arm 15 is held in its normal position by a spring 14 (shown in broken lines) mounted within the switch body 9*a*.

The switch 9 is fixed to a plastic mounting block 16 which shock mounts the switch in the housing. The mounting block 16 has positioning members 16*a* which are press fitted against the chamber walls to hold the switch in position. The mounting block also has a shoulder 16*c* which abuts the partition 5 and thereby spaces the switch arm the correct distance from the partition 5 so as to ensure the lever arm will be moved when the magnetic piston moves toward the partition 5. The electrical leads 17 and 18 of the switch are connected via wires 17*a* and 18*a*, respectively, to an electrical connector 19 fitted in the end of the chamber 2. The switch 9 shown is a two wire switch. However three wire double pole switches and the like can be used. The connector 19 is welded in position at the end of the chamber so that the entire switch mechanism is hermetically sealed in the chamber. Thus, there is no possibility of an electric short in the switch detonating any combustible atmosphere surrounding the switch housing. Furthermore, there is no possibility of damage to the switch mechanism by any corrosive external atmospheric conditions.

Under normal conditions, as indicated above, the piston 10 is biased away from the wall by the coil compression spring 7. The coil compression spring 14 of the switch 9 pushes the L-shaped lever arm 15 outwardly so that the portion 15*a* is brought away from the partition 5. When the pressure differential between the port 13 and the downstream surface of the piston exerts a force on the piston in excess of the force exerted against the piston by the spring 7, the piston moves toward the partition 5. As indicated above, only 0.050 inch piston travel is required to attract the arm sufficiently to overcome the pushing force of the spring 14, and compress the spring while swinging the portion 15*a* of the lever arm 15 toward the partition 5, resulting in actuation of the switch. The lever arm portion 15*a* moves only 0.040 inch for actuation of the switch to occur. Thus, it can be appreciated that only small movements of both the piston and the lever arm are necessary in the instant invention. The small movement of the piston and lever arm make it possible to make the switch housing quite compact.

When the pressure differential between the upstream and downstream sides of the piston diminishes, the spring 7 forces the piston back into its normal position. If it is so desired, the spring 14 biasing the arm 15 can be of sufficient strength to return the lever arm to its normal position when the piston 10 moves away from the partition 5, and thereby automatically shut off the switch. However, in the embodiment shown, a magnetic manually-operated reset is provided. This reset mechanism is a safeguard which ensures that some physical action must be taken, in order to shut off the switch. This helps ensure that the condition which is the cause of the signal is corrected before the switch is reset.

In the embodiment shown, when the magnetic piston 10 moves back to its normal position away from the partition, it still exerts a substantial magnetic force on the lever arm 15 acting against it. This magnetic force is greater than the force of the spring 14, and retains the lever arm portion 15*a* against the partition. In order to accomplish reset, a magnetic reset assembly 20 is provided on the side of the switch housing. The magnetic reset assembly is composed of a magnetic button assembly 22 slidably mounted within a cylindrical chamber 23 in a cylindrical housing portion 25. The housing portion 25 protrudes from the housing 27 which is generally ring-shaped. The housing 27 fits over and surrounds the exterior wall of the switch housing. The button assembly 22 is positioned in the correct radial location in relation to the switch by a dowel pin 31 mounted on the switch housing. The pin 31 extends along the switch housing wall and fits into a recess 31*a* in the housing portion 25. A snap ring 32 fits over the end of the switch housing into a groove 32*a* in the switch housing wall and abuts the housing 27 to hold the button assembly 22 in place. The button assembly 22 carries an Alnico V magnet 22*a* and is biased away from the wall of the chamber 2 by a coil compression spring 26. The button assembly 22 is held within the chamber 23 by a lip 32 on the housing portion 25, which engages an external flange 33 on the button assembly 22.

When reset of the switch is desired, the button assembly 22 is pushed inwardly toward the wall portion 30 of the switch housing. The magnetic force applied by button to the lever arm draws the portion 15*b* of the arm toward the wall portion 30 of the chamber 23 and thus swings the arm portion 15*a* back into its normal position shutting off the switch. When the button 22 is released, the spring 26 forces the button 22 away from the wall portion 30 and the switch is then again ready to be actuated by the piston 10. It is to be noted that only one of the arm portion 15*b* or the button assembly 22 need be a magnet, but both could be.

In FIGS. 3 and 4, a filter assembly incorporating a switch of the invention is shown. The filter assembly 50 includes a housing 51. The housing has an inlet 68 and an outlet 69. A wall 57 defines a cylindrical chamber which encloses a primary filter element 52, and a concentrically positioned reserve filter 53. A bottom plate 54 closes off the bottom of the chamber. The filter elements are supported in the chamber by a support piece 56 held against the bottom plate 54 by a snap ring 58.

The reserve filter 53 is mounted within a canister 59 having an annular cap 60 at one end thereof and a support ring 61 at the other end thereof. The support ring 61 rests against the support piece 56 on the end plate 54. The canister has an exterior shoulder 62, which supports and closes off the bottom

end of the primary filter element. The upper end of the primary filter is supported and closed off by a shoulder **64** on the housing. Fluid therefore under normal conditions to reach the outlet must pass through the primary filter. The ring **61** on the canister seats against and supports a beveled end cap **63** on the bottom end of the reserve filter element. A spring **65**, captured between a flange on the annular cap **60** of the canister and a retainer ring **66** mounted in the interior of the reserve filter element, forces the end cap **63** of the reserve filter against the ring **61**, so as to prevent fluid from bypassing the primary filter element, around the bottom of the primary filter until it becomes clogged. When the primary filter becomes clogged, however, the pressure differential acting on the reserve filter creates a force sufficient to overcome the force of the spring **65**. The reserve filter then moves away from the ring **61**, so that fluid can pass between the ring **61** and the end cap **63**, and pass through the reserve filter to the outlet. A spring-biased relief valve assembly **70** prevents fluid from bypassing the reserve filter until the reserve filter is clogged, whereupon the valve **70** opens, permitting fluid to pass directly to the outlet.

At the upper portion of the housing, a magnetic switch assembly of the invention and a reset locking mechanism (as are described hereinafter) are fitted in a generally cylindrical bore **75**. The magnetic switch assembly is best seen by reference to FIG. **4**. The magnetic switch assembly is similar to that described in connection with FIGS. **1** and **2** with certain exceptions as pointed out below. The switch assembly has a magnetic piston assembly **110** carrying an Alnico V magnet **110***a* on one side of the partition **105** of a two-chamber housing **100**. The magnetic piston in this embodiment (as contrasted to that shown in FIG. **1**) is biased by a coil compression spring **107** against the partition **105**, rather than away from it. The spring **107** is captured between a flange **111** on the piston and an annular insert **101** in the end of the housing **100**.

A port **112** opens into the chamber **103** on the upstream side of the piston. This port communicates with the upstream side of the filter via a passage **120** in the housing. The port **112** is covered by a sheet of wire mesh filter material **113**. A passage **122** exposes the downstream side of the piston to outlet pressure of the filter assembly. A sheet of wire mesh filter material **106** protects the downstream side of the magnetic piston assembly from contamination which could possible occur, should fluid bypass the reserve filter. The housing **100** is made of anodized aluminum.

An electrical switch **109** (similar to that described in connection with FIG. **2**) is positioned in chamber **102**, on the opposite side of the partition **105** from the chamber **103**. The switch has a steel lever arm **115** which is L-shaped as in the previous embodiment and is pivoted at P. In this embodiment however, the switch lever arm is biased against the partition **105** under normal conditions by a compression coil spring **114** (shown in dotted lines) within the switch body. The switch **109** is connected via electrical wires to a connector **119** mounted in the end of the chamber **102**. As in the previous embodiment the switch is mounted in position by a plastic mounting block **116**.

In the embodiment shown in FIG. **4**, there is no magnetic reset button, as described in connection with the previous embodiment. The switch itself is of the self-resetting type, that is, the lever arm **115** is sufficiently under the influence of spring **114** so that when the magnetic piston returns to its normal position adjacent the partition the magnetizable lever arm will be drawn back into its normal unactuated position against the partition. However, in the embodiment shown, in order to ensure that the switch is not reset without the filter element being replaced a piston-locking mechanism **150** is provided.

The piston-locking mechanism comprises a shaft **151**, having a flattened end portion **152**, which is carried by an annular flange **153** at the base of the magnetic piston assembly **110**. The other end of the shaft **151** is formed with a retainer cap **154**. The shaft is movable through a passage **156** in a housing **155**. A spring-loaded detent assembly **158** is mounted in the housing **155**. The detent assembly has a locking tab or catch **159**, which rests against the retainer cap **154** of the shaft **151**, under the force of a coil compression spring **160**.

The detent assembly also includes a cam follower **161**, which is movable under the force of the spring **160** into a bore **170** in the housing. The cam follower **161** cooperates with a cam surface **162** on a shaft **164** which is mounted in the bore **170**. The shaft **164** extends perpendicularly relative to the cam follower **161**. The bore **170** extends longitudinally in the housing head and terminates in an aperture **166** opening into the chamber occupied by the filter elements. The end of the shaft **164** extends into the chamber housing the filter elements, and abuts the upper end cap of the primary filter element. The shaft **164** is spring-loaded against the filter element by a spring **168**, which is held in position by a cap **169**, threadably mounted in the bore **170**.

The operation of the magnetic switch and the detent assembly is as follows: When the primary filter element becomes clogged with contaminants, the pressure differential between the ports **112** and **122** increases. It eventually reaches the predetermined threshold at which the magnetic piston assembly **110** is forced away from the partition **105**. When the magnetic piston moves more than 0.050 inch away from the partition, the spring **114** forces the L-shaped lever arm **115** away from the partition, actuating the switch and signalling that the primary filter is clogged. At the same time, the shaft **151** carried on the magnetic piston assembly **110** slides through the passage **156**. When the piston has moved far enough, so that the retainer cap moves passed the spring-loaded tab **159**, the tab on the detent assembly moves toward the shaft, and engages the bottom of the retainer cap on the shaft **151**, thus locking the magnetic piston assembly **110** away from the partition **105**.

The movement of the detent assembly toward the shaft causes the cam follower **161** to move into position abutting the cam surface **162** on the shaft. The switch **115** will remain actuated until the piston is freed from the detent assembly **160**, and returns to its normal position against the partition. The detend assembly releases the piston when the filter element is replaced. When the primary filter element is removed, the spring **168** forces the shaft **164** inwardly into the chamber occupied by the primary filter element. The cam surface on the shaft **162** engages the cam follower **161**, and forces the cam follower and the detent assembly therewith back into its original position. The tab **159** is then clear of the retainer cap **156**, and the piston spring **107** moves the piston assembly and the shaft **151** back through the passage **156** until the piston is against the partition **105**. When the primary filter is replaced, the spring-loaded shaft **164** is moved back into its original position, clear of the cam follower on the detent assembly.

In order to prevent operation of the detent assembly, as a result of a high pressure differential, caused for example by the high viscosity of the fluid due to its lower temperature rather than by clogging of the primary filter, a thermal lockout is provided. This comprises an L-shaped bimetallic strip **175**, shown in dotted lines in FIG. **4**. When the fluid in the assembly is cold, the strip moves into position so as to engage the cam follower **161**, to prevent the detent mechanism from trapping the piston when it moves away from the partition. Thus, although the switch may actuate when the fluid in the system is cold, it will not be necessary to disassemble the filter assembly to reset the indicator when the switch is actuated, due to the low temperature of the fluid in the system, rather than clogging of the filter.

Having regard to the foregoing disclosure, the following is claimed as the inventive and patentable embodiments thereof.

I claim:

1. A magnetic pressure-responsive switch comprising, in combination, a housing; a partition extending across the housing dividing the housing into noncommunicating first and second chambers; first and second fluid passages communicating the first chamber with first and second sources of fluid pressure; a magnetic piston movably mounted in the first

chamber and positioned relative to the first and second fluid passages so as to be exposed to pressure in both said passages, movable in said first chamber toward and away from the partition between first and second positions in response to a predetermined pressure differential between the two passages; an electrical switch mounted in the second chamber, said electrical switch having a pivoted, generally L-shaped magnetic lever arm for operation by pivoted movement between first and second positions, one portion of the lever arm being disposed adjacent to the partition so as to be magnetically attracted to the magnetic piston on the opposite side of the partition, the other portion of said lever arm being disposed generally perpendicularly to said partition; bias means engaging said other portion of the lever arm and urging said lever arm into said first position, whereby when the magnetic piston moves from the first to the second position, the lever arm on the opposite side of the partition is correspondingly moved from the first to the second position, to operate said electrical switch.

2. A magnetic pressure-responsive switch in accordance with claim 1 in which the electrical switch is a microswitch.

3. A magnetic pressure-responsive switch in accordance with claim 1, in which the lever arm is made of a magnetizable material and the magnetic piston includes a magnet.

4. A magnetic pressure-responsive switch in accordance with claim 1, in which the bias means engaging the switch lever arm is positioned adjacent a fulcrum of the lever arm.

5. A magnetic pressure-responsive switch in accordance with claim 1, in which the bias means engaging the lever arm is within the switch body.

6. A magnetic pressure-responsive switch in accordance with claim 1, in which the switch body is boxlike in shape and the lever arm is arranged to follow the shape of the switch body.

7. A magnetic pressure-responsive switch in accordance with claim 1, in which the second chamber closely encloses the electrical switch so as to permit movement of the lever arm but keep wasted space to a minimum.

8. A magnetic pressure-responsive switch in accordance with claim 1, in which the electrical switch in accordance with claim 1, in which the electrical switch is supported in the second chamber by a plastic-mounting block.

9. A magnetic pressure-responsive switch in accordance with claim 6, in which the mounting block has a shoulder which spaces the lever arm from the partition.

10. A magnetic pressure-responsive switch in accordance with claim 1, including filters across both the first and second fluid passages, to prevent passage of contaminants into the first chamber.

11. A magnetic pressure-responsive switch in accordance with claim 1, including magnetic means for manually resetting the electrical switch.

12. A magnetic pressure-responsive switch in accordance with claim 11, in which the magnetic means for manually resetting the electrical switch comprises a magnetic button positioned exteriorly of the second chamber but adjacent to a wall portion of the chamber in juxtaposition to the said other portion of the lever arm, said magnetic button being movable toward and away from the said wall portion of the second chamber so as to attract said other portion of the lever arm to set the electrical switch.

13. A magnetic pressure-responsive switch in accordance with claim 1, including means for holding the piston in its second position to prevent automatic resetting of the switch.

14. A magnetic pressure-responsive switch in accordance with claim 13 in which the means for holding the piston in its second position comprises catch means and means associated with the piston and positioned for engaging the catch means so as to be held by the catch means when the piston moves into its second position.

15. A magnetic pressure-responsive switch in accordance with claim 14 including means for automatically releasing the catch means.

16. A compact magnetic pressure-responsive switch comprising, in combination, a housing made of a nonmagnetizable material; a partition extending across the housing dividing the housing into noncommunicating first and second chambers; first and second fluid passages communicating the first chamber with the first and second sources of fluid pressure; a piston assembly movably mounted in the first chamber, positioned adjacent the partition and relative the first and second fluid passages so as to be exposed to pressure in both passages, said piston assembly having a magnet associated therewith; a spring engaging the piston assembly and normally urging the piston assembly into a first position, said piston assembly being adapted to move in the first chamber into a second position closely spaced from the first position in response to a predetermined pressure differential between the two passages sufficient to produce a force on the piston assembly in excess of the force of the spring; an electrical microswitch mounted in the second chamber, said electrical switch having a generally boxlike body and having pivotally mounted thereon a generally L-shaped lever arm made of a magnetizable material for operating the electrical switch by pivotal movement between closely spaced first and second positions, one portion of the lever arm being disposed in close proximity to the partition so as to be magnetically attracted to the magnetic piston assembly on the opposite side of the partition, the other portion of said lever arm being disposed generally perpendicularly to said partition, said L-shaped lever arm being positioned to generally follow the shape of the microswitch body; a spring incorporated within said switch body and engaging said other portion of the lever arm, and urging said lever arm into a first position; a plastic-mounting block mounted in the second chamber and fixed to the microswitch in a manner to position the switch in the second chamber such that the lever arm is located at a predetermined short distance from the partition; whereby when the magnetic piston assembly moves the short distance from its first to its second positions the lever arm on the opposite side of the partition is correspondingly moved the short distance from its first to second positions to operate the electrical switch, and an electrical connector mounted on the housing in juxtaposition to the second chamber and electrically connected to the electrical switch.

17. A compact pressure-responsive switch in accordance with claim 16, in which filters are provided across both the first and second passages to prevent passage of contaminants into the chamber.

18. A compact magnetic pressure-responsive switch in accordance with claim 16, including a magnetic switch reset button assembly mounted on the housing adjacent to said other portion of the magnetizable lever arm, said magnetic button assembly comprising a magnet biased normally away from said housing but movable toward said housing to attract and move said other portion of the lever arm out of its second position thereby resetting the switch.

19. A compact magnetic pressure-responsive switch in accordance with claim 16 including catch means for holding the magnetic piston assembly in its second position to prevent automatic resetting of the switch.

20. A magnetic pressure-responsive switch in accordance with claim 1 in combination with a filter assembly having a housing provided with an inlet and an outlet; a filter element in the housing positioned in the line of flow from the inlet to the outlet such that all flow through the housing must pass through the filter element; and passages in the housing communicating the upstream and downstream sides of the filter element with the first and second passages of the magnetic pressure-responsive switch so that when a predetermined pressure differential across the filter element is reached, the magnetic pressure-responsive switch is actuated.

21. The combination in accordance with claim 20 wherein the filter assembly includes a pressure relief valve adapted to permit fluid to bypass the filter element when a predetermined pressure differential is reached.

22. The combination in accordance with claim 20 including means for holding the piston of the switch in its second position comprising catch means, means associated with the piston and positioned for engaging the catch means when the piston moves into its second position, and means engaging the filter element in the housing and operatively associated with the catch means for automatically releasing the catch means when the filter element is removed from the housing for service.

23. A magnetic pressure-responsive device comprising, in combination, a housing; a partition extending across the housing dividing the housing into noncommunicating first and second chambers; first and second fluid passages communicating the first chamber with first and second sources of fluid pressure; magnetic differential pressure-responsive means movably mounted in the first chamber so positioned relative the two fluid passages as to be exposed to pressure in both fluid passages and arranged to move between first and second positions in the chamber in response to a predetermined pressure differential between the passages; signalling means mounted in the second chamber for signalling when the predetermined pressure differential is reached, said signalling means having a switch and a magnetic actuating member a portion of which is disposed adjacent to the partition so as to be magnetically attracted to the magnetic differential pressure-responsive means on the opposite side of the partition, and another portion of which is disposed along a wall of said second chamber, said actuating member being adapted to operate the said signalling means upon movement from a first to a second position such that movement of the magnetic differential pressure-responsive means from its first to its second positions results in movement of said actuating member from its first to its second position to operate the switch; and magnetic reset means positioned adjacent a wall of the second chamber in position to attract said another portion of the actuating member and movable toward and away from said chamber to move the actuating member from its second position back into its first position to reset said signalling means.

24. A magnetic pressure-responsive device in accordance with claim 23, in which the magnetic reset means has a magnetic button biased normally away from said chamber by a spring.

25. A magnetic pressure-responsive device in accordance with claim 24, in which the magnetic reset button is mounted in a housing fixed to the wall of the second chamber.