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(54) Title: CLOSED CONDUCTANCE FLUID CONTROL VALVES

(57) **Abstract:** A flapper valve assembly comprises a valve body defining a passageway; a flapper secured within the passageway and mounted for rotation within the passageway between an opened and a closed position; and a compressible O-ring provided on the periphery of the flapper so as to contact the wall of the passageway when the flapper is moved to the closed position. In one embodiment the compressible O-ring includes a toroidal helical wound spring disposed within a polymeric sleeve. The valve assembly provides increased control of pressure across a wide dynamic range, improved position resolution, is compatible with an array of chemistries and temperatures and has improved wear.

CLOSED CONDUCTANCE FLUID CONTROL VALVES

FIELD OF THE INVENTION

5 The present invention relates generally to a control and shutoff valve for regulating fluid flow through a conduit and provides very low conductance in the shutoff position.

BACKGROUND OF THE INVENTION

10 Fluid flow control and shutoff valves are well-known in the art as a means for regulating rates of fluid flow. One type of valve which has been designed for control and shutoff is a so-called butterfly or flapper valve in which a thin "flapper" or plate-like member is disposed inside a fluid passageway and centrally mounted on a rotatable shaft passing laterally through the interior of the passageway. See for example, US Patent Nos. 5485542 and 5564679 assigned to the present assignee. The plane of the flapper can thus
15 be oriented by rotating the shaft in a clockwise or counterclockwise direction through a limited range of motion. The flapper is precisely dimensioned so as to close and more or less seal the passageway to stop or at least substantially reduce fluid flow when the plane of the flapper is oriented substantially perpendicular to the longitudinal axis of the passageway. Alternatively, rotating the shaft and the flapper from this closed position to a
20 position substantially 90° from the closed position or so such that the plane of the flapper is substantially parallel to the longitudinal axis of the passageway results in opening the passageway so as to permit varying rates of fluid flow through the valve depending upon the rotational position of the flapper. Developments have been made to couple the rotation of a control stepping motor to the opening of a valve so that the flow rate through the valve is
25 linearly related to the position of the shaft of the stepping motor. See, for example, US Patent No. 4,327,894, and pending US Patent Application Serial No. 09/411,793 filed October 1, 1999, both being assigned to the present assignee and both documents being incorporated herein by reference.

30 The simplicity and ease of operation of such flapper valves makes them particularly well suited to regulating fluid flow.

 A number of important industrial chemicals exist in the liquid phase at or about

normal room temperature and pressure, but transition to the vapor phase under normal atmospheric pressure at elevated temperatures up to about 250°C. For many industrial applications, it is preferred to handle these chemicals in the vapor phase while, at the same time, minimizing excessive, unnecessary inputs of thermal energy. In many applications these vapor materials are delivered at very low vacuum pressures.

Some flapper valves have been developed for controlling the fluid flow rate in which case the flapper need not provide a complete seal with the wall of the passageway of the valve. Certain other flapper valves, however, are designed to provide complete shutoff, in which case the edge of the flapper needs to provide a complete seal with the wall of the passageway of the valve.

In control valves, the parts including the body in which the passage is formed and the flapper are typically made of metal, machined as closely as possible to design dimensions. In shut off valves, the flapper is typically provided with a solid relatively incompressible O-ring around its edge.

When assembling the flapper within the valve body, unless the flapper is mounted perfectly symmetrical on the rotation shaft and the shaft is perfectly positioned, as the flapper moves into and out of closed position, the edge of one part of the flapper on one side of the flapper will rub against the wall of the passageway, while the edge of the other part of flapper will make less or no contact with the wall of the passageway creating excessive wear on the rubbing side, while providing increased closed conductance on the other side.

Further, it is difficult to make machine parts with very tight tolerances that are repeatable, making it difficult to properly size each flapper with the passageway in which it will be seated so that when the flapper is near its closed position flow rates are very difficult to predictably control, limiting the dynamic range (the range of flow rates controlled by the valve).

The use of solid relatively incompressible polymeric O-rings on the flapper results in the need for high torque to close the flapper because of the low compressibility of the polymeric material, limiting the speed at which the valve can operate particularly moving to the closed position. In fact, operation at relatively high temperatures results in thermal expansion of the flapper, valve body and polymer increasing the torque problem. Further, chemistry, pressure and temperature incompatibility of polymers of the some O-rings can

create short life cycles for these parts.

In addition, the nature and construction of the shutoff flapper valve is that over time the edge of the flapper rubs against the wall of the passageway as it moves into and out of the closed position, making it difficult to predictably control the flow of fluid near the closed position of the flapper, and to maintain the flapper in a completely closed position at shut off. As a result of the rubbing, the tight tolerances required between the edge of the flapper and the wall of the passageway when the flapper is at or near the completely closed position of the flapper is difficult to maintain over time. This problem has become even more acute since many semiconductor processes are being carried out at relatively high pressures, where it is desirable to pass vapors through the valve at very low rates (where the flapper is near the closed position) and require low conductance at shut off (where minimal leakage through the valve occurs even though a large differential pressure can exist between the process chamber connected to the inlet of the valve and the vacuum pump connected to the outlet of the valve). Replacing the valve in the field tends to be costly, and because of the corrosive nature of some of the chemicals that pass thorough and may be deposited in the valve poses certain risks. Gate valves can provide a combination of both control and shutoff functions, but tend to be relatively expensive and complex.

SUMMARY OF THE INVENTION

The flapper valve assembly of this invention generally comprises a flapper plate disposed in a fluid passageway and centrally mounted on and rotatable with a support shaft that passes laterally through the fluid passageway between a fully opened and fully closed position. A flexible energized spring seal is provided around the edge of the flapper plate so that as the flapper plate can be moved in and out of the closed position with relatively less torque, with greater reliance of control of the rate of fluid flow through the valve, and relatively smaller conductance in the shut off position.

In one embodiment, the flexible energized spring seal includes an assembly of a helical spring element formed as a toroid and at least partially surrounded by a polymeric sleeve.

In one embodiment the sleeve only covers a part of the helical spring seal so that the exposed portion of the spring extends around the entire toroid.

In one embodiment the polymeric sleeve has an opened cross section around the spring.

In one embodiment the assembly includes a flapper having a groove formed around the periphery of the flapper for receiving the helical spring element in tension.

5 In one embodiment the flapper includes a pair of plates secured together so as to form the groove.

And in one embodiment the flexibility of the seal, i.e., the lateral compressibility of the seal, is related to the lateral flexibility or compressibility of the spring, and thus can be adjusted by substituting springs of predetermined lateral flexibility to provide corresponding
10 values of the compressibility of the seal.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

Fig. 1 is side elevational view of a flapper valve assembly incorporating the present
15 invention;

Fig. 2 is a cross sectional side view of a flapper valve assembly, taken along line 2-2 in Fig. 1 and partially cut away, wherein the valve is shown in the "closed" position,

Fig. 3 is a front elevation view of the flapper assembly of the flapper valve assembly of Figs.1 and 2,

20 Fig. 4 is a cross-sectional view of the flapper assembly shown along axis 4-4 of Fig. 3, and

Fig. 5 is an enlarged cross-sectional view of an embodiment of a flexible o-ring of the flapper assembly of Figs. 1-4.

25 DETAILED DESCRIPTION OF THE DRAWINGS

The flapper valve assembly of the present invention is designed to provide both control and shut-off functions. In particular the assembly is designed to (a) control pressure across a wide dynamic range by reducing the closed conductance; (b) provide sufficient position resolution near closed position to allow controlling this reduced conductance; (c)
30 be compatible with a wide array of process chemistries and temperatures, (d) last hundreds of thousands of cycles, and (e) be easily replaced in the field.

In Figs. 1 and 2, the flapper valve assembly 10 includes a valve body 12 having an inlet 14 typically connected to the upstream (higher pressure) side coupled to a process chamber and an outlet 16 typically connected to the downstream (lower pressure) side coupled to a vacuum pump. Inlet 14 and 16 respectively define the input and output of a passageway 18. The passageway 18 is gradually tapered at portion 20 between the inlet 14 and 16 so that the inlet is of a smaller cross sectional dimension than the outlet. A rotatable shaft 24 is rotatably mounted in the valve body 12 and is driven by a stepping motor 21 (Fig. 1 only). A suitable linearizing linkage (not shown) may also be used to couple the motor to the shaft so as to substantially linearize the relationship between the position of the shaft of the stepping motor and the flow rate through the valve.

A flapper assembly 22 is mounted on rotatable shaft 24 (so that the plane of the flapper assembly is parallel to and spaced from the shaft pivot axis) within the passageway 18 so that the flapper assembly is rotatable between a fully opened position wherein the flow rate is at a maximum value, and a fully closed position (the flapper assembly being shown in the fully closed position in Fig. 1) wherein the flow rate is ideally zero with zero conductance through the valve. The assembly 22 can be mounted in any suitable manner such as welded or with fasteners 26. The flapper assembly 22 is designed to contact the tapered portion 18 of the valve body around the periphery of the assembly such that tapered portion forms the valve seat for the flapper assembly. While preferred, it should be appreciated that it is not necessary for the internal diameter of the valve body to be tapered for the valve to operate.

Portions of flapper assembly 22 (as discussed further below), at least the wall of the passageway 18, rotatable shaft 24, and fasteners 26 all substantially comprise the same or different materials such as a corrosion-resistant metal or metallic alloy such as stainless steel. Shaft 24 may have internal thermal elements (not shown).

Construction of the flapper assembly 22 can be better understood by further reference to Figs. 2, 3 and 4. In a preferred embodiment of this invention, the flapper assembly 22 comprises a face plate 30 facing the inlet 14, a base plate 32 positioned between the face plate and the shaft 24, and a flexible energized spring seal 34 extending around the periphery of the assembly 22. The spring seal is "energized" in the sense that in use it is the subject of lateral compression, as will be more apparent hereinafter. The

base plate 32 includes an extended lip 36 extending around the periphery of the base plate 32 on the outlet side of the base plate opposite the face plate. The outer diameter of the face plate 30 is larger than the diameter of the inlet side of the base plate 32 so that the face plate and extended lip 36 form a U-shaped channel or annular groove 38 for receiving the flexible spring seal 34. The outer diameter of the face plate 30 however, is preferably smaller in diameter than the extended lip 36. The periphery of both the face plate and the extended lip 36 is of a diameter which is slightly smaller in dimension than the internal diameter of the tapered portion within which these parts rotate so that the only contact with the wall of the passageway is with the flexible spring seal as the flapper assembly is moved into a closed position so as to permit easy rotational movement of the flapper assembly within the tapered portion of the passageway.

As best seen in Figs. 2 and 4, in a preferred embodiment, the outermost edges of the face plate 30 and the extended lip 36 may each be beveled to insure a tighter fit inside the taper portion of the passageway. These beveled edges allow for improved gas-vacuum conductance across the valve assembly when the valve is in the closed position.

The flexible spring seal 34 is releasably secured in annular groove 38. In a preferred embodiment, annular groove 38 has a substantially rectangular cross section although its cross section may be of other cross-sectional shapes.

Fig. 5 shows a cross section of one embodiment of the flexible spring seal 34. The O-ring 34 preferably comprises an assembly comprising a coiled spring 40 formed as a toroid, and a sleeve 42 formed around at least a portion of the spring. O-ring 34 is preferably fabricated from a chemically and thermally resistant material that is compatible with the intended range of temperatures, pressures and materials to which the valve assembly is exposed. In one embodiment temperatures are anticipated to be 150°C or more and pressure differentials of 20 to 100 torr. Similarly, the hardness and flexibility of the material must be selected for minimizing wear at such temperatures and pressures, while preserving the seal's ability to laterally flex with minimal torque and release during use. Materials resistant to chemical attack at these temperatures and pressure include Teflon and Tefzel. For the same compatibility reasons, spring 40 is preferably fabricated from a stainless steel.

As best seen in Figs. 2 and 4, the flexible spring seal 34 has inner circumference

having a diameter slightly smaller than the diameter of the base plate of the flapper assembly 22, and an outer circumference having a diameter slightly larger than diameter of the extended lip 36 so that the spring is in tension when mounted in the annular groove 38. As best seen in Fig. 5, the sleeve preferably does not completely surround the spring 40, but is formed as a U-shaped cross-sectional element with an opening from receiving the coil spring. Preferably, the sleeve 42 is integrally formed with two sides 50a and 50b (respectively defining the inner and outer peripheries of the seal), and a connecting middle portion 52 connecting one end of each of the sides and the other ends of the sides being open at 54. In one embodiment the opening 54 is larger than the closed middle portion 52. When viewed in cross section, the sleeve 42 of the seal may be round, elliptical, squared, or rectangular cross section.

When fully assembled, as seen in Fig. 1, the seal 34 is positioned in annular groove 38 between face plate 30 and base plate 32 in contact with extended edge 36 and with the opening 54 facing the inlet 14. When fasteners 26 are secured, the adjacent surfaces of faces 22 and 34 will be drawn into direct contact with each other. O-ring 34 is positioned so that middle portion 52 of the O-ring abuts the extended lip 36. The opening 54 provides an area for distortion of the spring element 40 under lateral compression and flexes as the flapper assembly is moved into the closed position of Fig. 2.

Referring to Fig. 2, it should be understood that, for purposes of illustration, the distance between the outer edges of face and base plates 30 and 32 of the flapper assembly 22 and the inner wall of the passageway has been exaggerated. In practice, the outer edges of the face and base plates will be machined to close tolerances to obtain an extremely narrow gap with the wall of the passageway in the closed position. Although the gap can clearly vary, in one embodiment the gap is approximately fifty thousandths of inch distance. Gas vapors however, are substantially prevented from passing through the valve because of the spring seal which is under lateral compression between the flapper assembly and the wall of the passageway when the flapper is in the closed position is energized and thus reduces closed conductance of gas through the valve. The ability of the energized spring seal thus eliminates the need for tight tolerances on machine parts, and allows accurate control of flow rates with the flapper assembly near

the closed position thereby increasing the overall dynamic range of the valve.

In one embodiment the flexibility of the seal, i.e., the compressibility of the seal, is related to the lateral flexibility or compressibility of the spring, and thus can be adjusted by substituting springs of predetermined lateral flexibility to provide corresponding values in
5 the compressibility of the seal.

Although especially designed for regulating the flow of liquid-phase substances that are in the vapor state at an elevated temperature, the flapper valves of this invention may be adapted for use with both gaseous and liquid fluid flow. The valves of this invention may also be made smaller or larger to accommodate different fluid flow rates.

10 Since other changes and modifications may be made in the above-described apparatuses and processes without departing from the scope of the invention herein involved, it is intended that all matter contained in the above-description shall be interpreted in an illustrative and not in a limiting sense.

15

What is claimed is:

1. A flapper valve assembly comprising:

a valve body defining a passageway; and

5 a flapper secured within the passageway and mounted for rotation within the passageway between an opened and a closed position,

a compressible O-ring provided on the periphery of the flapper so as to contact the wall of the passageway when the flapper is moved to the closed position.

10 2. A flapper valve assembly according to claim 1, wherein the compressible O-ring includes an assembly of a helical spring element formed as a toroid and a polymeric sleeve at least partially surrounding the spring element.

15 3. A flapper valve assembly according to claim 2, wherein the sleeve only covers a part of the helical spring so that the exposed portion of the spring extends around the entire toroid.

4. A flapper valve assembly according to claim 3, wherein the polymeric sleeve has an opened cross section around the spring.

20 5. A flapper valve assembly according to claim 2, wherein the assembly further includes a flapper having a groove formed around the periphery of the flapper for receiving the helical spring element in tension.

25 6. A flapper valve assembly according to claim 5, wherein the flapper includes a pair of plates secured together so as to form the groove.

30 7. A flapper valve assembly according to claim 1, wherein the compressibility of the seal, is related to the lateral compressibility of the spring, and thus can be adjusted by substituting springs of predetermined lateral flexibility to provide corresponding values of

compressibility of the seal.

1/2

FIG. 1

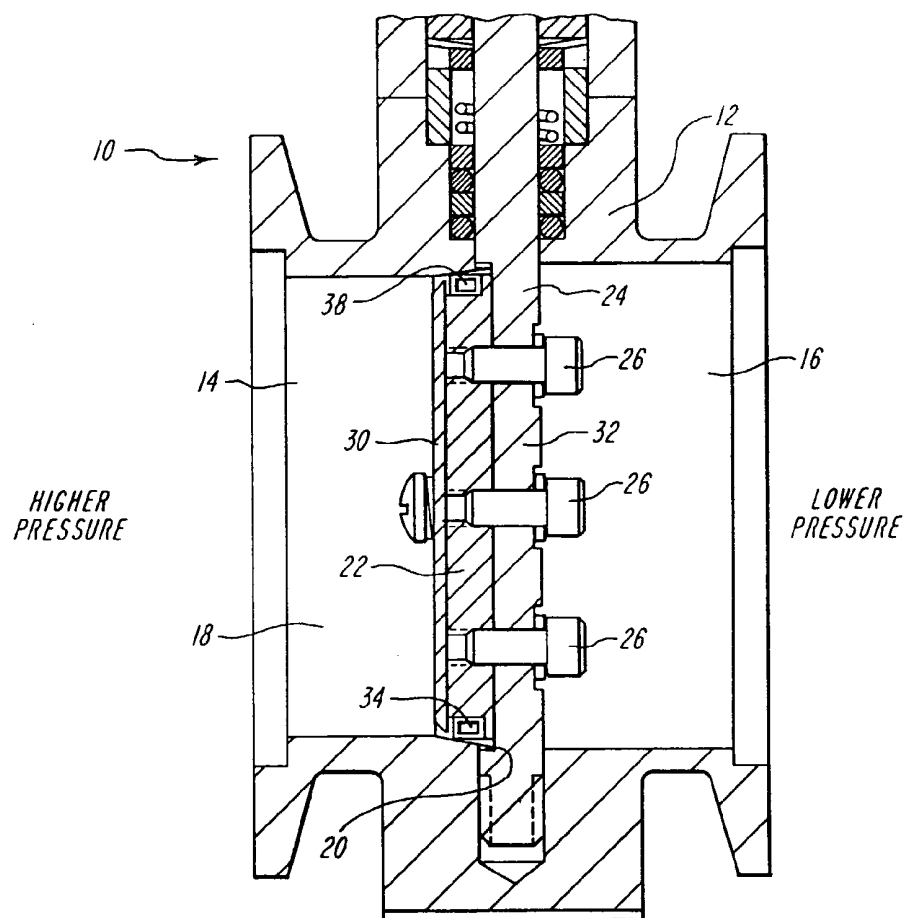
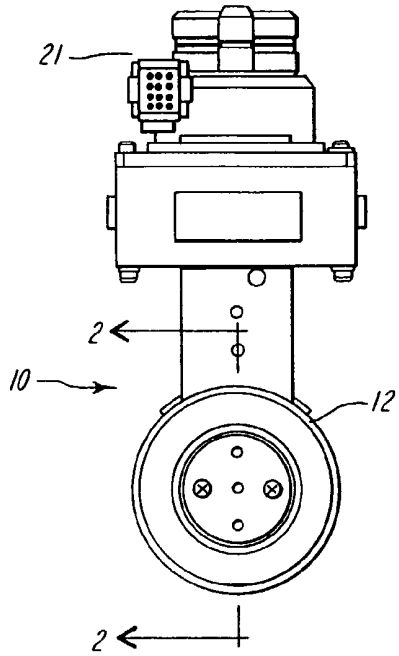


FIG. 2

2 / 2

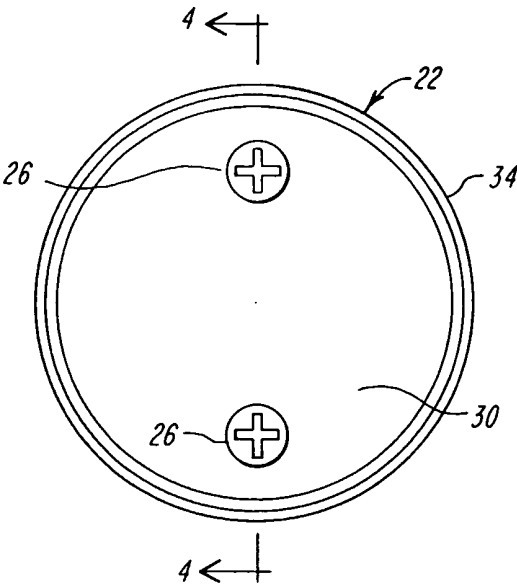


FIG. 3

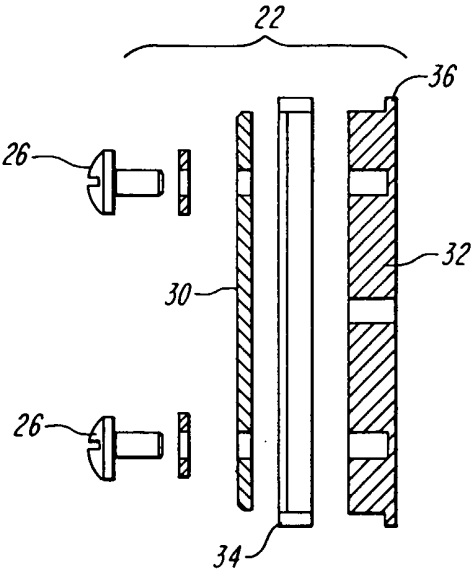


FIG. 4

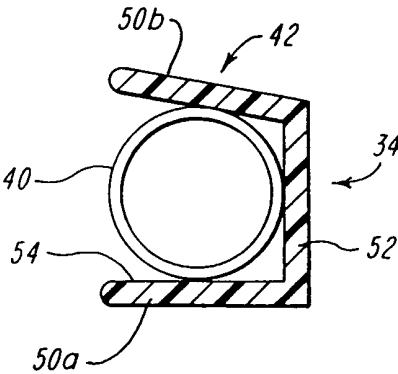


FIG. 5