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(71) Applicant: **INGERSOLL-RAND COMPANY**

Montvale, NJ 07645 (US)

(72) Inventor: **Lowe, Norman Philip**

**Wigan
Lancashire, WN6 0PX (GB)**

(74) Representative: **Holmes, Matthew Peter et al**

**MARKS & CLERK,
Sussex House,
83-85 Mosley Street
Manchester M2 3LG (GB)**

(54) **Valve for a compressor assembly**

(57) A compressor assembly including a separator (16) having a separator space (44). The separator is operable to remove a liquid from a mixture of the liquid and a gas. The assembly includes a sump (14) having a sump space (30) that is positioned to receive the liquid from the separator (16). A valve (46) is positioned between

the separator space (44) and the sump space (30) and is moveable to a closed position in response to a predetermined flow between the sump space (30) and the separator space (44). A biasing member (77) is positioned to bias the valve toward an open position.

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Description

BACKGROUND

[0001] The present invention relates to a valve configured for use in a compressor assembly. More particularly, the present invention relates to a valve configured to provide selective fluid communication between a separator and a sump of a compressor.

[0002] Rotary screw compressors typically include at least two oil-flooded intermeshing rotors that rotate in unison to create a flow of compressed gas. The rotors are flooded in a lubricant such as oil to lubricate and cool the rotors. As a result of the rotors being flooded in oil, the oil becomes entrained in the flow of compressed gas. Often, it is undesirable for oil to be entrained in the compressed gas because the oil can damage equipment that utilizes the compressed gas. In addition, the failure to recover and reuse the oil would require the constant addition of oil to replenish the compressor system. Therefore, before the compressed gas is transported to the equipment, a substantial amount of the entrained oil is removed from the compressed gas flow using an oil separator. The separated oil can be transported to a sump for storage and reuse in the compressor. In addition, the separated oil can be transported to an oil cooler to cool the oil, and/or an oil filter to filter the oil before it is directed back to the compressor for reuse.

SUMMARY

[0003] In one embodiment, the invention provides a compressor assembly including a separator having a separator space. The separator is operable to remove a liquid from a mixture of the liquid and a gas. The assembly includes a sump having a sump space that is positioned to receive the liquid from the separator. A valve is positioned between the separator space and the sump space and is moveable to a closed position in response to a predetermined flow between the sump space and the separator space. A biasing member is positioned to bias the valve toward an open position.

[0004] In another embodiment the invention provides a method of operating a compressor assembly having a sump in fluid communication with a separator. The method includes passing a mixture of a liquid and a gas into the separator. The mixture defines a separator pressure. The method also includes separating a substantial amount of the liquid from the mixture and passing the liquid to the sump to define a sump pressure. The method also includes biasing a valve toward an open position, and blocking a substantial amount of the liquid from passing into the sump by moving the valve toward a closed position when the difference between the separator pressure and the sump pressure exceeds a predetermined value.

[0005] In yet another embodiment the invention provides a valve that includes a chamber and a sump. The

chamber is positioned to receive a flow of fluid including a liquid and a gas. The sump is adapted to contain the liquid. The valve also includes a valve housing and a valve member. The valve housing is at least partially disposed within the sump to define a valve space in fluid communication with the chamber. The valve housing defines an aperture that provides fluid communication between the valve space and the sump. The valve member at least partially disposed within the valve housing and is movable between an open position in which liquid flows from the chamber to the sump and a closed position in which flow between the chamber and the sump is inhibited. A biasing member biases the valve member toward the open position, and the valve member is moveable toward the closed position in response to a pressure differential between the sump and the chamber that is greater than a predetermined value.

[0006] Other aspects of the invention will become apparent by consideration of the detailed description and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] Fig. 1 is a perspective view of a compressor assembly employing the present invention;

[0008] Fig. 2 is a section view of a portion of a compressor assembly including a valve embodying the present invention in an open position; and

[0009] Fig. 3 is a perspective section view of a portion of the compressor assembly, including the valve of Fig. 2 in a closed position.

[0010] Before any embodiments of the invention are explained in detail, it is to be understood that the invention is not limited in its application to the details of construction and the arrangement of components set forth in the following description or illustrated in the following drawings. The invention is capable of other embodiments and of being practiced or of being carried out in various ways. Also, it is to be understood that the phraseology and terminology used herein is for the purpose of description and should not be regarded as limiting. The use of "including," "comprising," or "having" and variations thereof herein is meant to encompass the items listed thereafter and equivalents thereof as well as additional items. Unless specified or limited otherwise, the terms "mounted," "connected," "supported," and "coupled" and variations thereof are used broadly and encompass both direct and indirect mountings, connections, supports, and couplings. Further, "connected" and "coupled" are not restricted to physical or mechanical connections or couplings.

DETAILED DESCRIPTION

[0011] Fig. 1 illustrates a compressor assembly 10 that includes a compressor core 12, a sump 14 and a separator 16. The compressor core 12 attaches to the sump 14 and includes a drive member 18 and a compressor

20, such as an oil flooded rotary screw compressor, a centrifugal compressor or any other suitable compressor design. The illustrated sump 14 includes support members 21 that are attached to the sump 14 to support the sump 14 above a foundation. In other constructions, the sump 14 is set upon a foundation to support the compressor assembly 10. The illustrated compressor 20, the sump 14, and the separator 16 include portions that are integrally formed, such as by casting. In another construction, the compressor assembly 10 can be formed by coupling the compressor 20 and the separator 16 to the sump 14, such as by welded or bolted connections.

[0012] As illustrated in Fig. 2, the sump includes a sump housing 24 having at least one wall 25, a base 26 and a cover 28. The walls 25, base 26 and cover 28 attach to one another to substantially enclose a sump space 30. In preferred constructions, the walls 25, base 26, and cover 28 are permanently attached to one another (e.g., welded), or integrally formed as a single piece, or a combination thereof. In these constructions, separation of the components is generally not possible without destroying or damaging one or more of the components. The sump 14 can be manufactured from steel, aluminum or any suitable material and can be formed using any suitable method, such as casting, molding, forging, welding, brazing, bolting, and the like. The sump space 30 contains a liquid such as oil, water, refrigerant, coolant, etc.

[0013] The cover 28 is a substantially flat component that extends to, and connects each wall 25 to substantially enclose the top of the sump space 30. In preferred constructions, the cover 28 defines a component support area that receives the compressor 20, the drive member 18, and the separator 16. In these constructions, the cover 28 provides structural support for the components it supports. The cover 28 includes a cover aperture 32 that extends through the cover 28. While the illustrated cover aperture 32 is a circular aperture, it should be understood that the cover aperture 32 can be virtually any shape. The cover 28 also includes a portion 34 adjacent to the cover aperture 32 with an increased thickness to provide additional stiffness to the cover 28 in the area adjacent the cover aperture 32.

[0014] The base 26 is a substantially flat component that extends to, and connects each wall 25 to substantially enclose the bottom of the sump space 30. The illustrated base 26 includes a base aperture 36 extending through the base 26 and positioned directly below the cover aperture 32 such that the centers of the base aperture 36 and the cover aperture 32 lie on a common axis that is substantially normal to the base 26. The illustrated base aperture 36 is substantially cylindrical and includes a threaded portion 38. The illustrated base 26 includes a portion 40 with an increased thickness that is adjacent the base aperture 36 to provide additional stiffness and thread length to the base 26 in the area adjacent the base aperture 36. In other constructions, other base aperture shapes may be employed.

[0015] With continued reference to Fig. 2, the cover 28 at least partially defines a separator housing 42 that extends from the cover 28 to at least partially form a separator space 44. In preferred constructions, the separator space 44 is positioned directly above the cover aperture 32. The illustrated separator housing 42 is integrally formed as part of the cover 28. The separator housing 42 can be integrally formed as part of the cover 28 by casting, molding, forging, or any suitable forming method. In another construction, the separator housing 42 can include a separate piece attached to the cover using any suitable connection, such as a welded, brazed or bolted connections.

[0016] A valve 46 having a valve housing 48, is positioned between the sump space 30 and the separator space 44. The valve housing 48 includes a first end 56, a second end 58 and a plug 60 coupled to the first end 56.

[0017] The plug 60 includes a blind bore 62, a recess 64, and an outer threaded portion 66 that engages the threads 38 of the base aperture 36 to couple the valve housing 48 to the base 26. The illustrated plug 60 also includes an O-ring seal 68 positioned between the plug 60 and the base 26 to inhibit the liquid contained within the sump space 30 from leaking through the base aperture 36. In preferred constructions, the valve housing 48 is integrally machined as a single piece with the plug 60. Alternatively, the valve housing 48 can be cast, forged or injection molded as a single piece with the plug 60. In still other constructions, the valve housing 48 and the plug 60 are fabricated using welding, brazing, soldering or other joining techniques.

[0018] The valve housing 48 extends through the cover aperture 32 such that the second end 58 of the valve housing 48 is positioned on the separator side of the cover aperture 32. The second end 58 connects the cover 28 at the cover aperture 32 to complete the connection of the valve housing 48 to the sump 14. The second end 58 of the valve housing 48 includes an undercut configured to receive an O-ring seal 70. The O-ring seal 70 inhibits fluid flow from the separator space 44 to the sump space 30 without traveling through the valve housing 48.

[0019] The valve housing 48 defines at least one valve housing aperture 72 that provides fluid communication between the separator space 44 and the sump space 30. The illustrated valve housing 48 includes two generally circular valve housing apertures 72. In other constructions a single hole or more than two holes can be employed. For example, one construction employs several rows of small holes that extend around the valve housing 48. In yet another construction, the holes may be other shapes or may include holes of several sizes.

[0020] The valve housing 48 also defines a valve seat 74 positioned between the valve housing apertures 72 and the second end 58 of the valve housing 48. The illustrated valve seat 74 is integrally-formed with the valve housing 48 and can be machined, cast, forged or injection molded integrally with the valve housing 48. In other constructions the valve seat 74 can be a separate element

coupled to the valve housing 48 using any suitable connection, such as welded, brazed, bolted, or threaded connections and the like.

[0021] In addition to the valve housing 48, the valve 46 includes a valve member 75, a rod 76, and a biasing member 77, disposed substantially within the valve housing 48. The rod 76 includes a first end 78, a second end 79 and a shoulder 80 positioned between the first end 78 and the second end 79. The first end 78 includes a portion that engages the blind bore 62 of the plug 60 to couple the rod 76 to the plug 60. It should be understood that the rod can be coupled to the plug using any suitable connection, such as a threaded, welded, brazed, or shrink-fit connection. In yet another construction, the rod 76 is integrally-formed with the plug 60 by machining, casting, forging or other forming techniques.

[0022] The second end 79 of the rod 76 extends through the cover aperture 32 and includes a threaded portion that receives a nut 82 and a plate 84. The nut 82 is threaded onto the second end 79 of the rod 76 to couple the plate 84 to the rod 76. In other constructions, the plate 84 can be coupled to the rod 76 using a welded or brazed connection. In still other constructions the plate can be integrally formed with the rod, such as by machining, casting, forging, or any other suitable process.

[0023] The valve member 75 defines a valve member aperture 86 sized to receive the rod 76 while still allowing the valve member 75 to slide along the portion of the rod 76 below the shoulder 80. However, the shoulder 80 of the rod 76 prevents the valve member 75 from sliding further along the rod 76 toward the second end 79. Furthermore, the valve member 75 is sized such that the valve member 75 and the inside of the valve housing 48 cooperate to define an annular passage 81. However, the valve member 75 is sized to engage the valve seat 74 which prevents further sliding of the valve member 75 along the rod 76 toward the first end 78 of the rod 76.

[0024] The illustrated valve member 75 also includes a plurality of bleed holes 88. While at least two circular bleed holes 88 are illustrated, the valve member 75 can include fewer than two or more than two bleed holes 88 in any suitable location or shape.

[0025] The valve member 75 includes a boss 90 and a recess 92. The boss 90 extends from the bottom of the valve member 75 to further define the recess 92. The illustrated boss 90 is integrally formed with the valve member 75, such as by machining, casting, molding, or any other suitable method. In another construction, the boss can be coupled to the valve element using a welded or brazed connection. The recess 92 can be formed in the valve member 75 by any suitable method, such as by machining, stamping, casting, or forging.

[0026] As illustrated in Fig. 2, the biasing member 77 is configured to bias the valve member 75 towards the shoulder 80. The illustrated biasing member 77 includes a coil spring disposed around the rod 76 and coupled to the valve member 75 and the plug 60. The boss 90 and the recess 92 of the valve member 75 define a guide that

enhances the connection between the biasing member 77 and the valve member 75. The recess 64 in the plug 60 engages the opposite end of the biasing member 77 and enhances the connection between the biasing member 77 and the plug 60.

[0027] Referring to Figs. 2 and 3, the illustrated configuration of the valve allows for the entire valve 46 to be received through the base and cover apertures 36, 32. Therefore, the valve 46 can be assembled outside of the sump space 30 and installed through the base and cover apertures 36, 32 as a single assembly.

[0028] In operation, the compressor core 12 operates to create a flow of compressed gas, typically air. The compressed gas includes some entrained lubricant that together defines a mixture. The mixture enters the separator space 44 and at least a portion of the liquid is separated from the flow of compressed gas. The separated liquid drains along the inside of the separator housing 42 towards the cover aperture 32. Meanwhile, the plate 84 substantially separates any gas vortices from the flow of liquid to reduce re-entrainment of the liquid in the compressed gas. Under normal operation conditions, the valve member 75 is in the open position, as illustrated in Fig. 2, to allow the liquid to flow from the separator space 44 to the valve housing 48, through the annular flow path 81, through the valve housing apertures 72, and into the sump space 30.

[0029] During compressor operation, the separator space 44 and the sump space 30 are each under a substantially uniform pressure. The mixture of the liquid and the compressed gas in the separator space 44 defines a separator pressure, while the liquid in the sump space 30 defines a sump pressure. Under normal operating conditions, the flow path between the separator space 44 and the sump space 30 causes a slight difference between the separator pressure and the sump pressure. Typically, the sump pressure will be slightly less than the separator pressure. When operating in these conditions, a downward force is applied to the valve member 75. The downward force is caused by the differential pressure on either side of the valve member 75. However, the biasing member 77 applies an opposing force that maintains the valve member 77 in the open position, as shown in Fig. 2.

[0030] Under an unusual operating condition, such as when the liquid quickly exits the sump 14, there will be an increase in the difference between the sump pressure and the separator pressure. The differential pressure (separator pressure minus sump pressure) between the separator space 44 and the sump space 30 produces a larger downward force. The larger downward force is enough to overcome the force of the biasing member 77 thus forcing the valve member 75 toward the seat 74, or toward the closed position, as shown in Fig. 3. As the valve member 75 moves toward the closed position the flow from the separator space 44 to the sump space 30 is reduced.

[0031] With the valve member 75 in the closed position, the bleed holes 88 allow only a limited amount of

flow to pass from the separator space 44 to the sump space 30. After the flow of the liquid exiting the sump 14 slows or stops, the limited flow through the bleed holes 88 eventually reduces the differential pressure between the separator space 44 and the sump space 30. At a predetermined differential pressure, the biasing member 77 will begin to move the valve member 75 along the rod 76 toward the shoulder 80, or from the closed position toward the open position of Fig. 2. The stiffness of the biasing member 77 determines the differential pressure at which the valve member 75 moves from the closed position to the open position. Likewise, the stiffness of the biasing member 77 determines the pressure differential that causes the valve member 75 to move from the open position to the closed position. Therefore, the biasing member 77 can be selected to determine the differential pressures that will cause the valve member 75 to move between the open position and the closed position. [0032] Thus, the invention provides, among other things, a valve 46 configured for use in a compressor assembly 10 and movable between an open position and a closed position in response to a predetermined flow or differential pressure between the separator space 44 and the sump space 30. Various features and advantages of the invention are set forth in the following claims.

Claims

1. A compressor assembly comprising:
 - a separator having a separator space and operable to remove a liquid from a mixture of the liquid and a gas;
 - a sump having a sump space and positioned to receive the liquid from the separator;
 - a valve positioned between the separator space and the sump space and moveable to a closed position in response to a predetermined flow between the sump space and the separator space; and
 - a biasing member positioned to bias the valve toward an open position.
2. The compressor assembly of claim 1, wherein the valve includes a bleed hole that provides uninterrupted fluid communication between the sump space and the separator space.
3. The compressor assembly of claim 1, wherein the biasing member is a coil spring.
4. The compressor assembly of claim 1, wherein the separator is at least partially formed as part of the sump.
5. The compressor assembly of claim 1, wherein the sump includes a base, and wherein a portion of the valve is coupled to the base.
6. The compressor assembly of claim 1, further comprising a plate positioned between the sump and the separator.
7. The compressor assembly of claim 1, wherein the valve includes a rod that is substantially fixed with respect to the sump and a valve member coupled to the rod and movable along the rod in response to the flow between the sump space and the separator space.
8. The compressor assembly of claim 7, wherein the valve member is coupled to the biasing member such that the biasing member biases the valve member toward an open position, and wherein the rod defines a shoulder that inhibits movement of the valve member toward the open position.
9. The compressor assembly of claim 1, wherein the valve threadably engages the sump.
10. A method of operating a compressor assembly having a sump in fluid communication with a separator, the method comprising:
 - passing a mixture of a liquid and a gas into the separator, the mixture defining a separator pressure;
 - separating a substantial amount of the liquid from the mixture;
 - passing the liquid to the sump to define a sump pressure;
 - biasing a valve toward an open position; and
 - blocking a substantial amount of the liquid from passing into the sump by moving the valve toward a closed position when the difference between the separator pressure and the sump pressure exceeds a predetermined value.
11. The method of claim 10, further comprising selecting a biasing member to select the predetermined value.
12. The method of claim 10, further comprising inhibiting re-entrainment of the liquid into the gas by positioning a plate between the sump and the separator.
13. The method of claim 10, further comprising fixedly attaching a rod to the sump and movably coupling a valve member to the rod, the valve member movable between a closed position and an open position.
14. A valve comprising:
 - a chamber positioned to receive a flow of fluid including a liquid and a gas;
 - a sump adapted to contain the liquid;

- a valve housing at least partially disposed within the sump to define a valve space in fluid communication with the chamber, the valve housing defining an aperture that provides fluid communication between the valve space and the sump; 5
a valve member at least partially disposed within the valve housing and movable between an open position in which liquid flows from the chamber to the sump and a closed position in which flow between the chamber and the sump is inhibited; and 10
a biasing member that biases the valve member toward the open position, and wherein the valve member is moveable toward the closed position in response to a pressure differential between the sump and the chamber that is greater than a predetermined value. 15
- 15.** The valve of claim 14, wherein the valve housing is coupled to the sump. 20
- 16.** The valve of claim 14, wherein the chamber is at least partially formed as part of the sump.
- 17.** The valve of claim 14, wherein a first end of the valve housing is coupled to the chamber, the chamber operable to separate the liquid from the gas. 25
- 18.** The valve of claim 14, further comprising a plate positioned between the sump and the separator. 30
- 19.** The compressor assembly of claim 14, wherein the valve includes a rod that is substantially fixed with respect to the sump and a valve member coupled to the rod and movable along the rod in response to the flow between the sump space and the separator space. 35
- 20.** The compressor assembly of claim 19, wherein the valve member is coupled to the biasing member such that the biasing member biases the valve member toward an open position, and wherein the rod defines a shoulder that inhibits movement of the valve member toward the open position. 40

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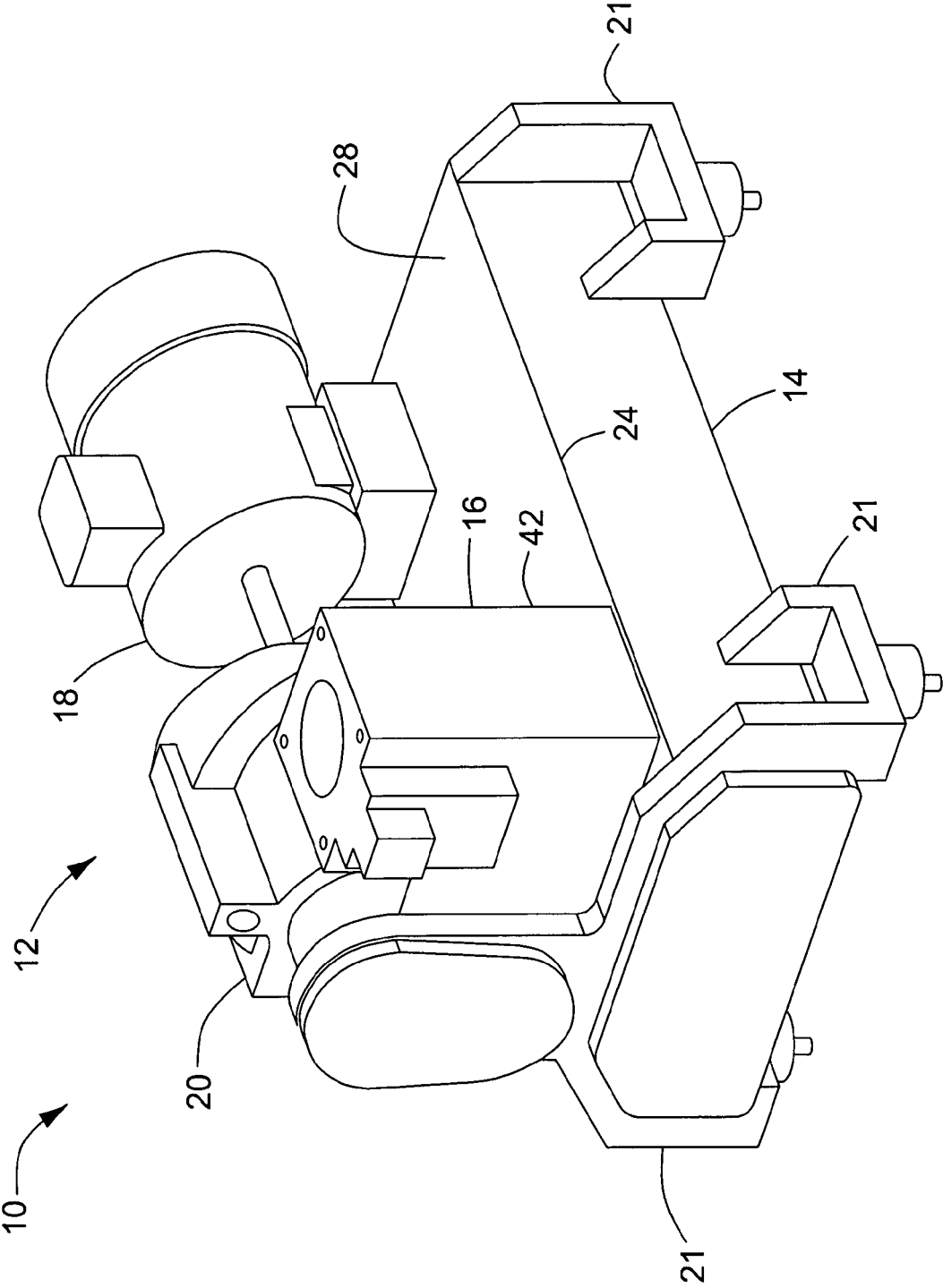


FIG. 1

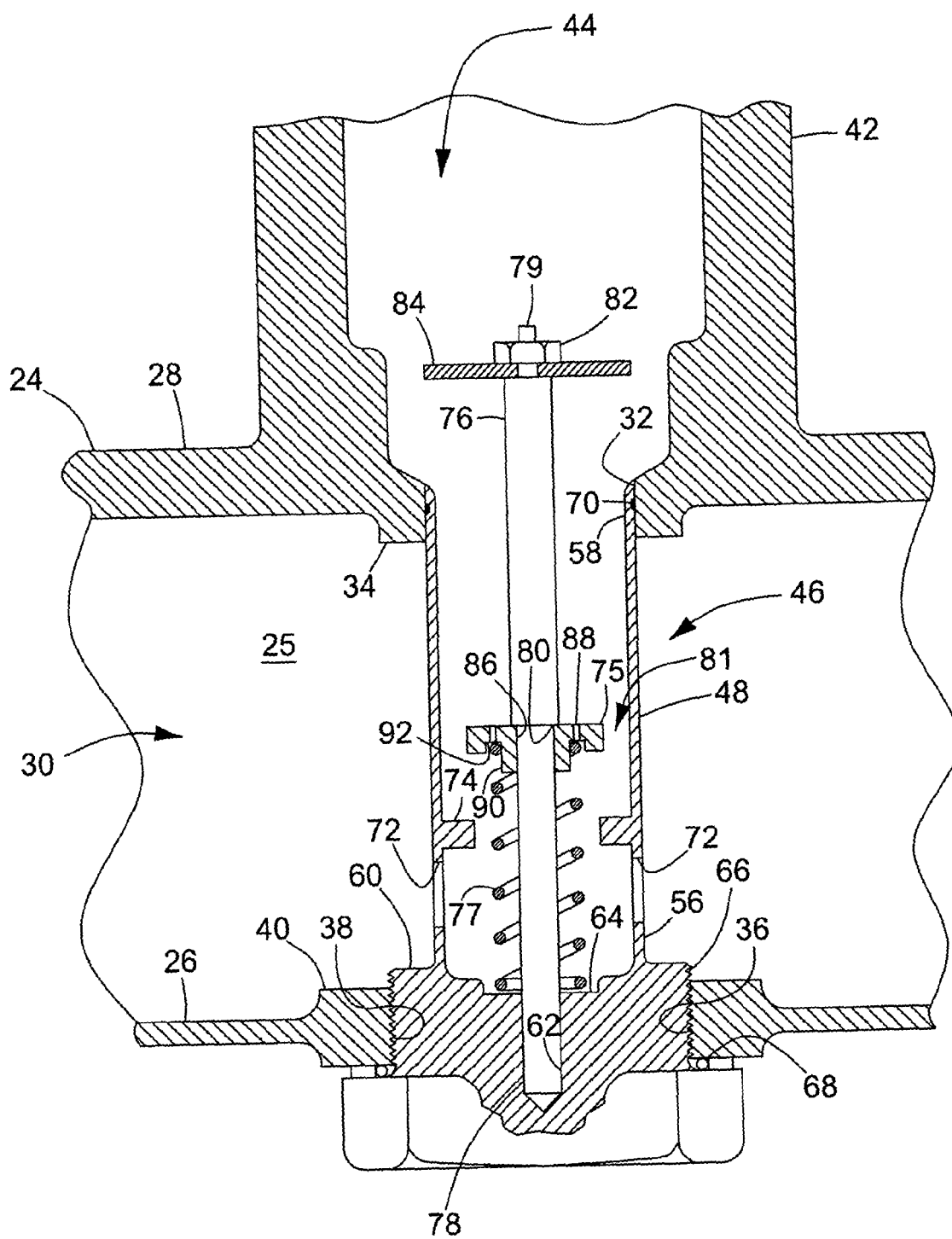


FIG. 2

