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Inventor(s)	LANDACRE; Brett et al.

VALVE HAVING A QUAD RING SEAL

Abstract

A valve apparatus including a hollow valve retainer that includes a poppet slidingly positioned therein. The poppet includes a radially inwardly extending groove that is configured for receipt of a quad-ring sealing member that improves the sealing characteristics of the valve apparatus, as well as reduces friction between the poppet and valve retainer to increase the useful life of the valve apparatus.

Inventors: **LANDACRE; Brett (Bloomfield Hills, MI), SIMMONDS; Jeffrey (Commerce Township, MI)**

Applicant: **MAC Valves, Inc.** (Wixom, MI)

Family ID: **96660680**

Assignee: **MAC Valves, Inc. (Wixom, MI)**

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Background/Summary

FIELD

[0001] The present disclosure relates to a valve having a quad ring seal.

BACKGROUND

[0002] This section provides background information related to the present disclosure which is not necessarily prior art.

[0003] Solenoid operated valves are frequently used in a variety of different applications, such as in sorters, packaging machines, food processors, and the like. These valves are used to control the flow of fluid and may be operated for millions of cycles. Inasmuch as these valves may be operated for millions of cycles, the seals that are used between a member of the valve that moves relative to another member of the valve may wear out to an extent that sealing integrity is compromised. Accordingly, it is desirable to provide a solenoid operated valve that includes seals that are not as susceptible to wear over the large number of cycles that the valve is operated.

SUMMARY

[0004] This section provides a general summary of the disclosure, and is not a comprehensive disclosure of its full scope or all of its features.

[0005] According to a first aspect of the present disclosure, there is provided a valve apparatus comprising a manifold having a bore, an inlet communicating with the bore, and an outlet communicating with and axially aligned with the bore; a valve cartridge at least partially received within the bore and including a valve assembly having a valve member that enables communication between the inlet and the outlet, and an actuator assembly for actuating the valve member; the valve assembly including a hollow valve retainer having a first end that is configured to mate with the actuator assembly and an opposite second end received within the bore and defining an outlet port that communicates with the outlet of the manifold, the hollow valve retainer including a first plate-shaped member and a second plate-shaped member connected by a pair of axially extending arms that separate the first and second plate-shaped members by a gap that serves as an inlet port of the valve retainer in communication with the inlet of the manifold, the first plate-shaped member including a first axially-extending through-hole that defines the outlet port and the second plate-shaped member including a second axially-extending through-hole that is configured for receipt of a poppet having the valve member therein, the first plate-shaped member includes a first face that faces the gap and an opposite second face that faces the outlet of the manifold, the first axially-extending through-hole extends between the first face and the second face, and the first axially-extending through hole includes a first chamfered surface that defines a valve seat at the first face that is configured to be contacted by the valve member when the valve apparatus is in a closed position and spaced apart from the valve member when the valve apparatus is in an open position; the poppet includes a proximate end positioned within the actuator assembly and a distal end that includes the valve member, the distal end having a radially inwardly extending groove between the valve member and the proximate end that is configured for receipt of an annular quad-ring sealing member that seals an interface between the poppet and the second axially-extending through hole of the valve retainer as the poppet and valve member are moved during operation of the valve apparatus by the actuator assembly; and the valve member at the distal end of the poppet includes a second chamfered surface that corresponds to the first chamfered surface that defines the valve seat.

[0006] According to the first aspect, the valve apparatus further comprises a biasing member that biases the poppet and valve member to the closed position, wherein the biasing member is in contact with an annular arm that extends radially outward from the poppet.

[0007] According to the first aspect, the radially inwardly extending groove having the annular quad-ring sealing member is positioned between the valve member and the annular arm that extends radially outward from the poppet.

[0008] According to the first aspect, the first axially-extending hole includes the first chamfered surface and a cylindrical surface connected to the first chamfered surface.

[0009] According to the first aspect, the first chamfered surface includes a first end connected to the first face of the first plate-shaped member and a second end that defines an apex, and a radially

outwardly extending surface connects the apex to the cylindrical surface, and wherein the radially outwardly extending surface that connects the apex to the cylindrical surface defines a seat configured for receipt of an annular seal member that is configured to be contacted by valve member when the valve apparatus is in the closed position.

[0010] According to the first aspect, the second plate-shaped member of the hollow valve retainer includes a first face that faces the gap and an opposite second face that faces the actuator assembly; and a hollow cylindrical protrusion extends axially outward from the second face and includes a terminal end that defines the first end of the hollow valve retainer that is configured to mate with the actuator assembly, an outer surface of the terminal end being threaded to threadingly mate with a threaded surface of a housing of the actuator assembly.

[0011] According to the first aspect, the housing of the actuator assembly is configured for receipt of the proximate end of the poppet.

[0012] According to the first aspect, the actuator assembly includes the housing, and a solenoid configured to magnetize a pole piece positioned in the housing to magnetically attract the proximate end of the poppet to move the valve member away from the valve seat and open the valve apparatus.

[0013] According to a second aspect of the present disclosure, there is provided a valve apparatus comprising a manifold having a bore, an inlet communicating with the bore, and an outlet with the bore; a valve cartridge at least partially received within the bore and including a valve assembly having a valve member that enables communication between the inlet and the outlet, and an actuator assembly for actuating the valve member; the valve assembly including a hollow valve retainer having a first end that is configured to mate with the actuator assembly and an opposite second end received within the bore, the hollow valve retainer having an inlet port that communicates with the inlet of the manifold and defines a first valve seat configured to be contacted by the valve member when the valve apparatus is in a closed position, and an outlet port that communicates with the outlet of the manifold; and the valve assembly including a poppet positioned within and movable relative to the hollow valve retainer, the poppet including a proximate end positioned within the actuator assembly and a distal end that includes a first piston, a second piston, and the valve member between the first piston and the second piston, the valve assembly including an adjustable valve seat positioned within and attached to the hollow valve retainer, the adjustable valve seat defining a second valve seat configured to be contacted by the valve member when the valve apparatus is in an open position; wherein each of the first piston and the second piston have a radially inwardly extending groove that is configured for receipt of an annular quad-ring sealing member that seals an interface between the first piston and the hollow valve retainer and an interface between the second piston and the adjustable valve seat.

[0014] According to the second aspect, the valve apparatus further comprises a biasing member that biases the poppet and valve member to the closed position, the biasing member being in contact with the second piston of the poppet.

[0015] According to the second aspect, the manifold includes a second outlet in communication with the bore, and the adjustable valve seat includes an outlet port in communication with the second outlet.

[0016] According to the second aspect, the actuator assembly includes a housing attached to the valve retainer and a solenoid configured to magnetize a pole piece positioned in the housing to magnetically attract the proximate end of the poppet to move the valve member away from the first valve seat and open the valve apparatus.

[0017] Further areas of applicability will become apparent from the description provided herein. The description and specific examples in this summary are intended for purposes of illustration only and are not intended to limit the scope of the present disclosure.

Description

DRAWINGS

[0018] The drawings described herein are for illustrative purposes only of selected embodiments and not all possible implementations, and are not intended to limit the scope of the present disclosure.

[0019] FIG. **1** is a perspective view of a valve apparatus according to a principle of the present disclosure;

[0020] FIG. **2** is a perspective view of a valve cartridge that is part of the valve apparatus illustrated in FIG. **1**;

[0021] FIG. **3** is an exploded perspective view of the valve apparatus illustrated in FIG. **1**;

[0022] FIG. **4** is a cross-sectional view of the valve apparatus illustrated in FIG. **1**;

[0023] FIG. **5** is an enlarged cross-sectional view of a portion of the valve apparatus illustrated in FIG. **4**;

[0024] FIG. **6** is a perspective view of another valve apparatus according to a principle of the present disclosure;

[0025] FIG. **7** is a perspective view of a valve cartridge that is part of the valve apparatus illustrated in FIG. **6**;

[0026] FIG. **8** is an exploded perspective view of the valve apparatus illustrated in FIG. **6**;

[0027] FIG. **9** is a cross-sectional view of the valve apparatus illustrated in FIG. **6**;

[0028] FIG. **10** is a perspective view of another valve apparatus according to a principle of the present disclosure;

[0029] FIG. **11** is a perspective view of a valve cartridge that is part of the valve apparatus illustrated in FIG. **10**;

[0030] FIG. **12** is an exploded perspective view of the valve apparatus illustrated in FIG. **10**;

[0031] FIG. **13** is a cross-sectional view of the valve apparatus illustrated in FIG. **10**.

[0032] Corresponding reference numerals indicate corresponding parts throughout the several views of the drawings.

DETAILED DESCRIPTION

[0033] Example embodiments will now be described more fully with reference to the accompanying drawings. The example embodiments are provided so that this disclosure will be thorough, and will fully convey the scope to those who are skilled in the art. Numerous specific details are set forth such as examples of specific components, devices, and methods, to provide a thorough understanding of embodiments of the present disclosure. It will be apparent to those skilled in the art that specific details need not be employed, that example embodiments may be embodied in many different forms and that neither should be construed to limit the scope of the disclosure. In some example embodiments, well-known processes, well-known device structures, and well-known technologies are not described in detail.

[0034] The terminology used herein is for the purpose of describing particular example embodiments only and is not intended to be limiting. As used herein, the singular forms “a,” “an,” and “the” may be intended to include the plural forms as well, unless the context clearly indicates otherwise. The terms “comprises,” “comprising,” “including,” and “having,” are inclusive and therefore specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof. The method steps, processes, and operations described herein are not to be construed as necessarily requiring their performance in the particular order discussed or illustrated, unless specifically identified as an order of performance. It is also to be understood that additional or alternative steps may be employed.

[0035] When an element or layer is referred to as being “on,” “engaged to,” “connected to,” or

“coupled to” another element or layer, it may be directly on, engaged, connected or coupled to the other element or layer, or intervening elements or layers may be present. In contrast, when an element is referred to as being “directly on,” “directly engaged to,” “directly connected to,” or “directly coupled to” another element or layer, there may be no intervening elements or layers present. Other words used to describe the relationship between elements should be interpreted in a like fashion (e.g., “between” versus “directly between,” “adjacent” versus “directly adjacent,” etc.). As used herein, the term “and/or” includes any and all combinations of one or more of the associated listed items.

[0036] Although the terms first, second, third, etc. may be used herein to describe various elements, components, regions, layers and/or sections, these elements, components, regions, layers and/or sections should not be limited by these terms. These terms may be only used to distinguish one element, component, region, layer or section from another region, layer or section. Terms such as “first,” “second,” and other numerical terms when used herein do not imply a sequence or order unless clearly indicated by the context. Thus, a first element, component, region, layer or section discussed below could be termed a second element, component, region, layer or section without departing from the teachings of the example embodiments.

[0037] Spatially relative terms, such as “inner,” “outer,” “beneath,” “below,” “lower,” “above,” “upper,” and the like, may be used herein for ease of description to describe one element or feature's relationship to another element(s) or feature(s) as illustrated in the figures. Spatially relative terms may be intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures. For example, if the device in the figures is turned over, elements described as “below” or “beneath” other elements or features would then be oriented “above” the other elements or features. Thus, the example term “below” can encompass both an orientation of above and below. The device may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein interpreted accordingly.

[0038] FIGS. **1** to **5** illustrate an example valve apparatus **10** according to a principle of the present disclosure. Valve apparatus **10** includes a manifold **12**, a valve assembly **14** (FIGS. **2** and **3**) at least partly positioned in the manifold **12**, and an actuator assembly **16** connected to the valve assembly **14** for actuating a valve member **18** (FIG. **3**) of valve assembly **14** between an open and a closed position for permitting a fluid to pass through the manifold **12** from an inlet **20** to an outlet **22**. Valve assembly **14** and actuator assembly **16** may collectively define a cartridge **24** that is configured to be attached to and detached from manifold **12**, as will be described in more detail later.

[0039] In the illustrated embodiment, manifold **12** is a block-shaped member having, as noted above, inlet **20** and outlet **22**. It should be understood, however, that outlet **22** may serve as the inlet and the inlet **20** may serve as the outlet, if desired. In any event, manifold **12** may be formed of a rigid material such as a metal or polymeric material. Manifold **12** also defines a bore **26** that, as best shown in FIG. **4**, is arranged coaxially with outlet **22**. Bore **26** is configured for receipt of at least a portion of cartridge **24** and particularly configured for receipt of valve assembly **14**. While not required, manifold may include a lid **28** that can be secured to manifold **12** using a plurality of fasteners **30**. Lid **28** may be used to secure valve assembly **14** within manifold **12** and, therefore, may include a through-hole **32** configured to permit at least a portion of cartridge **24** to pass therethrough. Similar to manifold **12**, lid **28** may be formed of a rigid material such as a metal material or a polymeric material.

[0040] As best shown in FIG. **4**, bore **26** defines an opening **34** formed in manifold **12**. A first cylindrical surface **36** of bore **26** extends axially inward from opening **34** before terminating at a first radially inwardly extending shoulder **38**. A second cylindrical surface **40** extends axially inward from radially inwardly extending shoulder **38**. Because first shoulder **38** extends between first cylindrical surface **36** and second cylindrical surface **40**, a diameter of first cylindrical surface **36** is greater than a diameter of second cylindrical surface **40**. A radially outwardly extending

cylindrical passage **42** that provides communication between inlet **20** and bore **26** is formed at second cylindrical surface **40**. A third cylindrical surface **44** is positioned axially inward from second cylindrical surface **40**, and is separated from second cylindrical surface **40** by a second radially inwardly extending shoulder **46**. Because second shoulder **46** extends between second cylindrical surface **40** and third cylindrical surface **44**, a diameter of second cylindrical surface **40** is greater than a diameter of third cylindrical surface **44**. Third cylindrical surface **44** is connected to outlet **22**, which may include a threaded surface **48***a*. Similar to outlet **22**, inlet **20** may also include a threaded surface **48***b*.

[0041] Valve assembly **14** is configured to mate with bore **26**. Valve assembly **14** includes a hollow valve retainer **50** having a first end **52** that is configured to mate with actuator assembly **16** and an opposite second end **54** defining an outlet port **56** (FIG. **3**) that communicates with outlet **22** of manifold **12** when the valve assembly **14** is in the open position. Valve retainer **50** may be formed of a rigid material such as a metal material or a polymer material. Valve assembly **14** also includes a poppet **58** positioned within and movable relative to valve retainer **50**.

[0042] Valve retainer **50** includes a first plate-shaped member **60** and a second plate-shaped member **62** connected by a pair of axially extending arms **64** (FIG. **2**). Arms **64** separate first and second plate-shaped members **60** and **62** by a gap **66** that serves as an inlet port **68** of valve retainer **50** in communication with inlet **20** of manifold **12**. First plate-shaped member **60** includes a first axially-extending through-hole **70** that defines outlet port **56**. Second plate-shaped member **62** includes a second axially-extending through-hole **72** that is configured for receipt of poppet **58** therein. Each of first plate-shaped member **60** and second plate-shaped member **62** also include an outer cylindrical surface **73***a* and **73***b* (FIG. **2**) that respectively include a radially inwardly extending recess **74** (FIG. **3**) configured for receipt of an annular sealing member **76** (FIG. **3**), which may be an O-ring. Outer cylindrical surface **73***a* of first plate-shaped member **60** is configured to be located adjacent third cylindrical surface **44** of bore **26** and outer cylindrical surface **73***b* of second plate-shaped member **62** is configured to be located adjacent second cylindrical surface **40** of bore **26** and, therefore, a diameter of first plate-shaped member **60** may be less than that of second plate-shaped member **62**. Further, by locating outer cylindrical surfaces **73***a* and **73***b* relative to third cylindrical surface **44** and second cylindrical surface **40**, respectively, the inlet port **68** is aligned with radially outwardly extending cylindrical passage **42** that provides communication between inlet **20** and bore **26** (FIG. **4**).

[0043] First plate-shaped member **60** includes a first face **78***a* that faces the gap **66** and an opposite second face **80***a* that faces outlet **22** of manifold **12**. First axially-extending through-hole **70** extends between first face **78***a* and opposite second face **80***a*, and includes a first chamfered surface **82** that defines a valve seat **84** at first face **78***a* configured to be contacted by valve member **18** when valve apparatus **10** is in the closed position (FIGS. **3** and **4**), and be spaced apart from valve member **18** when valve apparatus is in the open position (not shown).

[0044] As best shown in FIG. **5**, first chamfered surface **82** includes a first end **86** connected to first face **78***a* and a second end **88** that defines an apex **90**. As first axially-extending through-hole **70** extends from apex **90** to outlet port **56**, the surface **92** extends radially outwardly from apex **90** before transitioning to a cylindrical surface **94**. The radially outwardly extending surface **96** that connects apex **90** to cylindrical surface **94** defines a seat **98** configured for receipt of an annular seal member **100** that is held in place by a hollow orifice retainer **101** that in combination with first axially extending through-hole **70** defines outlet port **56**. Annular seal member **100** may be contacted by valve member **18** when valve apparatus **10** is in the closed position.

[0045] Second plate-shaped member **62** includes a first face **78***b* and an opposite second face **80***b* that faces actuator assembly **16**. A hollow cylindrical protrusion **102** (FIG. **4**) extends axially outward from second face **80***b*, a terminal end **104** of which defines opposite first end **52** of valve retainer **50**. As best shown in FIG. **4**, an interior surface **106** of protrusion **102** includes second face **80***b* that is connected to second axially-extending through-hole **72** and to an axially-extending

cylindrical surface **108**. A diameter of axially-extending cylindrical surface **108** is greater than that of second axially-extending through-hole **72** to account for various features poppet **58**, which will be described in more detail later. An outer surface **110** of protrusion **102** includes a threading **112** that is configured to mate with a threading **114** of a housing **116** of actuator assembly **16** and includes a radially outwardly extending shoulder **118** that is configured to be located adjacent to first cylindrical surface **36** and abut against radially inwardly extending shoulder **38** of bore **26**.
[0046] Poppet **58** is positioned between valve assembly **14** and actuator assembly **16**. Poppet **58** may be formed of a magnetically-attractable material (e.g., steel, iron, etc.), includes a proximate end **120** positioned within actuator assembly **16** and a distal end **122** that defines valve member **18**, and which is unitary with proximate end **120**. A radially outwardly extending arm **124** that defines a first seat **126** for a biasing member **128** or spring that biases poppet **58** and valve member **18** in a direction toward valve seat **84** of valve retainer **50** is located between proximate end **120** and distal end **122**.
[0047] In addition to valve member **18**, distal end **122** includes a radially inwardly extending groove **130** that is configured for receipt of an annular quad-ring seal member **132** that seals the interface between poppet **58** and second axially-extending through hole **72** of valve retainer **50**. The use of annular quad-ring seal member **132** provides increased sealing capability between valve assembly **14** and actuator assembly **16**, as well as an increased life-span in comparison to a conventional seal member such as an O-ring. Quad-ring seal member **132** may be formed of a material such as FKM, but may be formed of any conventional seal material known to one skilled in the art (e.g., rubber, EPDM, fluoroelastomer, and the like). A more detailed description of quad-ring seal member **132** will be provided later.
[0048] Valve member **18** at distal end **122** of poppet **58** includes a second chamfered surface **134** (FIG. **5**) that corresponds to first chamfered surface **82** that defines valve seat **84**. As best shown in FIG. **5**, second chamfered surface **134** is configured to contact annular seal member **100** to close valve apparatus **10**, but may be configured to contact valve seat **84** simultaneously. Put another way, valve seat **84** may serve as a hard stop for second chamfered surface **134**. An axial length L of valve member **18** is greater than a width W of gap **66**.
[0049] Again referring to FIG. **4** and as noted above, actuator assembly **16** is connected to valve assembly **14** by mating threading **114** of housing **116** with threading **112** of valve retainer **50**. Housing **116** is a generally hollow cylindrical structure that includes one end **136** having threading **114** and an opposite end **138** that defines a coupling **140** configured to be mated with an electrical connector **142** for providing a voltage or current to a solenoid **144** provided in housing **116**. Solenoid **144** includes a hollow yoke **146** that supports a solenoid coil **148** having opposing ends (not shown) that are electrically connected to a pair of leads **150** of electrical connector **142**.
[0050] Proximate end **120** of poppet **58** may function as an armature that is magnetically attracted to a pole piece **152** provided within an elongated aperture **154** of yoke **146**. Pole piece **152** is formed of a material that can be magnetized upon application of the voltage or current to solenoid coil **148**. Put another way, upon application of the voltage or current to solenoid coil **148**, pole piece **152** will be magnetized to attract poppet **58** thereto, which will pull valve member **18** away from valve seat **84** to open valve apparatus **10** and permit fluid to flow from inlet **20** through valve assembly **14** to outlet **22**. Pole piece **152** includes a threaded end **156** that mates with an interior threaded surface **158** of coupling **140** such that pole piece **152** is fixed during use of valve apparatus **10**. An opposing end **160** of pole piece **152** is spaced apart from proximate end **120** of poppet **58** such that proximate end **120** will contact opposing end **160** when pole piece **152** is magnetized and pulls proximate end **120** thereto to open valve apparatus **10**.
[0051] A hollow bushing **162** may be positioned between yoke **146** and poppet **58**. Bushing includes a hollow cylindrical sleeve **164** that extends along a portion of a length of poppet **58** and a radially outwardly extending flange **166** that serves as a second seat **168** for biasing member **128**. In addition, an annular sealing member **170** may be positioned between flange **166** and terminal

end **104** of protrusion **102** of valve retainer **50** to provide a seal between valve assembly **14** and actuator assembly **16**.

[0052] Again referring to FIG. **5**, quad-ring sealing member **132** is illustrated in more detail. Quad-ring sealing member **132** has four lobes **172***a*, **172***b*, **172***c*, and **172***d* that are separated by recesses **174***a*, **174***b*, **174***c*, and **174***d* such that quad-ring sealing member **132** has a cross-sectional shape that resembles an "X." As noted above, quad-ring sealing member **132** provides increased sealing capability between valve assembly **14** and actuator assembly **16**, as well as an increased life-span in comparison to a conventional seal member such as an O-ring. In this regard, lobes **172***a* and **172***b* provide a pair of sealing surfaces or seal lips that engage with second axially extending through-hole **72** and lobes **172***c* and **172***d* provide a pair of sealing surfaces or seal lips that engage with groove **130** formed in poppet **58**. In addition, because the amount of contact between the lobes **172***a*-**172***d* and the second axially extending through-hole **72** and groove **130** is less than what would occur if seal member **132** were replaced by, for example, an O-ring or D-ring, the amount of friction generated between sealing member **132** and these surfaces can be reduced, which can permit poppet **58** to move towards and away from valve seat **84** by applying a reduced voltage or current to solenoid **144**.

[0053] Now referring to FIGS. **6** to **9**, a second embodiment of the present disclosure will be described. The valve apparatus **200** illustrated in FIGS. **6** to **9** is similar to the valve apparatus **10** described above, but includes a different manifold **202**, a different valve assembly **204** (FIG. **7**), and a slightly different actuator assembly **206**.

[0054] Manifold **202** is a block-shaped member having an inlet **208** and outlet **210**. It should be understood, however, that outlet **210** may serve as the inlet and the inlet **208** may serve as the outlet, if desired. In any event, manifold **202** may be formed of a rigid material such as a metal or polymeric material. Manifold **202** also defines a bore **212** that, as best shown in FIG. **9**, is arranged transverse relative to each of inlet **208** and outlet **210**. Bore **212** is configured for receipt of at least a portion of a cartridge **214** that is comprised of the combination of valve assembly **204** and actuator assembly **206**, and is particularly configured for receipt of valve assembly **204**.

[0055] Bore **212** defines an opening **216** formed in manifold **202** and includes a threaded cylindrical surface **218** that is configured to mate with a correspondingly threaded surface **220** of a housing **222** of actuator assembly **206** such that cartridge **214** can be secured to manifold **202**. Bore **212** includes a first cylindrical surface **224** positioned axially inward from threaded cylindrical surface **218** that terminates at a first radially inwardly extending shoulder **226**. A second cylindrical surface **228** extends axially inwardly from radially inwardly extending shoulder **226**, and includes a first cylindrical opening **230** that communicates with inlet **208** before terminating at a second radially inwardly extending shoulder **232**. A third cylindrical surface **234** extends axially inwardly from second radially inwardly extending shoulder **232**, and includes a second cylindrical opening **236** that communicates with outlet **210** before terminating at a third radially inwardly extending shoulder **238**. A fourth cylindrical surface **240** extends axially inward from third radially inwardly extending shoulder **238** before terminating at an end face **242** of bore **212**. While not required, end face **242** may include an axially extending passage **244** that leads to the exterior atmosphere.

[0056] Valve assembly **204** is positioned within bore **212** such that valve assembly **204** may control fluid flow between inlet **208** and outlet **210**. Valve assembly **204** includes a valve retainer **246** including a valve retainer inlet port **248** aligned with first cylindrical opening **230** and inlet **208**, a valve retainer outlet port **250** aligned with second cylindrical opening **236** and outlet **210**, an axially extending passage **252** configured for receipt of a poppet **254** defining a valve member **256**, and an adjustable valve seat **258** positioned within axially extending passage **252** that surrounds a portion of poppet **254**.

[0057] Valve retainer **246** includes a first end **260** located proximate end face **242** and an opposite second end **262** that is configured to mate with each of adjustable valve seat **258** and housing **222** of actuator assembly **206**. Valve retainer inlet port **248** and valve retainer outlet port **250** are located

between first end **260** and opposite second end **262**, and are longitudinally (i.e., axially) spaced apart from each other. An exterior surface **264** of valve retainer **246** includes a plurality of radially inwardly extending slots **266** that are each configured for receipt of annular seal members **268** (e.g., O-rings) that sealingly engage with bore **212**. Additionally, valve retainer **246** includes a first valve seat **270** that is configured to be abutted by valve member **256** when valve assembly **204** is in the closed position (illustrated).

[0058] Opposite second end **262** includes an interior thread **272** configured to mate with an exterior thread **274** of adjustable valve seat **258** such that a position of adjustable valve seat **258** can be adjusted relative to valve retainer **246**. Opposite second end **262** also includes an outer threaded surface **276** that is configured to mate with an inner threaded surface **278** of housing **222** of actuator assembly **206** such that valve assembly **204** can be mated with actuator assembly **206** to collectively form cartridge **214**.

[0059] Poppet **254** is an elongated member that may be formed of a rigid material such as a metal material, and includes a valve assembly end **280** and an actuator assembly end **282** where valve assembly end **280** is received within valve retainer **246** of valve assembly **204** and actuator assembly end **282** is received within housing **222** of actuator assembly **206**. Valve assembly end **280** includes a first piston **284** received within first end **260** of valve retainer **246**, a second piston **286** received within opposite second end **262** of valve retainer **246**, and valve member **256** positioned between first piston **284** and second piston **286**. First piston **284** is configured to slide along axially extending passage **252** while second piston **286** is configured to slide along an inner surface **288** of adjustable valve seat **258**. First and second pistons **284** and **286** include a radially inwardly extending groove **290** that are each configured for receipt of a quad-ring sealing member **132** that is substantially similar to the quad-ring sealing member **132** described above relative to the first embodiment shown in FIGS. **1**-**5**. Inasmuch as quad-ring sealing members **132** are substantially the same as that described previously, further description of quad-ring sealing members **132** and the benefits afforded thereby will be omitted here.

[0060] Adjustable valve seat **258** is a hollow cylindrical member having an exterior surface **292** that includes exterior thread **274** and a groove **294** configured for receipt of an annular seal **296**, and inner surface **288** configured a bearing surface for second piston **286**. Adjustable valve member **258** includes a cylindrical recess **300** a bottom **302** of which defines a second valve seat **304** that is spaced apart from first valve seat **270** of valve retainer **246**, and that may be abutted by valve member **256** when valve assembly **204** is in the open position to permit fluid to flow from inlet **208** past valve member **256** to outlet **210**.

[0061] Actuator assembly **206** is connected to valve assembly **204** by mating outer threaded surface **276** of valve retainer with inner threaded surface **278** of housing **222**. Housing **222** is a generally hollow cylindrical structure that includes one end **306** having inner threaded surface **278** and an opposite end **308** that defines a coupling **310** configured to be mated with an electrical connector **312** for providing a voltage or current to a solenoid **314** provided in housing **222**. Solenoid **314** includes a hollow yoke **316** that supports a solenoid coil **318** having opposing ends (not shown) that are electrically connected to a pair of leads **320** of electrical connector **312**.

[0062] Actuator assembly end **282** of poppet **254** may function as an armature that is magnetically attracted to a pole piece **322** provided within an elongated aperture **324** of yoke **316**. Pole piece **322** is formed of a material that can be magnetized upon application of the voltage or current to solenoid coil **318**. Put another way, upon application of the voltage or current to solenoid coil **318**, pole piece **322** will be magnetized to attract poppet **254** thereto, which will pull valve member **256** away from first valve seat **270** to open valve apparatus **200** and permit fluid to flow from inlet **208** through valve assembly **204** to outlet **210**. Pole piece **322** includes a threaded end **326** that mates with an interior threaded surface **328** of coupling **310** such that pole piece **322** is fixed during use of valve apparatus **200**. An opposing end **330** of pole piece **322** is spaced apart from actuator assembly end **282** of poppet **254** such that actuator assembly end **282** will contact opposing end

330 when pole piece **322** is magnetized and pulls actuator assembly end **282** thereto to open valve assembly **204**.

[0063] A hollow bushing **332** may be positioned between yoke **316** and poppet **254**. Bushing includes a hollow cylindrical sleeve **334** that extends along a portion of a length of actuator assembly end **282** of poppet **254** and a radially outwardly extending flange **336** that serves as a spring seat **338** for a biasing member **340** (e.g., spring) positioned between flange **336** and second piston **286** that biases poppet **254** and valve member **256** into engagement with first valve seat **270**. In addition, an annular sealing member **342** may be positioned between flange **336** and opposite second end **262** of valve retainer **246** to provide a seal between valve assembly **204** and actuator assembly **206**.

[0064] Now referring to FIGS. **10** to **13**, a third embodiment of the present disclosure will be described. The valve apparatus **400** illustrated in FIGS. **10** to **13** is substantially similar to the valve apparatus **200** described above. Accordingly, features that are common to valve apparatus **200** and valve apparatus **400** will have the same reference numbers, albeit the features illustrated in FIGS. **10** to **13** will have reference numbers denoted by an apostrophe to distinguish these features from the valve assembly **200** illustrated in FIGS. **6** to **9**.

[0065] The primary differences between valve apparatus **200** and valve apparatus **400** is that valve apparatus **400** is a three-way valve including a manifold **402** having an inlet **404** and a pair of outlets **406***a* and **406***b* that communicate with a bore **408**. In addition, valve apparatus **400** includes a modified valve retainer **410** and modified adjustable valve seat **412** to account for the valve apparatus **400** being a three-way valve. In any event, valve apparatus **400** includes a valve assembly **204′** and an actuator assembly **206′** that mate to collectively form a cartridge **214′** that is received within a bore **408** of manifold **402**.

[0066] Valve assembly **204′** is positioned within bore **408** such that valve assembly **204′** may control fluid flow between inlet **404** and the pair of outlets **406***a* and **406***b*. Valve retainer **410** of valve assembly **204′** includes a valve retainer inlet port **248′** aligned with a first cylindrical opening **230′** formed in bore **408** and inlet **404**, a pair of valve retainer outlet ports **250′***a* and **250′***b* aligned with second cylindrical openings **236′***a*, **236′***b* and outlets **406***a*, **406***b*, an axially extending passage **252′** configured for receipt of a poppet **254′** defining a valve member **256′**, and adjustable valve seat **412** positioned within axially extending passage **252′** that surrounds a portion of poppet **254′**.

[0067] Valve retainer **410** includes a first end **260′** located proximate an end face **242′** of bore **408** and an opposite second end **262′** that is configured to mate with each of adjustable valve seat **412** and housing **222′** of actuator assembly **206′**. Valve retainer inlet port **248′** and valve retainer outlet ports **250′***a*, **250′***b* are located between first end **260′** and opposite second end **262′**, and are longitudinally (i.e., axially) spaced apart from each other. An exterior surface **264′** of valve retainer **410** includes a plurality of radially inwardly extending slots **266′** that are each configured for receipt of annular seal members **268′** (e.g., O-rings) that sealingly engage with bore **408**. Valve retainer **410** additionally includes a first valve seat **270′** that is configured to be abutted by valve member **256′** when valve assembly **204′** is in the closed position (illustrated).

[0068] Opposite second end **262′** includes an interior thread **272′** configured to mate with an exterior thread **274′** of adjustable valve seat **412** such that a position of adjustable valve seat **412** can be adjusted relative to valve retainer **410**. Opposite second end **262′** also includes an outer threaded surface **276′** that is configured to mate with an inner threaded surface **278′** of housing **222′** of actuator assembly **206′** such that valve assembly **204′** can be mated with actuator assembly **206′** to collectively form cartridge **214′**.

[0069] Poppet **254′** is an elongated member that may be formed of a rigid material such as a metal material, and includes a valve assembly end **280′** and an actuator assembly end **282′** where valve assembly end **280′** is received within valve retainer **410** of valve assembly **204′** and actuator assembly end **282′** is received within housing **222′** of actuator assembly **206′**. Valve assembly end **280′** includes a first piston **284′** received within first end **260′** of valve retainer **410**, a second piston

286′ received within opposite second end **262**′ of valve retainer **412**, and valve member **256**′ is positioned between first piston **284**′ and second piston **286**′. First piston **284**′ is configured to slide along axially extending passage **252**′ while second piston **286**′ is configured to slide along an inner surface **288**′ of adjustable valve seat **412**. First and second pistons **284**′ and **286**′ include a radially inwardly extending groove **290**′ that are each configured for receipt of a quad-ring sealing member **132** that is substantially similar to the quad-ring sealing member **132** described above relative to the first embodiment shown in FIGS. **1-4**. Inasmuch as quad-ring sealing members **132** are substantially the same as that described previously, further description of quad-ring sealing members **132** and the benefits afforded thereby will be omitted here.

[0070] Adjustable valve seat **412** is a hollow cylindrical member having an exterior surface **292**′ that includes exterior thread **274**′ and grooves **294**′ configured for receipt of annular seals **296**′, and inner surface **288**′ configured a bearing surface for second piston **286**′. Adjustable valve seat **412** includes a cylindrical recess **300**′ a bottom **302**′ of which defines a second valve seat **304**′ that is spaced apart from first valve seat **270**′ of valve retainer **410**, and that may be abutted by valve member **256**′ when valve assembly **204**′ is in the open position to permit fluid to flow from inlet **404** past valve member **256**′ to outlet **406***b*. When valve assembly **204**′ is in the illustrated closed state, fluid is able to continuously flow from inlet **404** to outlet **406***a* through an outlet passage **420** that communicates with cylindrical opening **236**′*a* formed in manifold **402**.

[0071] Actuator assembly **206**′ is connected to valve assembly **204**′ by mating outer threaded surface **276**′ of valve retainer **410** with inner threaded surface **278**′ of housing **222**′. Housing **222**′ is a generally hollow cylindrical structure that includes one end **306**′ having inner threaded surface **278**′ and an opposite end **308**′ that defines a coupling **310**′ configured to be mated with an electrical connector **312**′ for providing a voltage or current to a solenoid **314**′ provided in housing **222**′. Solenoid **314**′ includes a hollow yoke **316**′ that supports a solenoid coil **318**′ having opposing ends (not shown) that are electrically connected to a pair of leads (not shown) of electrical connector **312**′.

[0072] Actuator assembly end **282**′ of poppet **254**′ may function as an armature that is magnetically attracted to a pole piece **322**′ provided within an elongated aperture **324**′ of yoke **316**′. Pole piece **322**′ is formed of a material that can be magnetized upon application of the voltage or current to solenoid coil **318**′. Put another way, upon application of the voltage or current to solenoid coil **318**′, pole piece **322**′ will be magnetized to attract poppet **254**′ thereto, which will pull valve member **256**′ away from first valve seat **270**′ to open valve apparatus **400** and permit fluid to flow from inlet **404** through valve assembly **204**′ to outlet **406***b* rather than outlet **406***a*. Pole piece **322**′ includes a threaded end **326**′ that mates with an interior threaded surface **328**′ of coupling **310**′ such that pole piece **322**′ is fixed during use of valve apparatus **400**. An opposing end **330**′ of pole piece **322**′ is spaced apart from actuator assembly end **282**′ of poppet **254**′ such that actuator assembly end **282**′ will contact opposing end **330**′ when pole piece **322**′ is magnetized and pulls actuator assembly end **282**′ thereto to open valve apparatus **400**.

[0073] A hollow bushing **332**′ may be positioned between yoke **316**′ and poppet **254**′. Bushing **332**′ includes a hollow cylindrical sleeve **334**′ that extends along a portion of a length of actuator assembly end **282**′ of poppet **254**′ and a radially outwardly extending flange **336**′ that serves as a spring seat **338**′ for a biasing member **340**′ (e.g., spring) positioned between flange **336**′ and second piston **286**′ that biases poppet **254**′ and valve member **256**′ into engagement with first valve seat **270**′. In addition, an annular sealing member **342**′ may be positioned between flange **336**′ and opposite second end **262**′ of valve retainer **410**′ to provide a seal between valve assembly **204**′ and actuator assembly **206**′.

[0074] The foregoing description of the embodiments has been provided for purposes of illustration and description. It is not intended to be exhaustive or to limit the disclosure. Individual elements or features of a particular embodiment are generally not limited to that particular embodiment, but, where applicable, are interchangeable and can be used in a selected embodiment, even if not

specifically shown or described. The same may also be varied in many ways. Such variations are not to be regarded as a departure from the disclosure, and all such modifications are intended to be included within the scope of the disclosure.

Claims

1. A valve apparatus, comprising: a manifold having a bore, an inlet communicating with the bore, and an outlet communicating with and axially aligned with the bore; a valve cartridge at least partially received within the bore and including a valve assembly having a valve member that enables communication between the inlet and the outlet, and an actuator assembly for actuating the valve member; the valve assembly including a hollow valve retainer having a first end that is configured to mate with the actuator assembly and an opposite second end received within the bore and defining an outlet port that communicates with the outlet of the manifold, the hollow valve retainer including a first plate-shaped member and a second plate-shaped member connected by a pair of axially extending arms that separate the first and second plate-shaped members by a gap that serves as an inlet port of the valve retainer in communication with the inlet of the manifold, the first plate-shaped member including a first axially-extending through-hole that defines the outlet port and the second plate-shaped member including a second axially-extending through-hole that is configured for receipt of a poppet having the valve member therein, the first plate-shaped member includes a first face that faces the gap and an opposite second face that faces the outlet of the manifold, the first axially-extending through-hole extends between the first face and the second face, and the first axially-extending through hole includes a first chamfered surface that defines a valve seat at the first face that is configured to be contacted by the valve member when the valve apparatus is in a closed position and spaced apart from the valve member when the valve apparatus is in an open position; the poppet includes a proximate end positioned within the actuator assembly and a distal end that includes the valve member, the distal end having a radially inwardly extending groove between the valve member and the proximate end that is configured for receipt of an annular quad-ring sealing member that seals an interface between the poppet and the second axially-extending through hole of the valve retainer as the poppet and valve member are moved during operation of the valve apparatus by the actuator assembly; and the valve member at the distal end of the poppet includes a second chamfered surface that corresponds to the first chamfered surface that defines the valve seat.

2. The valve apparatus according to claim 1, further comprising a biasing member that biases the poppet and valve member to the closed position, the biasing member being in contact with an annular arm that extends radially outward from the poppet.

3. The valve apparatus according to claim 2, wherein the radially inwardly extending groove having the annular quad-ring sealing member is positioned between the valve member and the annular arm that extends radially outward from the poppet.

4. The valve apparatus according to claim 1, wherein the first axially-extending hole includes the first chamfered surface and a cylindrical surface connected to the first chamfered surface.

5. The valve apparatus according to claim 4, wherein the first chamfered surface includes a first end connected to the first face of the first plate-shaped member and a second end that defines an apex, and a radially outwardly extending surface connects the apex to the cylindrical surface, and wherein the radially outwardly extending surface that connects the apex to the cylindrical surface defines a seat configured for receipt of an annular seal member that is configured to be contacted by valve member when the valve apparatus is in the closed position.

6. The valve apparatus according to claim 1, wherein the second plate-shaped member of the hollow valve retainer includes a first face that faces the gap and an opposite second face that faces the actuator assembly; a hollow cylindrical protrusion extends axially outward from the second face and includes a terminal end that defines the first end of the hollow valve retainer that is

configured to mate with the actuator assembly, an outer surface of the terminal end being threaded to threadingly mate with a threaded surface of a housing of the actuator assembly.

7. The valve apparatus according to claim 6, wherein the housing of the actuator assembly is configured for receipt of the proximate end of the poppet.

8. The valve apparatus according to claim 7, wherein the actuator assembly includes the housing, and a solenoid configured to magnetize a pole piece positioned in the housing to magnetically attract the proximate end of the poppet to move the valve member away from the valve seat and open the valve apparatus.

9. A valve apparatus, comprising: a manifold having a bore, an inlet communicating with the bore, and an outlet with the bore; a valve cartridge at least partially received within the bore and including a valve assembly having a valve member that enables communication between the inlet and the outlet, and an actuator assembly for actuating the valve member; the valve assembly including a hollow valve retainer having a first end that is configured to mate with the actuator assembly and an opposite second end received within the bore, the hollow valve retainer having an inlet port that communicates with the inlet of the manifold and defines a first valve seat configured to be contacted by the valve member when the valve apparatus is in a closed position, and an outlet port that communicates with the outlet of the manifold; and the valve assembly including a poppet positioned within and movable relative to the hollow valve retainer, the poppet including a proximate end positioned within the actuator assembly and a distal end that includes a first piston, a second piston, and the valve member between the first piston and the second piston, the valve assembly including an adjustable valve seat positioned within and attached to the hollow valve retainer, the adjustable valve seat defining a second valve seat configured to be contacted by the valve member when the valve apparatus is in an open position; wherein each of the first piston and the second piston have a radially inwardly extending groove that is configured for receipt of an annular quad-ring sealing member that seals an interface between the first piston and the hollow valve retainer and an interface between the second piston and the adjustable valve seat.

10. The valve apparatus according to claim 9, further comprising a biasing member that biases the poppet and valve member to the closed position, the biasing member being in contact with the second piston of the poppet.

11. The valve apparatus according to claim 9, wherein the manifold includes a second outlet in communication with the bore, and the adjustable valve seat includes an outlet port in communication with the second outlet.

12. The valve apparatus according to claim 9, wherein the actuator assembly includes a housing attached to the valve retainer and a solenoid configured to magnetize a pole piece positioned in the housing to magnetically attract the proximate end of the poppet to move the valve member away from the first valve seat and open the valve apparatus.