Dec. 3, 1968 L. W. KEIL ETAL 3,413,951

DIFFERENTIAL PRESSURE INDICATOR

Filed June 15, 1964

FIG. 1

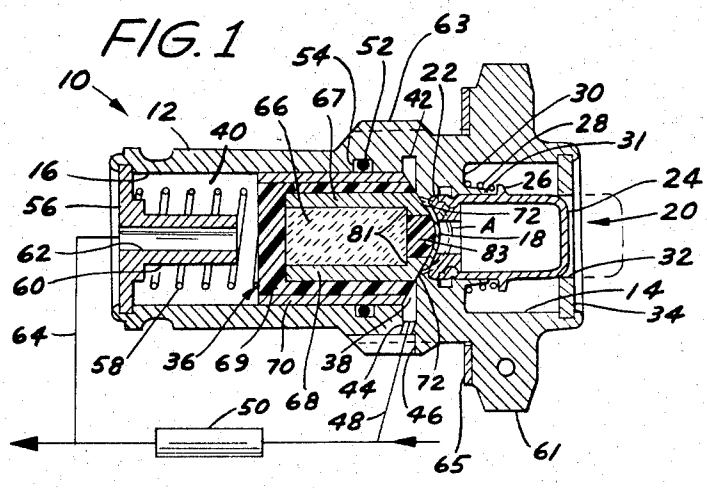
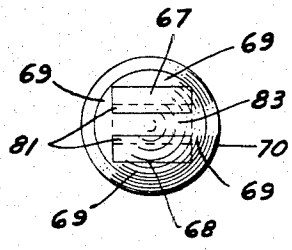


FIG. 2



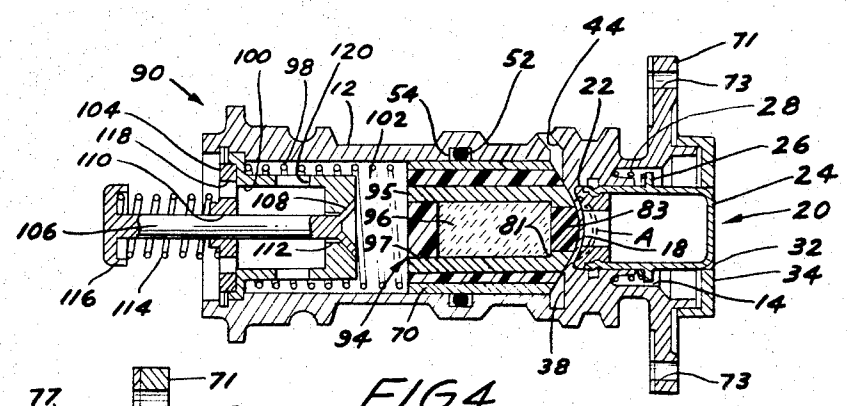


FIG. 4

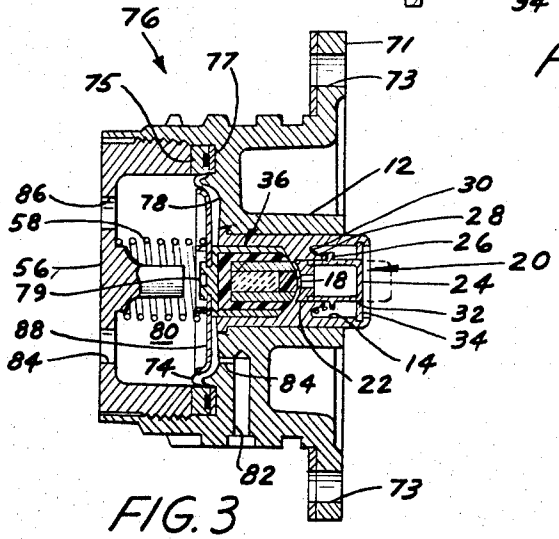


FIG. 3

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DIFFERENTIAL PRESSURE INDICATOR

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ABSTRACT OF THE DISCLOSURE

This application discloses a magnetic pressure indicating device which will provide a visual signal when a predetermined pressure differential is attained, the signal being maintained until the device is reset, the device in its preferred form including a body having three chambers formed therein, a magnetic piston assembly to which a pressure is communicated forming a movable wall between the first chamber and the second sealed chambers, a dome-shaped fixed wall between the second and third chambers, an armature assembly slidably mounted in the third chamber and urged away from the dome-shaped wall by a spring, the armature assembly being retained against the fixed wall by the magnetic piston assembly until the piston assembly is moved away from the wall by a predetermined pressure, and a signal button secured to the armature assembly for indicating when the assembly has moved away from the fixed wall.

This invention relates generally to differential pressure indicators, and more particularly to an improved magnetic device for indicating the existence of a pressure differential exceeding a predetermined value.

In hydraulic systems wherein fluid passes through a filter, for example, it is desirable to provide means for indicating when the filter has become loaded with foreign matter. In the case of aircraft applications, the device should be a small, light-weight, fool-proof unit that will not give a false indication in response to G forces. In some cases, it is desirable that the device continue to indicate a loaded filter until the condition of the filter is investigated; in other cases, it is preferable that the device have the ability to be reset to the non-indicating condition without a filter change.

Since the pressure drop across a filter increases in proportion to the accumulation of foreign matter, a suitable indication of the clogged condition may be provided by a device which is actuated in response to a predetermined pressure differential across the filter element. Such devices are known, the purpose of this invention being to provide certain improvements over known devices.

Accordingly, a primary object of this invention is to provide a simple, light-weight warning device which may be associated with a filter system for visually indicating when the filter element has become clogged.

Another object of the invention is to provide such a device which employs a magnet and armature means that responds to a predetermined pressure differential across a filter element, and that will withstand a relatively high accelerative force, say 30 G's or more, without giving a a false signal.

A more specific object of the invention is to provide such a device which employs a single magnet assembly and a signal button assembly separated by a wall, the button including an armature in which sufficient magnetic force is induced to hold the armature against the force of a compressed spring until the magnet assembly is moved a sufficient distance away from the wall by a predetermined pressure differential.

A still further object of the invention is to provide such a device in which the magnet, the armature and the wall separating these two elements are of an improved design.

Another object of the invention is to provide such a device having a second armature for preventing the device from being reset without investigating the filter.

These and other objects and advantages of the invention will become more apparent when reference is made to the following specification and the accompanying drawings wherein:

FIGURE 1 is a longitudinal cross-sectional view of an indicator device embodying the invention, the device being associated with a schematically illustrated filter element;

FIGURE 2 is an end view of the magnet assembly shown by FIGURE 1;

FIGURE 3 is a longitudinal cross-sectional view of a modification of the invention;

FIGURE 4 is a longitudinal cross-sectional view of a second modification of the invention.

Before discussing the drawings in detail, it should be understood that with the exception of the magnet assembly, one end of which is shown by FIGURE 2, the devices shown are of a cylindrical construction. Thus, the longitudinal cross-sectional views shown by FIGURES 1, 3 and 4 are adequate for a complete disclosure.

With the above general description in mind, FIGURE 1 illustrates a device **10** comprising an aluminum or other non-magnetic body **12** having a pair of cylindrical cavities **14** and **16** formed from the opposite ends thereof. A relatively thin dome-shaped wall **18** separates the two cavities, the purpose of the shape of the wall to be described later.

The cavity **14** adjacent the convex side of the wall **18** houses a signal button assembly **20**, which includes a ferro-magnetic, corrosion resistant armature **22** fixedly secured to a hollow signal button **24**, the latter having an external flange **26** formed thereon. A resilient means, such as a coil spring **28**, located between the flange **26** and a wall **30** of the cavity **14**, urges the button **24** away from the dome-shaped wall **18** and through an opening **32** formed in a cover plate **34** secured by any suitable means to one end of the body **12**. The spring and button may be guided by an annular flange **31**, the indicating portion of the button shown by the dotted line.

A magnetic piston assembly **36** positioned on the concave side of the wall **18** serves as a pressure responsive movable wall dividing the cavity **16** into two chambers **38** and **40**, chamber **38** being normally completely occupied by the piston assembly **36** because of its engagement with the wall **18**. An annulus **42** is formed around the chamber **38** to communicate therewith, and a passageway **44** communicates between the annulus **42** and an inlet port **46**. The inlet port **46** may be connected by means of a conduit **48** to a source of high pressure fluid, such as the upstream side of a filter system including the filter element **50**.

A seal **52** positioned in a groove **54** formed in the wall of the cavity **15** may surround the magnetic piston assembly **36** and prevent leakage between the chambers **38** and **40**. In lieu of a seal **52**, a controlled clearance fit around the piston assembly **36** may be provided. A non-magnetic element **56** is secured at the outer end of the body **12**, the cover **56** serving as a seat for another resilient means, such as coil spring **58**, which continuously urges the piston assembly **36** toward the dome-shaped wall **18**. The element **56** further includes a projection **60** extending into the chamber **40**, the projection **60** serving as a stop for the piston assembly **36**. An axial passageway **62** through the element **56** communicates between the chamber **40** and a conduit **64** connected to a source of lower pressure fluid,

such as the downstream side of the filter element 50. The body 12 may be externally threaded at 63 enabling the same to be secured in a threaded cavity formed in a housing including the passages or conduits 48 and 64 connecting with the filter 50. For this purpose, a seal 65 may be provided, and the body 12 may have a hexagonal portion 61 for turning the body 12.

The magnetic piston assembly 36 comprises a magnet 66 having north and south pole bars, 67 and 68, adjacent the poles thereof and being surrounded on all but one end 72 thereof by a suitable potting material 69. In order to provide a maximum exposed area of the pole bars 67 and 68, without providing too convenient a metallic path for the lines of magnetic force to flow through on the magnet side of the wall 18, the ends 72 may be formed to include internal flanges 81, separated by a gap 83 which is also filled with potting material 69. The material 69 and the magnet 66 are enclosed by a non-magnetic sleeve 70 which is slidably mounted in the cavity 16, as previously explained. As in the case of the armature 22, the uncovered ends 72 of the pole bars 67 and 68, and a portion of the potting material are shaped to substantially conform to the concave side of the dome-shaped wall 18. By having the magnet 66 and arranged with the north and south poles 67 and 68 oppositely disposed, a relatively strong magnetic circuit is readily completed, as by the field represented by lines A, resulting in a powerful attraction of the armature. The proposed magnet construction permits the use of a relatively light-weight magnet assembly which is ideal for aircraft applications wherein the device 10 would at times be subjected to extreme high dynamic loads or G forces.

Operation

So long as the filter element 50 is clean, the pressures entering the annulus 42 and the chamber 40 will be substantially equal and the magnetic piston assembly 36 will be retained against the concave side of the wall 18 by the spring 58. While the assembly 36 is in this position, the signal button assembly 20 will be retained against the convex side of the wall 18 due to the magnetic attraction of the armature portion 22 thereof by the magnet 66. This is the normal condition of device 10 when the filter is clean and the button assembly 20 has been reset.

When the filter element 50 becomes sufficiently clogged with foreign material to drop the downstream pressure in the conduit 64 to a predetermined value below the upstream pressure, the resulting pressure differential will be applied across the magnetic piston assembly 36, causing it to move away from the wall 18 against the force of the spring 58. Since the magnetic force induced in the ferromagnetic armature 22 is proportional to the reciprocal of the square of its distance from the magnet 66, once this induced force becomes less than the force of the spring 28, the signal button assembly 20 will be propelled to its dotted line position until the flange 26 abuts against the cover plate 34. The signal button 24 will thus remain exposed until such time as it has been manually depressed or reset after the magnetic assembly 36 has returned to its normal position against the wall 18 due to a reduction in the differential pressure thereacross, as would be the case if the dirty filter were replaced.

As already pointed out, the wall 18 is formed with a dome shape. Likewise, the adjacent end of the armature 22 and the exposed ends 72 of the pole bars 67 and 68, as well as a portion of the potting material surrounding the magnet, are formed to fit the convex and the concave side, respectively, of the wall 18.

Devices of this type may be subjected to relatively high pressures, 600 p.s.i. for example. The relatively small size of this unit (approximately 1¾ in. over-all length) and the need for a good flux path to enable the small magnet to prevent false indications as a result of dynamic loading up to 30 or more G's requires a relatively thin wall 18. It can be seen that a thin flat wall would be subjected to severe flexing or bending stresses. In other words, the high pressure to the left of the wall 18 would tend to dome it out to the right, and the extent of this deformation may be sufficient to prevent a relatively small flat end magnet from holding an armature against the wall. It must be remembered that the magnet assembly 36 travels only a very short distance before the force of spring 28 is sufficient to overcome the magnetic attraction of the armature.

By originally forming the wall 18 with a dome shape, it is subjected to tensile forces, rather than flexing forces, so that higher differential forces may be applied with negligible effect on the normal operation of the indicator assembly and without causing permanent deformation to the indicator body. Forming the armature 22 and the magnet assembly 36 to conform to the shape of the wall not only shortens the flux path so as to obtain maximum efficiency from a small magnet, but it also increases the adjacent areas of the magnet and the armature to provide a more efficient flux circuit.

FIGURE 3 modification

FIGURE 3 illustrates a modified differential pressure indicating device 76. Since the structure thereof is in many respects the same as that shown by FIGURE 1, all elements common to FIGURE 1 bear the same reference numerals.

For applications where it is desirable that the magnetic piston assembly 36 be responsive to a relatively low pressure differential, say 4.5 p.s.i. for a unit of this size, it may be desirable to secure a relatively large area diaphragm 74 to the flat end of the piston assembly 36, the diaphragm 74 serving as a movable wall between the larger chambers 78 and 80. The higher pressure fluid is communicated to the chamber 78 via passageways 82 and 84, while the lower pressure fluid is communicated to the chamber 80 via ports 86 in the cover 56.

Another minor respect in which the FIGURE 3 modification differs from FIGURE 1 is in the method of attachment of the device 76 to other associated structure. That is, the body 12 of the FIGURE 3 device includes an outer flange 71 having openings 73 to enable it to be secured to a surface by means such as screws. Of course, the higher pressure fluid is supplied to chamber 78 on one side of the diaphragm rather than to one side of the magnet assembly as in FIGURE 1. Also, the element 56 is externally threaded so that it can serve as a means of securing the outer periphery of the diaphragm 74 between ring type inserts 75 and 77. Additionally, the sleeve 70 of the magnet assembly 36 is closed at one end to provide means 79 for securing the assembly to the diaphragm washer 88.

As in FIGURE 1, the spring 58, which is confined between the element 56 and the diaphragm washer 88, urges the piston assembly 36 against the wall 18. Due to the relatively large area of the diaphragm 74 and with the proper selection of other design factors, small pressure differentials across the diaphragm will be sufficient to move the magnet assembly 36 away from the dome-shaped wall 18, even though dynamic loads of 30 or more G's will not be sufficient to overcome the attraction of magnet assembly 36 to the armature 22.

FIGURE 4 modification

If for any reason the pressure differential across the piston assembly 36 of FIGURE 1, or across the diaphragm 74 of FIGURE 3, drops to a value below that required to overcome the force of spring 58, the spring 58 will return the assembly 36 to the wall 18. Obviously, it is then possible to manually depress or reset the signal button 24, and the armature will remain against the wall 18.

In certain cases, it may be desirable to employ a device having a signal button which cannot be reset, even though it is manually depressed, until corrective action or some positive step is performed, and such a device 90 is illustrated in FIGURE 4.

In this embodiment, wherein elements common to FIGURES 1 and 3 are identified with the same reference numerals, the magnetic piston assembly **94** includes magnet **96** with north and south pole bars, **95** and **97**, which are exposed at both ends. A spring **98** urges the magnetic piston assembly **94** against the wall **18**, and a ferro-magnetic or other magnetically susceptible element **100** is confined in the chamber **102** by any means such as a retaining ring **92**. An aluminum or other non-magnetic reset rod **106** having a flared end **108** extends through openings **110** and **112** in the end plate **104** and the element **100**, respectively, the rod **106** being urged away from the magnet assembly **94** by means of a spring **114** mounted between the outer face of the end plate **104** and a flanged end **116** formed on the rod **106**. Again, lower pressure fluid enters the chamber **102** via ports **118** and **120** formed in the end plate **104** and the element **100**, respectively, and the higher pressure enters chamber **38** through port **44**, it being understood that the device **90**, like devices **10** and **76**, will be suitably mounted in an environment similar to that shown by Pall 2,942,572.

In operation, once the pressure differential across the magnet assembly **94** reaches the predetermined value, the assembly **94** will be moved to the left against the force of the spring **98**. The rate of the spring **98** is designed so that the distance of magnet travel multiplied by the spring rate produces a spring force increase less than the original magnetic force between the magnet assembly **94** and armature **22**. Therefore, as soon as a separation occurs the magnet assembly **94** will snap completely to the stop position. The increasing magnetic attraction between the magnet assembly **94** and the armature **100** also assists this snap action. As before, the button assembly **20** will be moved to the right by the spring **28**, exposing the signal button **24** through the opening **32**.

Once the magnet assembly **94** contacts the ferro-magnetic element **100**, it will remain in that position even after the pressure differential across the assembly **94** has subsided. In other words, the assembly will not automatically return to the wall **18**, and the signal button **24** cannot be reset.

In order to reset the button **24** in its normal position against the wall **18**, it is necessary to either remove the device **94** or to otherwise gain access to the rod **106** so that it may be forced to the right to the dotted line position against the force of the spring **114**. This will move the magnet assembly **94** away from the element **100** and allow the spring **98** to return the assembly **94** to the wall **18**. Being non-magnetic. the rod **106** will be returned to its solid line position by the spring **114**. It is only at this time that the signal button **24**, when depressed, will again remain against the wall **18** by virtue of the attractive force of the magnet assembly **94**. The necessity of gaining access to the rod **106** reasonably assures investigation or corrective action, such as the replacement of the expended filter.

From the above discussion, it is apparent that there have been provided three embodiments of a differential pressure indicator which is of a simple design that is easy to manufacture. Due to the thin, dome-shaped wall and the magnet design, a relatively small, inexpensive and light-weight magnet assembly and armature and indicating button assembly may be employed. The small, light-weight assemblies, in combination with the thin wall, provide a magnetic efficiency which reduces the sensitivity of the device to dynamic forces of 30 G's or higher.

In two embodiments of the invention, the magnet assembly will return to the separating wall at any time that the differential pressure drops below the critical value, at which time the indicator button can be reset. In the other modification, a positive act must be performed before the button can be permanently reset. Additionally, one modification mentioned includes a larger area diaphragm secured to the magnet assembly so as to make the device operative to relatively low pressure differentials, but still relatively insensitive to G loading.

Referring to FIGURE 1, it is to be noted that the relationship between the dimensions of the exposed end faces **72** of the pole bars **67** and **68** and the armature **22** is extremely important. In other words, in order to maintain maximum attractive force and minimum weight for withstanding high dynamic loads as may occur in aircraft applications, careful consideration must be given to various factors.

For example, the magnet **66** may itself consist of a relatively light-weight ceramic material and the ferro-magnetic armature **22** may have a bored-out center portion without reducing its magnetic attraction to the ends **72** of the pole bars **67** and **68**. Additionally, in order that the lines of magnetic force not be "choked off" in crossing from the end faces **72** through the wall **18** into the armature **22** due to insufficient adjacent areas, it has been found advantageous to enlarge the end faces **72** by forming the pole bars **67** and **68** to include internal flange portions **81**. Not only does this serve to increase the pole bar areas directly across from the armature, but it also provides a more convenient path for the flux lines A to travel through from the ends **72** of the pole bars into the adjacently disposed annular area of the armature.

It is important that the internal flanges **81** not meet one another or be formed too close together, since that would cause the flux lines to take the path of the least resistance and cross from one pole bar to the other without penetrating the domed wall **18**. In other words, it is important that a sufficient gap **83** which may also be filled with the potted material **69**, be maintained between the flanges **81**. A suitable relationship of dimensions between the magnet assembly and the armature is illustrated in FIGURE 1.

Obviously, in all of the devices shown, the various pertinent design factors may be varied within limits to change the operating characteristics thereof. It should also be apparent that the invention may be employed in any environment where it is desired that a visual or some other signal be given when the pressure differential across some point in a fluid flow system reaches a predetermined value. Obviously, the dome-shaped wall structure is not limited to use in a magnet-armature type of device.

While but three embodiments of the invention have been disclosed and described, it is apparent that other modifications thereof are possible within the scope of the appended claims.

What we claim as our invention is.

1. A visual warning device, comprising an aluminum body having a pair of cavities formed therein, a dome-shaped wall between said cavities, a spring-biased signal button assembly including an armature slidably mounted in one of said cavities, said armature having a concave face formed adjacent said dome-shaped wall, a permanent magnet slidably mounted in the other of said cavities, said magnet having a convex face formed adjacent said dome-shaped wall, said convex face being subjected to fluid under a relatively high pressure, said other end of said magnet at times being exposed to a relatively low fluid, first resilient means for urging said permanent magnet toward said dome-shaped wall, a ferro-magnetic element fixedly located in said other of said cavities adjacent said other end of said permanent magnet, a non-magnetic rod slidably mounted through said ferro-magnetic element, and a second resilient means for urging said rod away from said permanent magnet.

2. A visual warning device, comprising an aluminum body having a pair of cavities formed therein, a dome-shaped wall between said cavities, a spring-biased signal button assembly including an armature slidably mounted in one of said cavities, said armature having a cancave face formed adjacent said dome-shaped wall, a permanent magnet slidably mounted in the other of said cavities, said other cavity having a portion thereof enlarged, said magnet having a convex face formed adjacent said dome-

shaped wall, a diaphragm mounted in said enlarged portion for dividing said enlarged portion into first and second chambers, said diaphragm being fixedly secured at its center to the end of said magnet opposite said convex face, said first chamber being subjected to fluid under a relatively high pressure, said second chamber being at times subject to a relatively low pressure fluid, and resilient means for urging said diaphragm toward said dome-shaped wall.

3. A differential pressure indicating device, comprising a non-magnetic housing having axially aligned first and second cavities formed at the opposite ends thereof and separated by a wall, a piston disposed for axial movement in said first cavity, said piston having a seal so as to provide a first chamber between said piston and said wall and a second chamber at the other end of said piston, means for supplying a higher pressure fluid to said first chamber, means for supplying fluid to said second chamber at a pressure which is at times lower than the pressure in said first chamber, said wall being generally dome-shaped with respect to said first chamber so as to be subjected to tensile or compression stresses rather than to flexing stresses by said higher pressure fluid and so as to have a greater area than if said wall were flat, the end of said piston adjacent said wall being shaped to conform substantially to the dome-shaped area of said wall, resilient means urging said piston into engagement with said wall, the force of said resilient means being selected to allow said piston to move away from said wall in response to a predetermined differential pressure across said piston, an indicator member disposed for axial movement in said second cavity, the end of said indicator member adjacent said wall being shaped to conform substantially to the dome-shaped area of said wall, resilient means for urging said indicator member away from said wall, either said piston or said indicator member being magnetic per se and the other being magnetically permeable at the end thereof adjacent said wall, the magnetic attraction between said piston and said indicator member through said non-magnetic wall being sufficient to retain said parts in contact with said wall against the force of said resilient means urging said indicator member away from said wall until said predetermined differential pressure moves said piston a predetermined distance from said wall, said dome-shaped wall permitting higher pressures and greater magnetic efficiency than if said wall were flat.

4. A differential pressure indicating device, comprising a non-magnetic housing having aligned first and second cavities formed at the opposite ends thereof and separated by a generally dome-shaped wall having a greater area than if said wall were flat, a piston disposed for axial movement in said first cavity, said piston having a seal so as to provide a first chamber between said piston and said wall and a second chamber at the other end of said piston, means for supplying a higher pressure fluid to said first chamber, means for supplying fluid to said second chamber at a pressure which is at times lower than the pressure in said first chamber, said wall being convex with respect to said first chamber so as to be subjected to tensile or compression stresses rather than to flexing stresses by said higher pressure fluid, the end of said piston adjacent said wall being shaped to conform substantially to the dome-shaped area of said wall, resilient means urging said piston into engagement with said wall, the force of said resilient means being selected to allow said piston to move away from said wall in response to a predetermined differential pressure across said piston, an indicator member disposed for movement in said second cavity, the end of said indicator member adjacent said wall being shaped to conform substantially to the dome-shaped area of said wall, resilient means for urging said indicator member away from said wall, either said piston or said indicator member being magnetic per se and the other being magnetically permeable at the ends thereof adjacent said wall, the magnetic attraction between said piston and said indicator member through said non-magnetic wall being sufficient to retain said parts in contact with said wall against the force of said resilient means urging said indicator member away from said wall until said predetermined differential pressure moves said piston a predetermined distance from said wall, said greater area dome-shaped wall permitting higher pressure operation and greater magnetic efficiency between said conforming piston and indicator member than if said wall were flat.

5. A differential pressure indicating device, comprising a non-magnetic housing having aligned first and second cavities formed at the opposite ends thereof and separated by a wall, a piston disposed in said first cavity, said piston having a seal so as to provide a first chamber between said piston and said wall and a second chamber at the other end of said piston, means for supplying a higher pressure fluid to said first chamber, means for supplying fluid to said second chamber at a pressure which is at times lower than the pressure in said first chamber, said wall being convex with respect to said first chamber so as to be subjected to tensile or compression stresses rather than to flexing stresses, the end of said piston adjacent said wall being shaped to conform to the shape of said wall, resilient means urging said piston into engagement with said wall, the force of said resilient means being selected to allow said piston to move away from said wall in response to a predetermined differential pressure across said piston, an indicator member disposed for movement in said second cavity, the end of said indicator member adjacent said wall being shaped to conform to the shape of said wall, and resilient means for urging said indicator member away from said wall, at least said piston or said indicator member being magnetic per se, the magnetic attraction between said piston and said indicator member through said non-magnetic wall being sufficient to retain said parts in contact with said wall against the force of said resilient means urging said indicator member away from said wall until said predetermined differential pressure moves said piston a predetermined distance from said wall, magnetic stop means for holding said piston away from said wall against the force of said resilient means whenever said piston is moved against said stop, and non-magnetic means for forcing said piston away from said stop.

6. A differential pressure indicating device, comprising a body formed to provide aligned cavities separated by a fixed non-magnetic wall, a pressure differential responsive member disposed for sealed axial movement in one of said cavities on one side of said wall so as to divide said one cavity into separate fluid chambers and an indicating member disposed in the other of said cavities on the other side of said wall, said indicating member being spring-biased away from said wall and said pressure differential responsive member being spring-biased toward said wall, one of said members being magnetic per se and the other of said members being attracted by said one member, said attraction overcoming the spring-bias of said indicating member when both of said members are in engagement with said wall and said attraction being overcome by movement of said pressure differential responsive member a critical distance away from said wall by a predetermined pressure differential in said separate chambers, said wall being formed dome-shaped and the adjacent ends of said pressure differential responsive member and said indicating member being shaped to conform to the shape of said wall so as to increase the adjacent end areas of said members and thus the efficiency of the magnetic attraction therebetween, as compared to the efficiency of the attraction between said members if said wall were flat.

7. A differential pressure indicating device such as that recited in claim 6, wherein said pressure differential responsive member is a dynamically-sealed piston.

8. A differential pressure indicating device such as that

recited in claim **6**, wherein said pressure differential responsive member is a piston-diaphragm assembly.

9. A differential pressure indicating device such as that recited in claim **8**, wherein said diaphragm is disposed at the end of said piston opposite said wall and has a pressure responsive area greater than the pressure responsive area of said piston.

10. The differential pressure indicating device such as that recited in claim **6**, wherein magnetic stop means for holding said differential pressure responsive member away from said wall against said spring-bias whenever the same is moved into engagement with said stop and non-magnetic means are provided for forcing said member away from said stop.

11. A differential pressure indicating device such as that recited in claim **6**, wherein said pressure differential responsive member is a magnet per se, a ferromagnetic stop member is disposed adjacent the end of said pressure differential responsive member opposite said wall so as to magnetically retain the same against said stop member whenever said pressure differential moves said member to said stop and a non-magnetic reset rod is slidably mounted through said stop member for freeing said member from said stop, said reset rod being spring-biased into an operative position.

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