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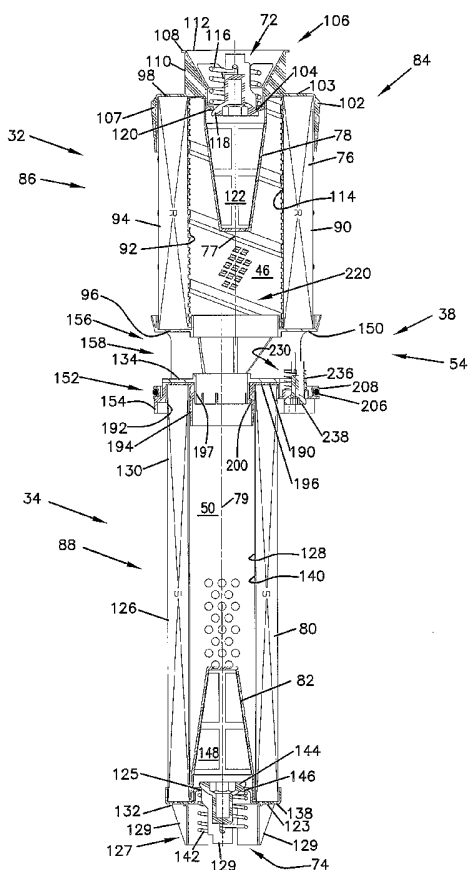
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(54) Title: FILTER ARRANGEMENT AND METHODS



(57) Abstract: A filter element arrangement includes a first filter member and a second filter member joined together axially by an end cap construction. The end cap construction includes a first cap secured to an end of the first filter member, a second cap secured to the end of the second filter member, a first slotted wall extending axially from the first cap, a second slotted wall extending axially from the second cap, and a wall construction connecting the first slotted wall and the second slotted wall. A filter assembly includes a filter element arrangement as characterized above operably installed within a housing construction. The housing construction includes a first inlet port arrangement, a second inlet port arrangement, a first outlet port arrangement, an access opening, and a removable cover mounted over the access opening. A method of servicing a filter assembly includes removing a cover from a body of a housing construction and then removing the filter element. The filter element can be of the type characterized above. The step of removing the filter element includes releasing a first seal and a second seal.



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FILTER ARRANGEMENT AND METHODS

5 This application is being filed on 19 September 2005 as a PCT International Patent application in the name of Donaldson Company, Inc., a U.S. national corporation, applicant for the designation of all countries except the US, and Jeffrey J. Theisen and Gary H. Gift, both citizens of the U.S., applicants for the designation of the US only, and claims priority to the following U.S. provisional patent applications: Provisional Application No. 60/611,832 filed September 20, 2004; 10 Provisional Application No. 60/649,398 filed February 1, 2005; and Provisional Application No. 60/709,864 filed August 18, 2005. Each of these applications is incorporated herein by reference in its entirety.

15 TECHNICAL FIELD

This disclosure relates to filter assemblies, filter elements, methods of filtering, and methods of servicing. In example implementations, this disclosure relates to filtering technology useful for purifying hydraulic systems used in, for example, heavy equipment.

20 BACKGROUND

Filter devices are used in many types of applications. In one application, filter devices are used to filter hydraulic fluid, for example, hydraulic oil, in hydraulic systems. In many cases, the hydraulic systems have to meet high demands to fulfill their intended function while not wearing over the operating times. Over a period of use, filter devices will become clogged with debris and particulate matter. The filter devices, therefore, must be either cleaned or replaced. In many useful filters currently used, the filters are designed to be removed, disposed of, and replaced with new filters.

30 Improvements in filter devices are continually being sought.

SUMMARY

A filter element arrangement includes a first filter member and a second filter member joined together axially by an end cap construction. The end cap construction includes a first cap secured to an end of the first filter member, a second cap secured to the end of the second filter member, a first slotted wall extending axially from the first cap, a second slotted wall extending axially from the second cap, and a wall construction connecting the first slotted wall and the second

slotted wall. In some implementations, the first filter member functions as a return-line filter, while the second filter member functions as a suction filter.

A filter assembly includes a filter element arrangement as characterized above operably installed within a housing construction. The housing construction
5 includes a first inlet port arrangement, a second inlet port arrangement, a first outlet port arrangement, an access opening, and a removable cover mounted over the access opening. In some embodiments, the housing construction includes a housing body and a sleeve.

A method of servicing a filter assembly includes removing a cover from a
10 body of a housing construction and then removing the filter element. The filter element can be of the type characterized above. The step of removing the filter element includes releasing a first seal and a second seal. In some embodiments, the step of removing the element from the housing includes closing an anti-drain valve assembly to prevent fluid from flowing into the housing.

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BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of a filter element arrangement constructed according to principles of this disclosure;

FIG. 2 is a top plan view of the filter element arrangement of FIG. 1;

20 FIG. 3 is a cross-sectional view of a filter assembly including a housing holding the filter element arrangement depicted in FIG. 1;

FIG. 4 is a cross-sectional view of the filter element arrangement of FIG. 1, having a first filter member and a second filter member, the cross-section being taken along the line 4-4 of FIG. 2;

25 FIG. 5 is a top perspective view of a first end cap construction useable in the filter element arrangement of FIG. 4;

FIG. 6 is a bottom perspective view of the first end cap construction of FIG. 5;

30 FIG. 7 is a cross-sectional view of the first end cap construction of FIGS. 5 and 6;

FIG. 8 is a top perspective view of a second cap mountable on the second filter member depicted in FIG. 4;

FIG. 9 is a bottom perspective view of the second cap depicted in FIG. 8;

35 FIG. 10 is a top plan view of a sleeve and internal components used to hold the second filter member;

FIG. 11 is cross-sectional view of the sleeve and internal components, including an anti-drain valve, depicted in FIG. 10, the cross-section being taken along the line 11-11 of FIG. 10;

FIG. 12 is a perspective view of an anti-drain valve depicted in FIG. 11;
FIG. 13 is another perspective view of the anti-drain valve of FIG. 11;
FIG. 14 is a side elevational view of the anti-drain valve of FIGS. 12 and 13;
FIG. 15 is a top plan view of the anti-drain valve of FIGS. 12-14; and
5 FIG. 16 is a cross-sectional view of the anti-drain valve of FIGS. 12-15, the cross-section being taken along the line 16-16 of FIG. 15.

DETAILED DESCRIPTION

In general, a filter assembly 30 includes a filter element arrangement 84, and
10 a housing construction 36. The filter element arrangement 84 generally includes a first filter member 32 and a second filter member 34 arranged to clean the fluid. In the example shown, the housing construction 36 includes a housing body 39, a removable service cover 100, and a sleeve 37. In the example shown, the first filter member 32 is in the housing body 39, while the second filter member 34 is enclosed
15 with the sleeve 37. In the embodiment depicted in FIG. 3, there is a construction 38 between the first filter member 32 and second filter member 34 that is oriented to provide seals and help to direct fluid through the filter assembly 30. Specifically, the construction 38 forms a first seal 40 between the first filter member 32 and the housing 36. The construction 38 forms a second seal 42 between the second filter
20 member 34 and the housing 36.

Further, in preferred embodiments, the construction 38 helps to direct fluid flow through the filter assembly 30. For example, the construction 38 helps to direct fluid from a clean side 46 of the first filter member 32 through a first outlet port arrangement 48. The first seal 40 prevents unclean fluid from passing through the
25 first outlet port arrangement 48 without first passing through the filter media in the first filter member 32 and then reaching a clean side 46 of the first filter member 32. Similarly, the construction 38 helps to direct fluid from a clean side 50 of the second filter member 34 through the first outlet port arrangement 48. The second seal 42 helps to ensure that only fluid from the clean side 50 of the second filter member 34
30 will flow through the outlet port arrangement 48.

In the specific embodiment illustrated, the construction 38 is an end cap construction 54. Details about specific, preferred end cap constructions 54 are described in further detail below.

Still in reference to FIG. 3, the housing construction 36 depicted includes the
35 housing body 39 and the removable service or access cover 100. The housing body 39 includes a surrounding wall 64, and may be an integral part of a transmission casing. The housing body 39 includes a first inlet port arrangement 58, and a second inlet port arrangement 60. The first inlet port arrangement 58, in the embodiment

shown, includes a pair of inlets 61, 62 defined by wall 64 of the housing body 39. Inlets 61, 62 are arranged to be in fluid flow communication with the first filter member 32. In this example, the inlets 61, 62 are arranged to be in fluid communication with an unfiltered volume 66 of the first filter member 32. Of course, operation through the first filter member 32 could be reversed, in which case the inlets 61, 62 would be outlets and the unfiltered volume 66 would be the clean side 46. The inlets 61, 62 are fluidly isolated from the second filter member 34 by the existence of both the first seal 40 and the second seal 42. The second inlet port 60 is depicted in this embodiment as an opening 68 in the sleeve 37. The opening 68 is in fluid communication with an unfiltered volume 70 of the second filter member 34. The opening 68 is fluidly isolated from the outlet port arrangement 48 by the second seal 42.

In example implementations, the inlets 61, 62, and outlet port arrangement 48 will be connected or secured to appropriately sized fittings for the conveyance of the fluid. In the example shown, the sleeve 37 defining the inlet opening 68 may be submerged within a tank containing the fluid to be filtered. For example, the sleeve 37 defining the opening 68 can be submerged within hydraulic oil in a gear box of the tractor 28.

Also depicted in FIGS. 3 and 4, the preferred first filter member 32 includes a first bypass valve assembly 72. Similarly, the second filter member 34 includes a second bypass valve assembly 74. If the first filter member 32 becomes clogged and the restriction across the first filter member increases over a predetermined level, the first bypass valve assembly 72 will allow the fluid to flow into the clean side 46 without passing through filter media 76. In the embodiment shown in FIG. 4, the first bypass valve assembly 72 includes a screen 78 to provide some level of filtering of the fluid. The second bypass valve assembly 74 operates in a similar fashion. If the second filter member 34 becomes clogged such that restriction rises above a predetermined level, the fluid will be allowed to bypass the filter media 80 and flow into the clean side 50. The fluid flows through a screen 82 to provide some level of filtering before the fluid reaches the clean side 50. Further details about the first bypass valve assembly 72 and second bypass valve assembly 74 are discussed below.

General operation of the filter assembly 30 is now described. Fluid, such as hydraulic fluid from a portion of the system 22, such as from the ICV assembly flows through inlet 61 and inlet 62. From there, the fluid flows into the unfiltered liquid volume 66. The fluid then flows through the filter media 76 and into the clean side 46. From there, the fluid flows through the end cap construction 54 and exits the housing 36 through the first outlet port arrangement 48. From there, the fluid is

directed to other components of the system, such as a flow control valve. The second filter member 34 can act as a suction filter. When it operates as a suction filter, a component in the system 22, such as a pump, creates suction or a vacuum pressure through the first outlet port arrangement 48 and draws fluid through the opening 68. For example, if the opening 68 is submerged in a gear box, hydraulic oil will be drawn into the second filter member 34 by drawing it from the unfiltered liquid volume 70, through the filter media 80, and to the clean side 50. The clean fluid then flows through the outlet port arrangement 48 where it is conveyed to downstream components, such as a pump.

With the above, general structure and operating principles in mind, we return now to description of the specific embodiment depicted. In FIG. 1, the filter element arrangement is depicted in perspective at 84. The filter element arrangement 84 includes the first filter member 32 and second filter member 34. In certain example applications, the first filter member 32 can also be referred to as a return line filter 86, while second filter member 34 can be referred to as a suction filter 88.

As can be seen in FIG. 4, in the preferred embodiment, the first filter member 32 and the second filter member 34 are arranged to be stacked, one next to the other. For example, the first axial end 96 of the first filter member 32 is adjacent to the second end 134 of the second filter member 34. In preferred arrangements, the first filter member 32 and the second filter member 34 each defines a longitudinal axis 77, 79. The longitudinal axes will be at least parallel, and in this embodiment, non-colinear. By the term "non-colinear", it is meant that the longitudinal axis 77 of the first filter member 32 and the axis 79 of the second filter member 34 will not be common or uniform, but they will be parallel and co-planar. In other embodiments, the filter members can be co-linear.

In reference now to FIG. 4, the first filter member 32 includes a first tubular construction 90 of filter media 76. The first tubular construction 90 is shaped in a tube and has an interior volume 92. The interior volume 92, in this example, corresponds to the clean side 46 of the first filter member 32. In typical embodiments, the first tubular construction 90 will be cylindrical in shape. The filter media 76 can be many different types of media, and in the example shown, is pleated media 94. The first tubular construction 90 has a first end 96 and an opposite, second end 98. In the embodiment shown in FIG. 1, the second end 98 is adjacent to the removable service or access cover 100, while the first end 96 is adjacent to the second filter member 34.

In the embodiment shown, the pleated media 94 is secured to the end cap construction 54 at the first end 96. The first filter member 32 depicted further includes a first tubular construction end cap 102. The first tubular construction end

cap 102 is secured to the second end 98 of the filter media 76. In preferred embodiments, the pleated media 94 is potted within the first tubular end cap 102 and the end cap construction 54.

5 The first tubular end cap 102 defines an aperture 104 in selective fluid communication with the interior volume 92. Specifically, the aperture 104 is in fluid communication with the first bypass valve assembly 72. When pressure causes the bypass valve assembly 72 to open, fluid is allowed to flow from the aperture 104, through the first bypass valve assembly 72, and into the interior volume 92. Further description of the first bypass valve assembly 72 is discussed below.

10 In reference to FIG. 1, the first tubular end cap 102 further includes an end piece 106 projecting axially therefrom. The end piece 106, in the embodiment shown, includes a ring member 108 axially spaced from a remaining portion of the end cap 102. A plurality of vanes 110 extends between the ring member 108 and the remaining portion of the end cap 102. The ring member 108 can be used as a handle
15 112 for the operator to grasp when servicing the filter assembly 30.

 The first tubular end cap 102 defines a planar portion 103 covering the second end 98. The aperture 104 is defined by the planar portion 103 and is in communication with the first bypass valve 72. The end piece 106 projects axially from the planar portion 103.

20 In the embodiment shown, the first tubular end cap 102 further defines a baffle 107. The baffle 107 helps to direct liquid flow that enters through the inlet ports 61, 62. In the embodiment shown, the baffle 107 extends axially from the planar portion 103 along the filter media 76. Specifically, in the embodiment shown, the baffle 107 surrounds or circumscribes an outer periphery of the filter
25 media 76 at a location adjacent to the second end 98 of the first filter member 32. In the embodiment shown, the baffle 107 is integral with and is a same piece of material as a remaining portion of the first tubular end cap 102. As shown, the baffle 102 extends less than one-third of a total length of the first filter member 32, typically less than 25% and greater than 5% of the length of the first filter member
30 32. As used herein, the length of the first filter member 32 is defined as the distance between the first end 96 and the second end 98. In FIG. 3, the baffle 107 can be seen aligned with the inlet ports 61, 62. In use, liquid entering the housing 36 through the inlet ports 61 and 62 will be deflected by the baffle 107 to other portions of the first filter member 32. Without the baffle 107, the liquid entering the ports 61
35 and 62 could flow directly into the region of media adjacent to the ports 61 and 62 and wear out that section of media before the rest of the media 76 were used.

 In reference again to FIG. 4, in the preferred embodiment illustrated, the first filter member 32 further includes an inner liner or filter support 114. The inner

support 114 is perforated to allow for the passage of fluid therethrough to reach the interior volume 92. In the embodiment shown, the inner support 114 extends between and is potted within the first tubular construction end cap 102 and the end cap construction 54. The inner support 114 helps provide support to the pleated media 94 to prevent it from collapsing from fluid pressures.

The first bypass valve assembly 72 can be seen oriented within the interior of the filter media 76. The bypass valve assembly 72 can be one of many conventional types of bypass valves. In the one shown in FIG. 4, the bypass valve assembly 72 includes a spring 116 and a valve head 118. The valve head 118 is biased to sit against a valve seat 120. The interface of the valve head 118 and valve seat 120 operates to block unfiltered liquid from reaching the clean side 46, unless the filter media 76 is occluded. If the filter media 76 is clogged, or occluded, or restriction across the filter media 76 reaches a level higher than a predetermined amount, the pressure on the fluid will overcome the force of the spring 116 and move the valve head 116 away from the valve seat 120. When this happens, fluid will be allowed to pass through the gap or opening created between the valve head 118 and valve seat 120. The fluid will then allow to flow into volume 122. Volume 122 is a volume defined by the interior of the tubular screen 78. The fluid then flows from volume 122 through the screen 78 and into the clean side 46. The screen 78 allows for a coarse degree of filtering of the fluid.

Before the details on the end cap construction 54 and how they relate to the first filter member 32 are discussed, details of the second filter member 34 are now discussed.

The second filter member 34 generally includes a second tubular construction 126 of filter media 80. The second tubular construction 126 is in a tubular shape defining an interior volume 128. The interior volume 128 corresponds to the clean side 50 of the second filter member 34. In preferred embodiments, the tubular construction 126 is cylindrical. A variety of different types of filter media 80 is useable. In the embodiment shown, pleated filter media 130 is depicted.

Referring to FIG. 4, the second tubular construction 126 has a first end 132 and the opposite, second end 134. In the embodiment shown, the second end 134 is adjacent to the first filter member 32, while the first end 132 is adjacent to an end 136 of the housing 36 (FIG. 3). Secured to the first end 132 is a second tubular construction end cap 138. The pleated media 130, in the embodiment depicted, is secured and extends between the second tubular construction end cap 138 and the end cap construction 54. In preferred embodiments, the pleated media 130 is potted within the second tubular construction end cap 138 and the end cap construction 54.

The second tubular construction end cap 138 defines a planar portion 123 axially covering the first end 132 of the filter media 80 of the second tubular construction 126. Also defined by the end cap 138 is an aperture 125 in communication with the second bypass valve assembly 74. In the specific
5 embodiment shown, there is also an end flange arrangement 127.

The end flange arrangement 127 allows the filter element arrangement 84 to be stood upright on the end flange arrangement 127 during manufacturing. In preferred implementations, it is also part of an anti-drain valve assembly, to be described further below. In the embodiment shown, the end flange arrangement 127
10 includes a plurality of protrusions 129 extending from the planar portion 123.

Also extending between the second tubular construction end cap 138 and the end cap construction 54 is a second inner support 140. The inner support 140 is perforated to allow fluid flow therethrough. The inner support 140 helps to support or hold the pleated media 130 to prevent it from collapsing due to fluid pressure.
15

The second bypass valve assembly 74 can be any type of conventional bypass valve arrangement. The one depicted in FIG. 3 includes a spring 142, a valve head 144, and a valve seat 146. When the filter media 80 becomes clogged or occluded, or for any other reason causing the restriction to rise, when the fluid pressure on the valve 144 exceeds the force of the spring 142, the valve head 144
20 will move away from the valve seat. This will allow fluid to flow through the second bypass valve assembly 74 and into volume 148. Volume 148 is the volume that is bordered by the screen 82. In the embodiment shown, the screen 82 is tubular. The fluid will flow into the volume 148 and then through the screen 82 to reach the clean side 50.

General operation of the filter assembly will now be described, followed by a description of the end cap construction 54. Return flow enters the transmission housing 36 through inlet ports 61, 62. In the example system described, this fluid would be returning from the ICV assembly. Liquid travels through the ports 61, 62, into the volume 66, through the filter media 76 and inner filter support 114 and
30 enters the interior volume 46. When the pressure differential across the filter media 76 is great enough, such as when the filter 32 becomes plugged or during a cold-start condition, the bypass valve assembly 72 opens to allow liquid to flow from the volume 66 and through the bypass valve assembly 72. The liquid then passes through the screen 78 and to the interior volume 46. Once the flow is in the interior
35 volume 46, it travels to the end cap construction 54, and exits through outlet 48 would be used by a transmission lubrication circuit.

A reverse flow check valve 230 is provided to minimize back flushing of the second filter member 34. When there is a surge flow coming from, for example, the

ICV assembly, through the return ports 61, 62, the liquid can go across the filter media 76 or across the bypass valve assembly 72 to reach the interior volume 46. Excess flow will then travel to the outlet port 48. If the flow at the outlet port 48 is greater than the flow demanded by downstream equipment (such as pumps), the pressure created by the excess flow will cause the reverse flow check valve 230 to open, and the liquid will return through the inlet port 60 back to the gear box. The reverse flow check valve 230 will help to decrease the amount of flow that travels in a reverse direction (inside to outside) through the filter media 80 of the second filter member 34. If there is no excess flow, the reverse flow check valve 230 will stay closed to prevent unfiltered flow from the gear box from traveling through the outlet port 48 to downstream equipment (such as a pump).

With the above general operating principles in mind, a description of an example embodiment of the end cap construction 54 is provided. In the embodiment shown, the end cap construction 54 is divided into two sub-assemblies, including a first end cap construction 151 and a second end cap construction 152. Details on the end cap construction 54 are discussed further below.

In reference now to FIGS. 5 - 7, one example of the first end cap construction 151 is illustrated in perspective view. In the illustrated embodiment, the first end cap construction 151 has a first cap 150. The first cap 150 is used for, in the illustrated embodiment, securing to the first filter member 32 and forming a seal 40 (FIG. 3) between the first filter member 32 and the housing construction 36. Analogously, the end cap construction 54 includes, as part of the second end cap construction 152, a second cap 154 (FIGS. 1 and 4). In the embodiment illustrated in FIG. 1, the second cap 154 is for connecting to the second filter member 34 and for providing seal 42 between the second filter member 34 and the housing 36. In preferred embodiments, the first cap 150 is secured to the filter media 76 by potting the media 76 within the first cap 150, while the second cap 154 is secured to the filter media 80 by potting.

Still in reference to FIGS. 5 - 7, in the one illustrated, the first end cap construction 151 includes first and second slotted walls 156, 158. In the embodiment shown, the first slotted wall 156 extends axially from the first cap 150. The second slotted wall 158 extends from the second cap 154, when the first end cap construction 151 and second end cap construction 152 are operably secured together (FIGS. 1 and 4). The way in which the first end cap construction 151 and second end cap construction 152 are operably secured together is discussed in further detail below. The slotted walls 156, 158 can be formed by a plurality of vanes 159, 160, respectively, extending axially from end caps 150, 154. See FIGS. 5 and 6.

Between the first slotted wall 156 and the second slotted wall 158 is a wall structure 162. In this embodiment, the wall structure 162 is a solid ring 164 defining an open aperture 166. Wall structure 162 connects the first slotted wall 156 and the second slotted wall 158. In this embodiment, the wall structure 162 does not form a seal with the housing 36. Liquid can regularly flow from the clean side of the first filter member 32 to the clean side of the second filter member 34, and a tight seal is not needed between the two clean liquid volumes 46, 50.

Attention is directed to FIG. 7, in which a cross-sectional view of the first end cap construction 151 is depicted. In the embodiment shown, the first cap 150 is shown as a ring-shaped first tray 168 sized to hold an end of the filter media 76. The first tray 168 has an outer circular wall 170, an inner circular wall 172, and a base 174 which joins the outer wall 170 and inner wall 172. The inner wall 172 defines a first cap aperture 176. The first cap aperture 176 is in fluid communication with the interior volume 46 of the first filter member 32. The aperture 176 is also in fluid communication with the first slotted wall 156. In this manner, the first slotted wall 156 extends axially from the first tray 168 to the wall structure 162. The first slotted wall 156 defines openings, or slots, or fluid apertures 178 (FIGS. 5 and 6) to allow for the flow of fluid from the interior volume 46 of the first filter member 32, through the first cap aperture 176, and then through the slots or holes 178 in the first slotted wall 156.

The first end cap construction 151 also includes a first seal member 180. In the embodiment shown, the first seal member 180 projects from and circumscribes the outer wall 170. In the embodiment shown, the first seal member 180 circumscribes the first tubular construction 90 and is oriented to form the first seal 40 (FIG. 3) between the first filter member 32 and the housing construction 36. In the particular embodiment illustrated, the first seal member 180 is an integral part of the first cap 150 and of the overall first end cap construction 151. In this example, the use of the term "integral part" means that the seal member 180 is molded to be a continuous and same piece of material as the rest of the first end cap construction 151. Of course, the first end cap construction 151 may be made from multiple pieces. In the embodiment shown, the first end cap construction 151 is shown as a single, molded piece made from a same piece of material. In the embodiment shown in FIG. 7, the first seal member 180 is angled relative to the outer wall 170 of the tray 168. The angle illustrated is an acute angle between 2° - 45° , for example 3° - 20° . The first seal member 180 is molded to be thin enough to be flexible to form a lip seal at the first seal 40, but strong enough to hold the seal. The first end cap construction 151 can be molded from plastic, such as nylon.

In reference now to FIGS. 5 - 7, the first end cap construction 151 illustrated further includes a base section 182 arranged normal to the second slotted wall 158. Thus, as can be seen in FIGS. 5 - 7, the second slotted wall 158 extends between the wall structure 162 and the base section 182. The base section 182 is generally ring-shaped defining a base section aperture 184. The base section aperture 184 is circumscribed by a neck 186. The neck 186 projects axially from the base section 182 and, in preferred embodiments, extends into a portion of the second end cap construction 152, described further below. The neck 186 can be part of a projection-pocket arrangement between the second end cap construction 152 and the first end cap construction 151, described further below. Before more details about the projection-pocket arrangement 188 are described, the second end cap construction 152 is first described.

In reference now to FIGS. 1 and 4, the second end cap construction 152 is illustrated. The second end cap construction 152 includes the second cap 154 that is sized to hold the end of the filter media 80 of the second filter member 34. The second cap 154 includes a ring-shaped second tray 190 that has an outer wall 192, an inner wall 194, and a base 196 joining the outer wall 192 and the inner wall 194. The inner wall 194 defines an opening or aperture 197 in fluid communication with the interior volume 50. The aperture 197 can be part of the projection-pocket arrangement 188, in that it receives the neck 186 of the base section 182. In the embodiment shown, the neck 186 includes deflecting hooks 198 (FIG. 6) that catch a ledge 200 lining the aperture 197 to help hold together the first end cap construction 151 and second end cap construction 152. When the first end cap construction 151 and the second end cap construction 152 are operably secured together, liquid is allowed to flow from the clean interior volume 50 of the second filter member 34 and through the channel 202 (FIG. 7) defined by the neck 186 and into the second slotted wall 158. The second slotted wall 158 defines openings or slots 204 which allows the passage of the liquid therethrough and then out of the housing 36 through outlet port 48.

A second seal member 206 projects from and circumscribes the outer wall 192. When the second end cap construction 152 is installed within the housing 36, the second seal member 206 is oriented to form second seal 42 (FIG. 3) between the second filter member 34 and the housing construction 36. The second seal member 206 can be many different geometries. In the embodiment illustrated, the second seal member 206 is an O-ring seal member 208.

In reference to FIGS. 8 and 9, the second cap 154 further includes an outside ring 210 arranged eccentrically relative to the outer wall 192 of the second tray 190. By "eccentric," it is meant that the center point of the aperture 197 of the second tray

190 is different from the center point of the outside ring 210. Oriented between the outer wall 192 of the second tray 190 and the outside ring 210 is a pocket arrangement 212. The pocket arrangement 212 includes at least two pockets 213 defined therein. By the term "pockets", it is meant recesses defined by the second
5 cap 154. In the embodiment shown in FIGS. 8 and 9, there are six pockets 213. The pockets 213 are part of the projection-pocket arrangement 188, which is discussed below.

The outside ring 210 also defines a groove 214 on a radial portion. The groove 214 holds the seal member 206.

10 The projection-pocket arrangement 188 provides axial connection between the second cap 154 and the base section 182. The projection-pocket arrangement 188 includes at least one of the base section 182 and the second cap 154 to include at least one axial projection, while at least one of the base section 182 and the second cap 154 includes at least one pocket to receive the at least one axial projection.

15 While the parts can be reversed and interchanged, in the particular embodiment illustrated, the second cap 154 defines the pockets 213 that are used in the projection-pocket arrangement 188. In FIGS. 5 - 7, the first end cap construction 151, specifically the base section 182, defines the at least one projection 216 that is used in the projection-pocket arrangement 188.

20 Specifically, and in reference to FIGS. 7 - 9, the base section 182 includes at least one projection 216, and in the embodiment illustrated, two projections 216 axially extending from a second filter member engaging surface 218. In the embodiment shown, each projection 216 is wedge-shaped, and is sized to be received within appropriately sized pockets 213 defined by the second cap 154. The
25 projection-pocket arrangement 188 helps to maintain the rotational orientation of the first end cap construction 151 relative to the second end cap construction 152, in view of the first filter member 32 and second filter member 34 being not coaxial. When the two projections 216 are operably received within the two pockets 213, and when the neck 186 is operably received within the aperture 197 of the second tray
30 190, the first end cap construction 151 and the second end cap construction 152 are secured together, ensuring that the first filter member 32 is fully assembled to the second filter member 34.

Preferably, the components of the projection-pocket arrangement 188 are made from glass-filled nylon, which allows the components (the projections 216 and
35 hooks 198 on the neck 186) to deform slightly when the components are assembled together. When the filter assembly 30 is completely assembled, there can be a small amount of rotational movement between the first filter member 32 and second filter member 34. The projections 216 can be designed to be slightly smaller than the

corresponding pockets 213, thereby allowing for some movement. This movement can be desirable in case there is a misalignment between the sleeve 37 around the second filter member 34 and the housing body 39.

As mentioned above, the parts of the projection-pocket arrangement 188 can be reversed. This means that the projections can be on the second cap 154, while the pockets are defined in the base section 182. This also means that the base section 182 can have a combination of pockets and projections, while the second cap 154 similarly has a combination of projections and pockets to mate with the base section 182.

Once again referring to FIGS. 1 and 4, it can be seen that the second cap 154 operably holds the reverse-flow check valve 230. In particular, the reverse-flow check valve 230 is oriented between the outside ring 210 and the outer wall 192 of the second tray 190. The reverse-flow check valve 230 is, in this embodiment, oriented between two of the pockets 213. In FIGS. 5 and 6, it can be seen how the base section 182 defines an open section 232, between the two projections 216, to allow for a portion of the reverse-flow check valve 230 to be positioned. FIGS. 8 and 9 show a seal 234 for the valve 230, located between pockets 213.

The reverse-flow check valve 230 includes, in general, a spring 236, a valve head 238, and a valve seat 234. In the case of a surge flow flowing through the inlet ports 58, 62, the liquid can go across the filter media 76 of the first filter member 32 or across the bypass valve assembly 72 to get to the interior volume 46. Excess flow will then travel to the volume 240. The volume 240 is in fluid flow communication with the open interior volume 50 of the second filter member 34. The liquid will then flow through exit port 48. If, however, the flow at exit port 48 is greater than the flow demanded by downstream equipment (for example, pumps) the pressure created by the excess flow will cause the reverse-flow check valve 230 to open by exerting pressure on the valve head 238. When the pressure on the valve head 238 overcomes the force exerted by the spring 236, the valve head 238 will move away from the valve seat 234 opening a passageway defined by the second cap 154. The liquid flowing through passageway is returned to the liquid container in which the second filter member 34 is resting within (for example, a gear box). If there is no excess flow, then the spring 236 will keep the reverse-flow check valve 230 closed to prevent unfiltered flow from the gear box from traveling into the volume 240 and out of the exit port 48 to downstream equipment, such as pumps.

In accordance with principles of this disclosure, the filter assembly 30 can include an anti-drain valve assembly constructed and arranged to prevent an interior of the housing construction 36 from draining of fluid when the filter element arrangement 84 is removed from the housing construction 36 for servicing. As

embodied herein, and in particular attention to the embodiment shown in FIGS. 10 - 16, an anti-drain valve assembly is illustrated at 250. In FIG. 11, the anti-drain valve assembly 250 illustrated includes a valve member 252 slidably secured along the housing construction 36, specifically, an interior wall 254 of the sleeve 37. The valve member 252 slides along the interior wall 254 to cover and uncover the opening 68 in the second inlet port arrangement 60 (FIG. 3). A biasing member 256 is oriented to urge the valve member 252 into a position covering the second inlet port arrangement 60.

When the filter element arrangement 84 is installed within the sleeve 37, the element 84 pushes against the valve member 252 and against the biasing member 56 to a position shown in FIG. 3. In FIG. 3, the valve member 252 is pushed in a direction toward the end of the housing 136, which exposes the opening 68 in the inlet port arrangement 60. In the embodiment shown in FIG. 11, the biasing member 256 is embodied as a coiled spring 258. In FIG. 3, it can be seen how the protrusions 129 of the end flange arrangement 127 on the second end cap 138 engage the valve member 252 to move the valve member 252 against the biasing member 256 to a position uncovering the second inlet port arrangement 60.

FIGS. 12 - 16 show various views of the valve member 252. In the specific embodiment shown, the valve member 252 includes a bowl 260 defining a center aperture 262. Axially extending from the bowl 260 is a neck 264 circumscribing the aperture 262. The neck provides a seat 266 for the spring 258.

Extending from the bowl 260 in a direction opposite from the neck 264 is a door 268. The door 268 is the portion of the valve member 252 that selectively covers or uncovers the second inlet port arrangement 60. In the embodiment shown, the door 268 includes a tab arrangement 270 oriented to engage an edge 272 (FIG. 3) of the second inlet port arrangement 60 to provide a stop to the valve member 252 relative to the second inlet port arrangement 60. In the specific embodiment illustrated, the tab arrangement 270 includes a pair of tabs 274 radially projecting or extending away from the door 268. Without the tabs 274, when the filter element arrangement 84 is removed from the sleeve 37, the spring would push the valve member 252 in a direction outside of the sleeve 37. Without the tabs 274, there would be nothing trapping the valve member 252 within the sleeve 37. Thus, the tabs 274 limit the travel of the valve member 252 to a position until the tabs 274 engage the edge 272. FIG. 11 shows the valve member 252 in a "closed" position, in which the door 268 is covering the opening 68, and the tabs 274 are biased against the edge 272.

In the particular embodiment shown, also extending from the bowl 260, and spaced from the door 268, is an upright wall 276. The upright wall 276 helps to

provide for a smoother slidable engagement between the valve member 252 and the interior wall 254 of the sleeve 37.

In accordance with principles of this disclosure, the valve member 252 and the housing construction 36 (in this embodiment, the sleeve 37) include a notch and
5 rib arrangement to provide slidable securement of the valve member 252 along the interior wall 254 of the sleeve 37. As embodied herein, a notch and rib arrangement is illustrated at 278 in FIG. 11 to allow the valve member 252 to slide along the interior wall 254 in order to allow the door 268 to expose or cover the opening 68 in the sleeve 37. Specifically, one of the valve member 252 and the sleeve 37 defines a
10 notch, while the other of the valve member 252 and the sleeve 37 defines a rib slidably received by the notch. In the specific embodiment shown, the sleeve 37 defines rib 280, while the valve member 252 defines at least one notch 282 to slidably receive the rib 280. In the particular embodiment illustrated, the valve member 252 includes a pair of notches 282. The notches 282 receive a pair of ribs
15 280 in the sleeve 37. The notch and rib arrangement 278 allows slidable engagement between the valve member 252 and the sleeve 37, without the valve member 252 moving rotationally within the sleeve 37. This alignment of the notch and rib arrangement 278 ensures that the door 268 will remain in a position to allow it to either selectively cover or uncover the opening 68 in the second inlet
20 arrangement 60.

In use, when the filter element arrangement 84 is removed from the sleeve 37 for servicing, the spring 258 biases the valve member 252 toward an open end 284 (FIG. 11) of the sleeve 37. Travel of the valve member 252 is stopped by
engagement between the tabs 274 and the edge 272 of the opening 68. The door 268
25 then covers the opening 68, which prevents liquid from the gear box or reservoir from draining into the sleeve 37 and out of the housing body 39 when the access cover 100 is removed and the filter element arrangement 84 is removed.

A method of servicing is now described. To service the filter assembly 30, first, the access cover 100 is removed from the housing body 39. The connection
30 between the access cover 100 and the housing body 39 can be through a variety of mechanisms, and in the example shown, it is a threaded connection 286 with a seal 288 between the cover 100 and body 39. In this embodiment, the access cover 100 is unscrewed from the housing 36 and is completely removed from the housing 36 and then set aside. The service provider then reaches into the housing 36 and grasps
35 the filter element arrangement 84 at the handle 112. The filter element arrangement 84 is then removed from the housing 36 by pulling axially from the housing 36 through the opening exposed by the access cover 100. In doing so, the seal 40 and seal 42 are released. By removing the filter element arrangement 84, both the first

filter member 32 and the second filter member 34 are removed together, along with the end cap construction 54 joining the first filter member 32 and second filter member 34. Also removed with the filter member 32 and filter member 34 are the bypass valve assemblies 72 and 74, as well as the reverse-flow check valve 230.

- 5 The old filter element arrangement 84 is then disposed of. In many preferred arrangements, the filter element arrangement 84 comprises non-metallic parts, which are readily incinerateable.

When the filter element arrangement 84 is removed, the spring 258 pushes against the valve member 252 to cause the valve member 252 to slide along the
10 interior wall 254 of the sleeve 37 until the tabs 274 engage the edge 272 of the second inlet port 60. Specifically, the notches 282 in the valve member 252 slides along the ribs 280 in the sleeve 37 until the door 268 closes the opening 68. This prevents liquid from the gear box or reservoir from draining into the sleeve 37 and out of the housing body 39 when the access cover 100 and the filter element
15 arrangement 84 is removed.

Next, a new filter element arrangement 84 is provided. The new filter element arrangement 84 is inserted axially into the opening of the housing 36, until the seals 40 and 42 are in place. When inserting the filter element arrangement 84 into the sleeve 37, the second inlet port arrangement 60 is opened because the valve
20 member 252 is urged in a direction toward the end 136 of the sleeve 37. Specifically, the protrusions 129 of the end flange arrangement 127 push against a flange engagement surface 288 in the bowl 260 of the valve member 252. This causes the door 268 to uncover or expose the opening 68 in the second inlet port arrangement 60. The valve member 252 is held in place in the open position when
25 the cover 100 is secured to the housing 36. In this embodiment, the access cover 100 is threaded in place to be secured to the housing 36. The filter assembly 30 is again ready for filtering operations.

CLAIMS:

1. A filter element arrangement comprising:
- 5 (a) a first tubular construction of filter media defining a first end, a second opposite end, and an interior volume;
- (b) a second tubular construction of filter media defining a second tubular construction first end, a second tubular construction second end, and a second tubular construction interior volume;
- 10 (c) an endcap construction between the first tubular construction and the second tubular construction; the endcap construction including:
- (i) a first cap defining an aperture secured to the first tubular construction first end;
- (A) the first cap aperture being in fluid communication with the first tubular construction interior volume;
- 15 (ii) a second cap defining an aperture secured to the second tubular construction second end;
- (A) the second cap aperture being in fluid communication with the second tubular construction interior volume;
- (iii) a first, slotted wall extending axially from the first cap;
- 20 (A) the first slotted wall defining an interior in fluid communication with the first tubular construction interior volume;
- (iv) a second, slotted wall extending axially from the second cap;
- (A) the second slotted wall defining an interior in fluid communication with the second tubular construction interior volume; and
- 25 (v) a wall structure connecting the first slotted wall and the second slotted wall.
- 30 2. A filter element arrangement according to claim 1 wherein:
- (a) the first tubular construction of filter media defines a first longitudinal axis; and
- (b) the second tubular construction of filter media defines a second longitudinal axis;
- 35 (i) the first longitudinal axis and the second longitudinal axis being one of generally parallel or co-linear.

3. A filter element arrangement according to claim 1 further comprising:
- (a) a first seal member circumscribing the first tubular construction first end oriented to form a seal with a filter housing, when the filter element arrangement is operably installed in a filter housing; and
- 5 (b) a second seal member circumscribing the second tubular construction second end oriented to form a seal with a filter housing, when the filter element arrangement is operably installed in a filter housing.
4. A filter element arrangement according to claim 3 wherein:
- 10 (a) the first seal member is an integral part of the first cap of the endcap construction; and
- (b) the second seal member comprises an O-ring secured to the second cap of the endcap construction.
- 15 5. A filter element arrangement according to claim 4 further including:
- (a) a first bypass valve assembly and screen arrangement oriented in the interior volume of the first tubular construction of filter media; and
- (b) a second bypass valve assembly and screen arrangement oriented in the interior volume of the second tubular construction of filter media.
- 20 6. A filter element arrangement according to claim 4 further including
- (a) a first tubular construction endcap secured to the second end of the filter media of the first tubular construction; and
- (b) a second tubular construction endcap secured to the first end of the filter media of the second tubular construction.
- 25 7. A filter element arrangement according to claim 6 wherein:
- (a) the first tubular construction endcap defines: a planar portion axially covering the second end of the filter media of the first tubular construction; an aperture in communication with the first bypass valve assembly; and an end piece projecting axially from the planar portion; and
- 30 (b) the second tubular construction endcap defines: a planar portion axially covering the first end of the filter media of the second tubular construction; an aperture in communication with the second bypass valve assembly; and an end flange arrangement projecting axially from the second tubular construction endcap planar portion.
- 35

8. A filter element arrangement according to claim 7 wherein:
- (a) the end piece projecting axially from the planar portion includes:
 - (i) a ring member axially spaced from the first tubular construction endcap planar portion; and
 - 5 (ii) a plurality of vanes extending between the first tubular construction endcap planar portion and the ring member.
9. A filter element arrangement according to claim 7 further including:
- (a) a first inner support extending between the first tubular construction endcap and the first cap; and
 - 10 (b) a second inner support extending between the second tubular construction endcap and the second cap.
10. A filter element arrangement according to claim 9 further comprising:
- 15 (a) a check valve assembly oriented in communication with the second tubular construction of filter media.
11. A filter element arrangement according to claim 1 wherein:
- (a) the first tubular construction of filter media defines a first longitudinal axis; and
 - 20 (b) the second tubular construction of filter media defines a second longitudinal axis;
 - (i) the first longitudinal axis and the second longitudinal axis are parallel and not co-linear.
- 25
12. A filter element arrangement according to claim 11 wherein:
- (a) the endcap construction first cap includes:
 - (i) a ring-shaped first tray sized to hold the first end of the first tubular construction of filter media;
 - 30 (A) the first tray having an outer wall, an inner wall, and a base joining the outer wall and inner wall;
 - (ii) a first seal member projecting from and circumscribing the outer wall of the first tray;
 - (b) the endcap construction second cap includes:
 - 35 (i) a ring-shaped second tray sized to hold the second end of the second tubular construction of filter media;
 - (A) the second tray having an outer wall, an inner wall, and a base joining the outer wall and inner wall;

- (ii) an outside ring arranged eccentrically relative to the outer wall of the second tray;
 - (iii) a second seal member circumscribing the outside ring;
 - 5 (c) the endcap construction first slotted wall extends axially from the first tray to the wall structure;
 - (d) the endcap construction second slotted wall extends axially from the wall structure to the second tray;
 - (e) the endcap construction further including a base section arranged normal to the second slotted wall;
 - 10 (i) the base section and the second cap including a projection-pocket arrangement to provide axial connection between the second cap and the base section; and
 - (A) the projection-pocket arrangement including:
 - 15 (1) at least one of the base section and the second cap including at least one axial projection;
 - (2) at least one of the base section and the second cap including at least one pocket to receive the at least one axial projection;
 - 20 (3) the second cap defining the projection-pocket arrangement between the outer wall of the second tray and the outside ring;
 - (f) the wall structure is arranged normal to the first slotted wall and second slotted wall; the wall structure being disc-shaped.
- 25 13. A filter element arrangement according to claim 11 wherein:
- (a) the endcap construction further includes a base section arranged normal to the second slotted wall; and
 - (b) the base section and the second cap include a projection-pocket arrangement to provide axial connection between the second cap and
 - 30 the base section.
14. A filter element arrangement according to claim 13 wherein:
- (a) the projection-pocket arrangement includes:
 - 35 (i) at least one of the base section and the second cap including at least one axial projection;
 - (ii) at least one of the base section and the second cap including at least one pocket to receive the at least one axial projection.

15. A filter element arrangement according to claim 14 wherein:
- (a) the projection-pocket arrangement includes:
 - (i) at least two projections extending axially from the base section; and
 - 5 (ii) at least two pockets defined by the second cap and sized to receive the at least two projections.
16. A filter element arrangement according to claim 15 wherein:
- (a) the endcap construction second cap includes:
 - 10 (i) a ring-shaped second tray sized to hold the second end of the second tubular construction of filter media;
 - (A) the second tray having an outer wall, an inner wall, and a base joining the outer wall and inner wall;
 - (1) the inner wall defining an aperture;
 - 15 (ii) an outside ring arranged eccentrically relative to the outer wall of the second tray;
 - (A) the at least two pockets being defined between the outer wall of the second tray and the outside ring; and
 - (b) the base section further includes an axially projecting hoop that
20 extends into the aperture of the inner wall of the second tray.
17. A filter element arrangement according to claim 11 wherein:
- (a) the endcap construction second cap includes:
 - 25 (i) a ring-shaped second tray sized to hold the second end of the second tubular construction of filter media;
 - (A) the second tray having an outer wall, an inner wall, and a base joining the outer wall and inner wall;
 - (ii) an outside ring arranged eccentrically relative to the outer wall of the second tray; and
 - 30 (iii) a check valve assembly oriented between the outside ring and the outer wall of the second tray.
18. A filter assembly comprising:
- 35 (a) a housing construction having: a first inlet port arrangement; a second inlet port arrangement; a first outlet port arrangement; an access opening, and a removable cover removably mounted over the access opening; and

- (b) a filter element operably mounted in the housing construction; the filter element including:
- (i) a first tubular filter member in fluid communication with the first inlet port arrangement and first outlet port arrangement;
 - 5 (ii) a second tubular filter member in fluid communication with the second inlet port arrangement and first outlet port arrangement;
 - (iii) an endcap construction securing the first tubular filter member and second tubular filter member together; the endcap construction including:
 - 10 (A) a first cap secured to the first tubular filter member;
 - (1) the first cap forming a first seal between the first tubular filter member and the housing construction;
 - 15 (B) a second cap secured to the second tubular filter member;
 - (1) a second seal being between the second tubular filter member and the housing construction;
 - 20 (C) a first, slotted wall extending axially from the first cap;
 - (1) the first slotted wall being in fluid communication with the first outlet port arrangement;
 - 25 (D) a second, slotted wall extending axially from the second cap;
 - (1) the second slotted wall being in fluid communication with the first outlet port arrangement; and
 - 30 (E) a wall structure connecting the first slotted wall and the second slotted wall.
19. A filter assembly according to claim 18 further comprising:
- (a) a first bypass valve assembly and screen arrangement oriented in an interior volume of the first tubular filter member; and
 - 35 (b) a second bypass valve assembly and screen arrangement oriented an interior volume of the second tubular filter member.

20. A filter assembly according to claim 19 wherein:
(a) the first bypass valve assembly is secured to and is a permanent part of the first tubular filter member.
- 5 21. A filter assembly according to claim 19 further comprising:
(a) the second bypass valve assembly is secured to and is a permanent part of the second tubular filter member.
- 10 22. A filter assembly according to claim 18 wherein:
(a) the endcap construction further includes a base section arranged normal to the second slotted wall;
(i) the base section and the second cap including a projection-pocket arrangement to provide axial connection between the second cap and the base section.
- 15 23. A filter assembly according to claim 18 wherein:
(a) the first tubular construction of filter media defines a first longitudinal axis;
(b) the second tubular construction of filter media defines a second longitudinal axis;
(i) the first longitudinal axis and the second longitudinal axis are parallel and not co-linear;
(c) the endcap construction second cap includes:
(i) a ring-shaped second tray sized to hold the second end of the second tubular construction of filter media;
(A) the second tray having an outer wall, an inner wall, and a base joining the outer wall and inner wall;
(ii) an outside ring arranged eccentrically relative to the outer wall of the second tray; and
(iii) a check valve assembly oriented between the outside ring and the outer wall of the second tray.
- 25 24. A filter assembly according to claim 19 wherein:
(a) the housing construction includes an anti-drain valve assembly constructed and arranged to prevent an interior of the housing construction from draining of fluid when the filter element is removed from the housing construction for servicing.
- 35

25. A filter assembly according to claim 24 wherein:
- (a) the anti-drain valve assembly includes:
- (i) a valve member slidably secured along an interior wall of the housing construction for covering and uncovering the second inlet port arrangement; and
- (ii) a biasing member urging the valve member to a position covering the second inlet port arrangement.
26. A filter assembly according to claim 25 wherein:
- (a) the filter element includes protrusions extending from the second tubular filter element; the protrusions engaging the valve member to move the valve member against the biasing member to a position uncovering the second inlet port arrangement.
27. A filter assembly according to claim 26 wherein:
- (a) the valve member includes a bowl with a door extending from the bowl;
- (i) the door being selectively movable to be in covering or uncovering relation to the second inlet port arrangement;
- (ii) the door including a tab arrangement engaging an edge of the second inlet port arrangement to provide a stop to the valve member relative to the second inlet port arrangement.
28. A filter assembly according to claim 26 wherein:
- (a) the valve member and the housing construction include a notch and rib arrangement to provide slidable securement of the valve member along the interior wall of the housing construction;
- (i) one of the valve member and the housing construction defining a notch while the other of the valve member and the housing construction define a rib slidably received by the notch.
29. A method of servicing a filter assembly; the method comprising:
- (a) removing an access cover from a body of a housing construction;
- (b) pulling a filter element from the body; the filter element including:
- (i) a first filter member and a second filter member secured together by an endcap construction; the endcap construction including:

- 5
- (A) a first cap secured to the first filter member;
 - (B) a second cap secured to the second filter member;
 - (C) a first, slotted wall extending axially from the first cap;
 - (D) a second, slotted wall extending axially from the second cap; and
 - (E) a wall structure connecting the first slotted wall and the second slotted wall.
- 10 30. A method according to claim 29 wherein:
- (a) the step of pulling includes releasing:
 - (i) a first seal between the first cap and the body; and
 - (ii) a second seal between the second cap and the body.
- 15 31. A method according to claim 29 wherein:
- (a) the step of pulling includes closing an anti-drain valve assembly to prevent fluid from flowing into the body.

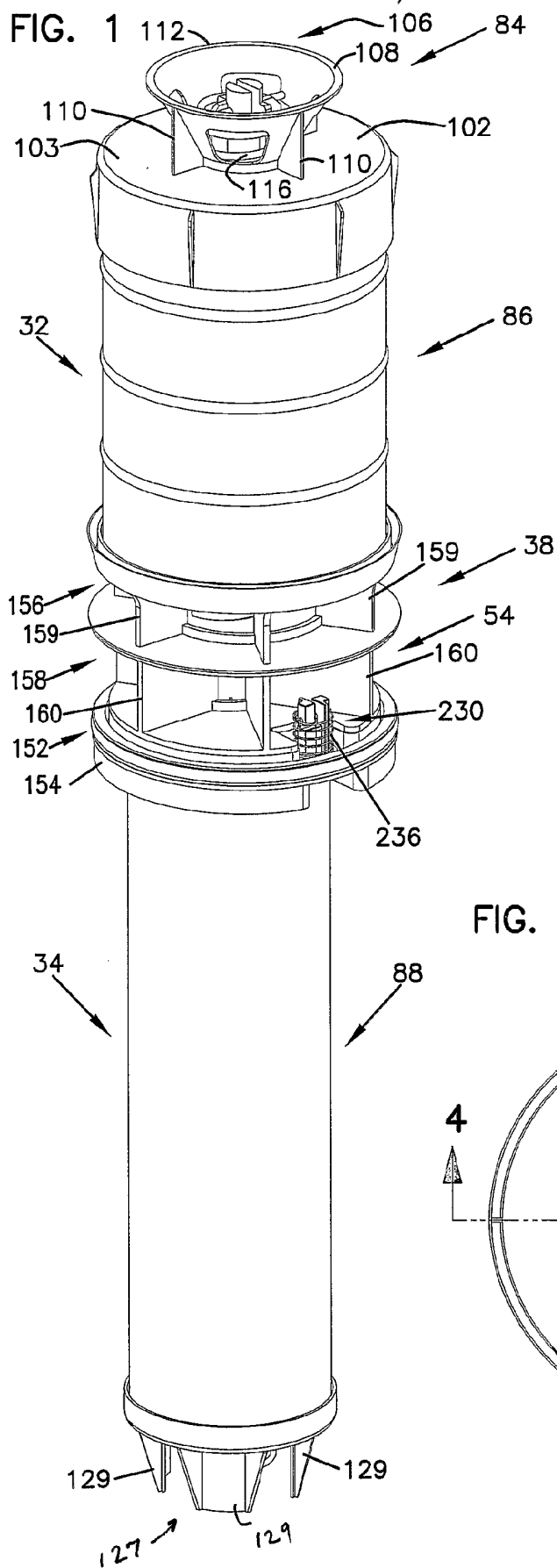


FIG. 2

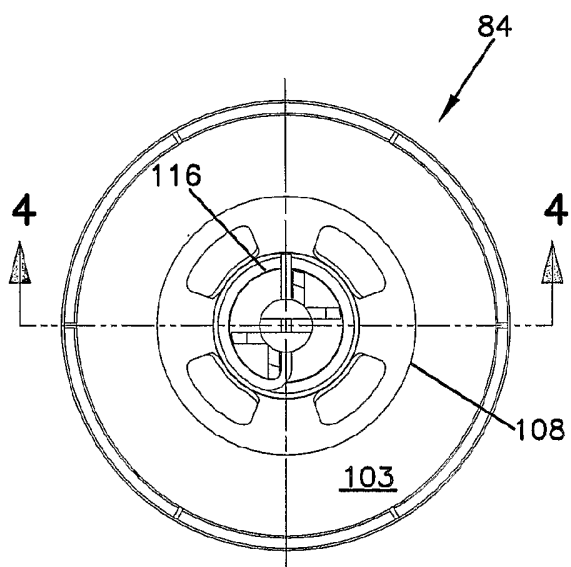


FIG. 3

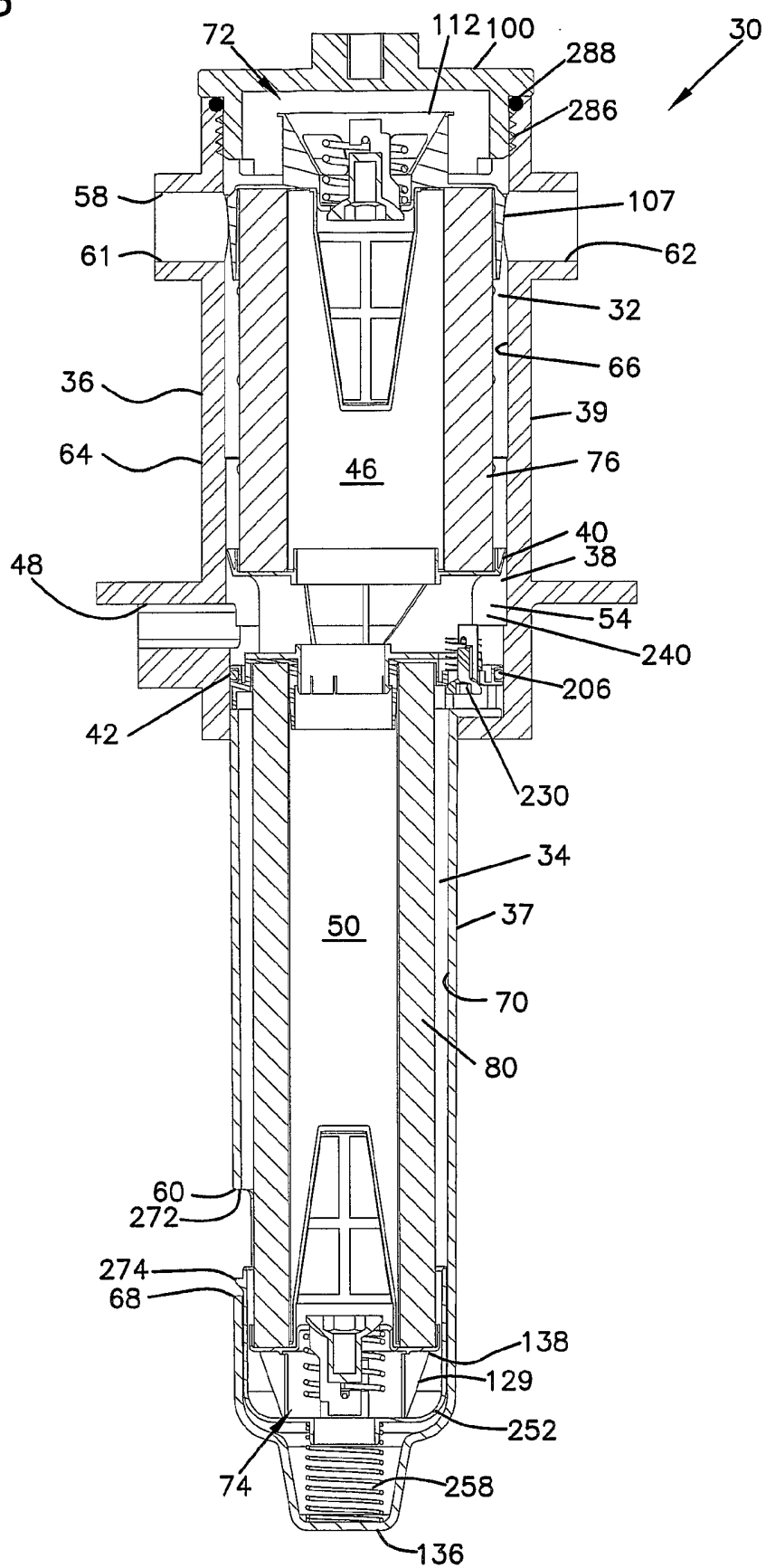


FIG. 4

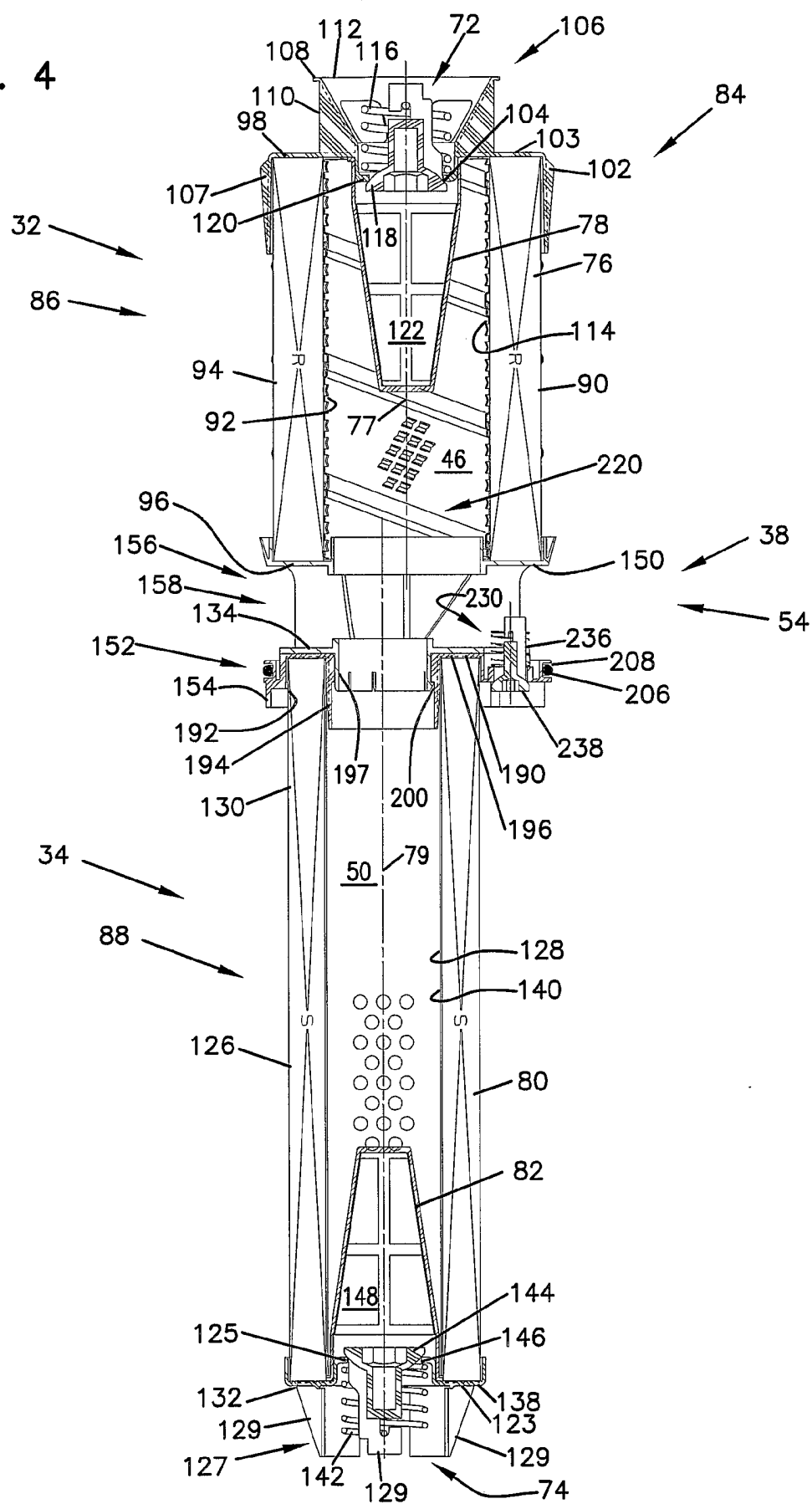


FIG. 5

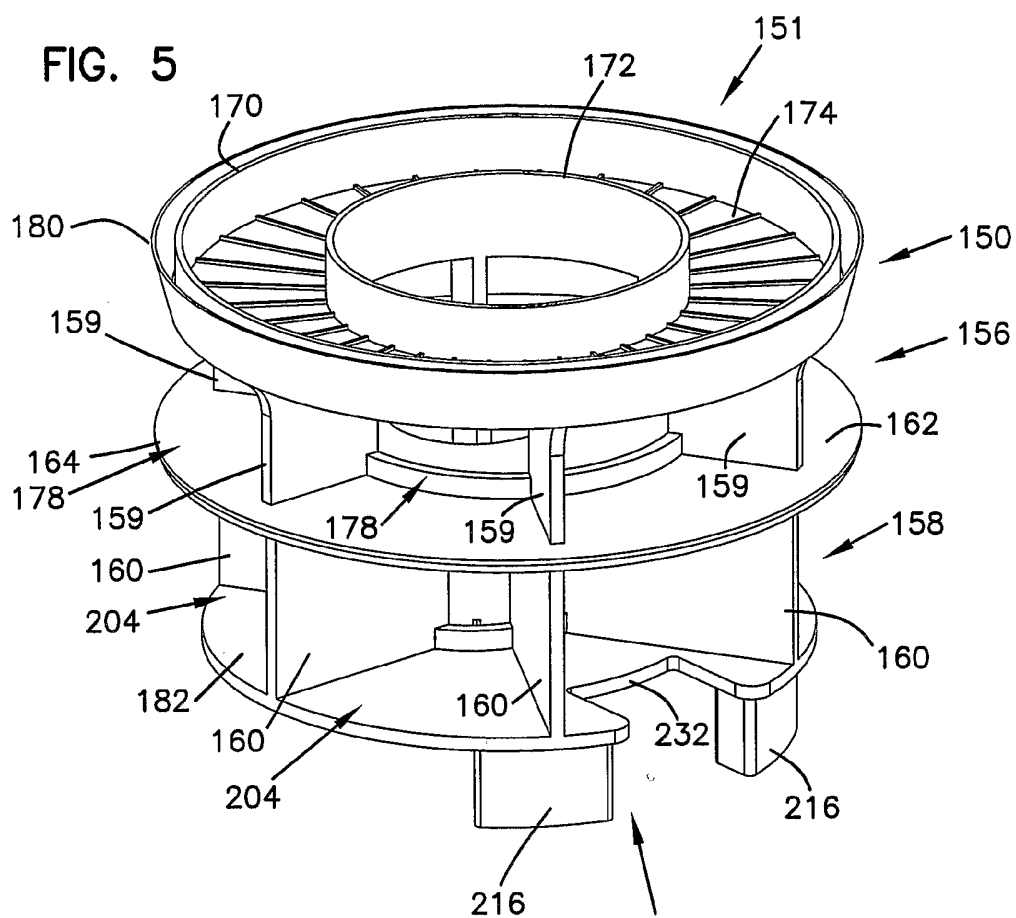


FIG. 6

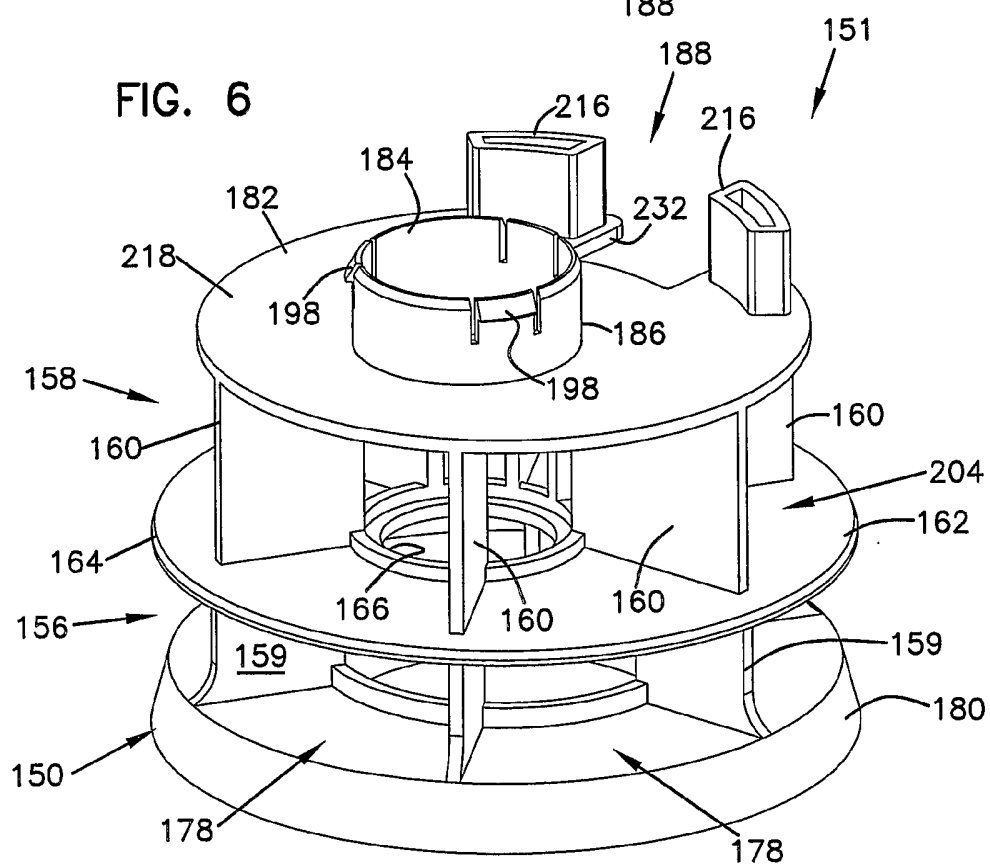


FIG. 7

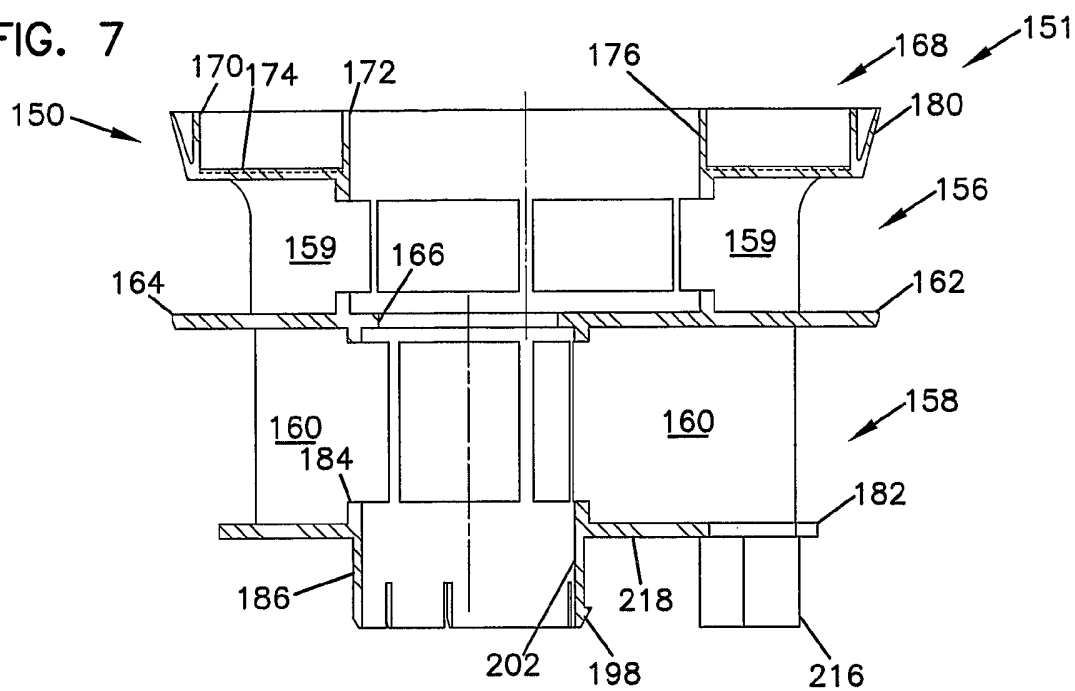


FIG. 8

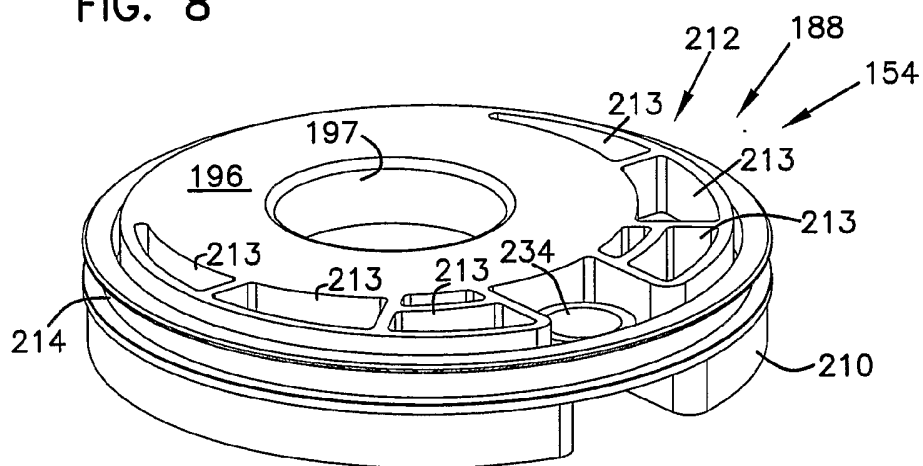
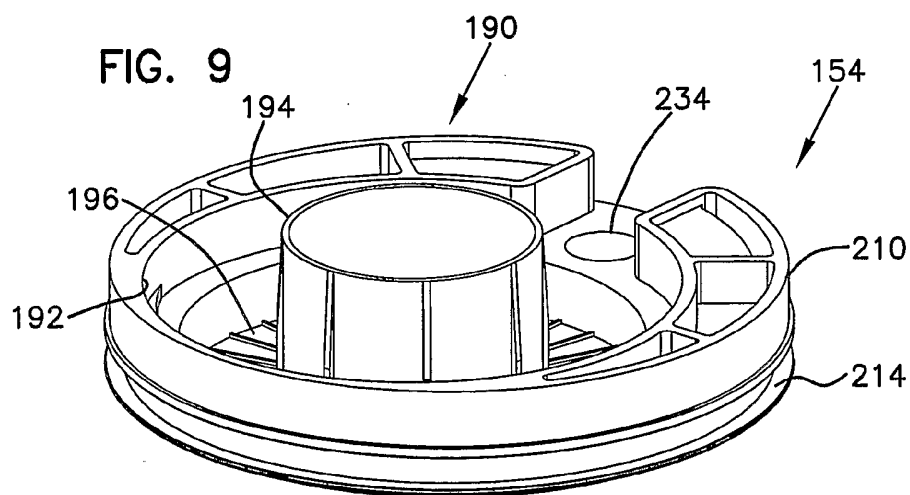


FIG. 9



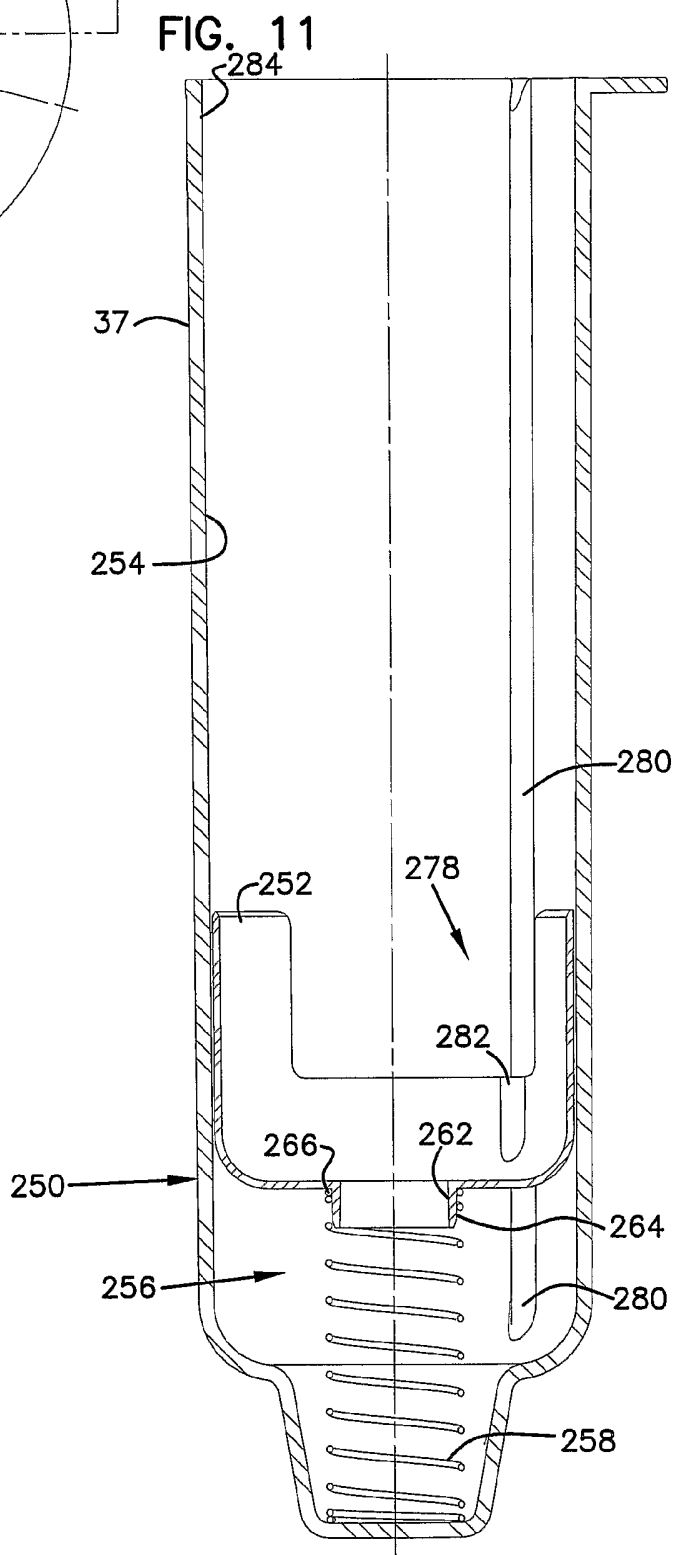
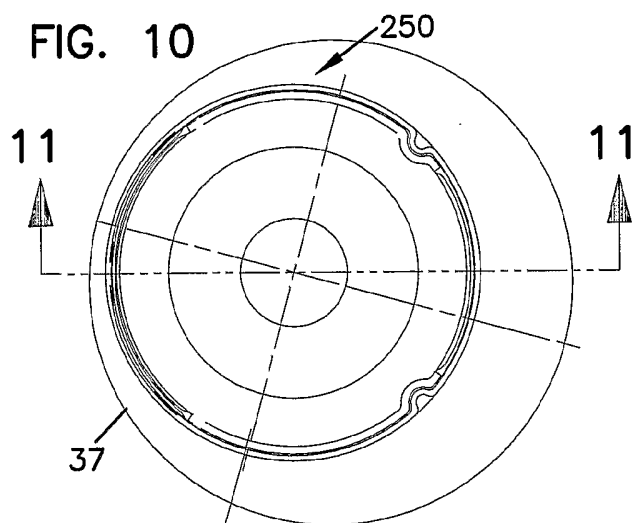


FIG. 12

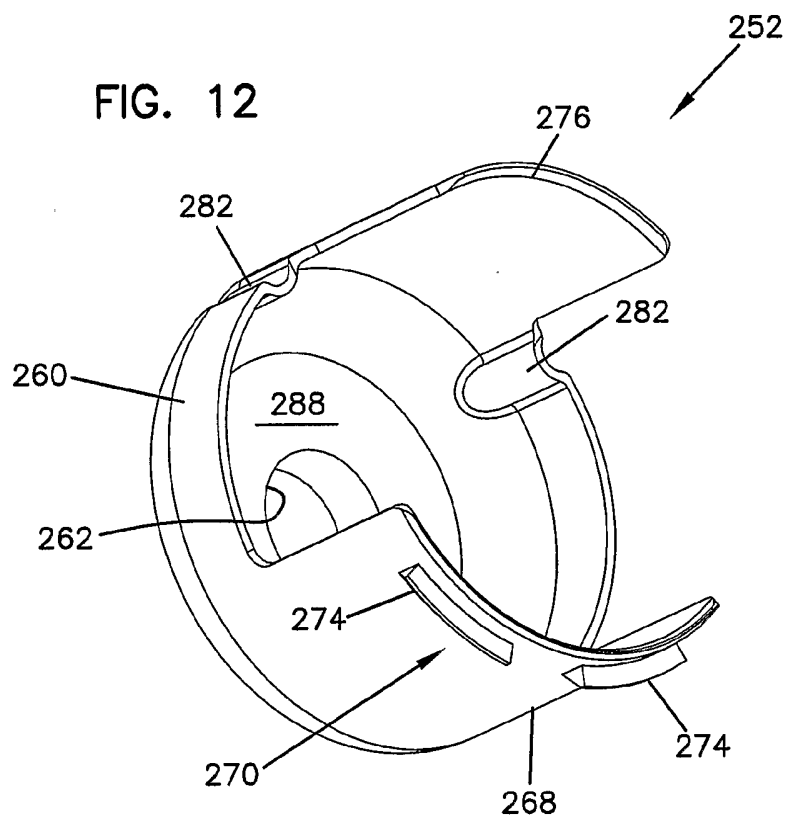


FIG. 13

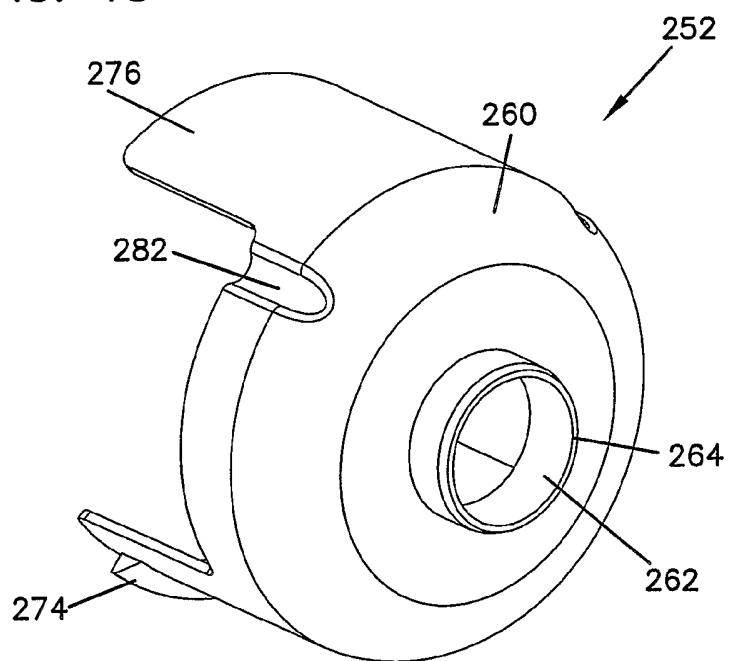


FIG. 14

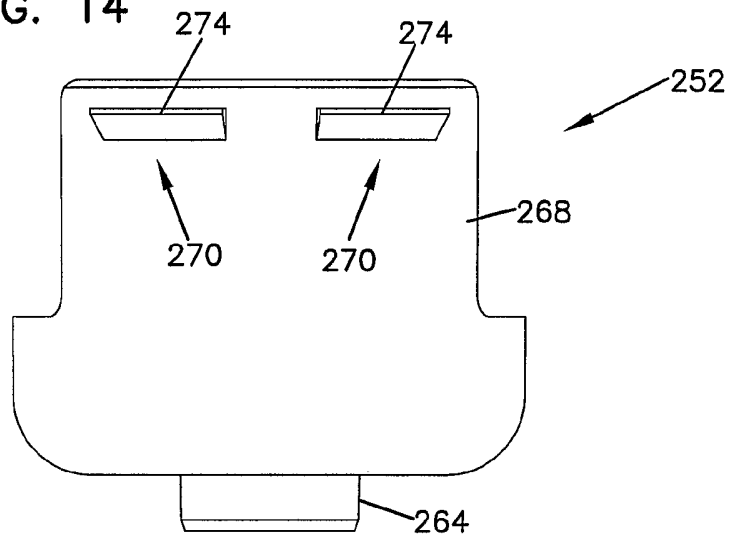


FIG. 15

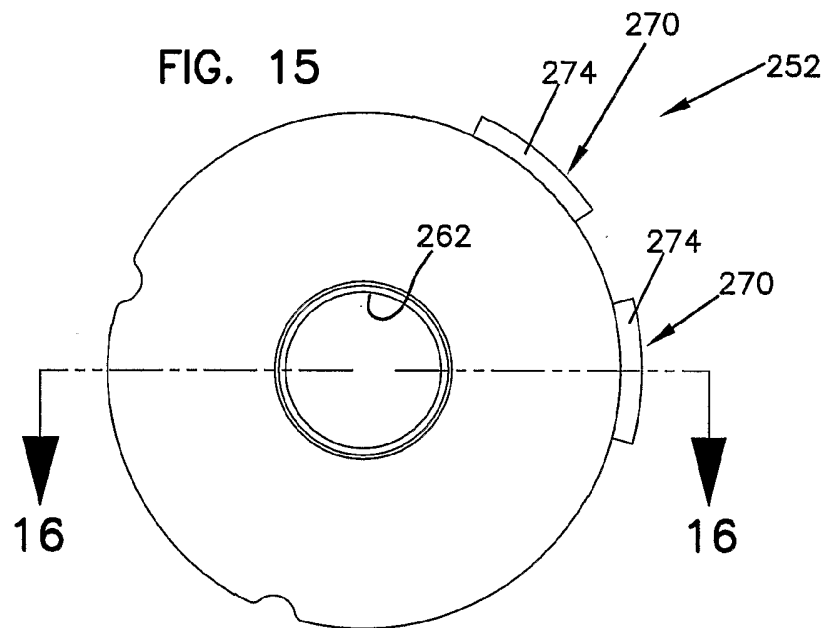
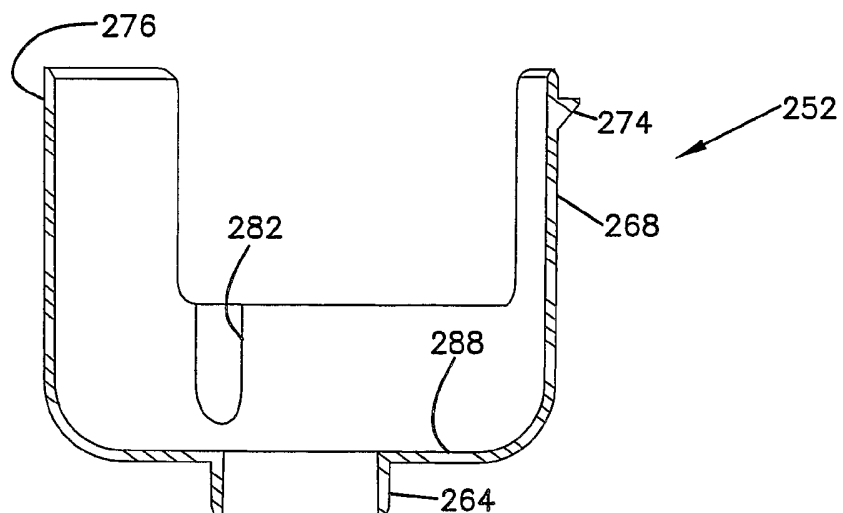


FIG. 16



INTERNATIONAL SEARCH REPORT

PCT/US2005/034139

A. CLASSIFICATION OF SUBJECT MATTER

B01D29/21 B01D35/147 B01D35/153 B01D29/52

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B01D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2 868 383 A (NICOLLS WILFRID EDWARD WALTER) 13 January 1959 (1959-01-13) figure 1	1,2,29
A	US 3 344 923 A (PALL DAVID B ET AL) 3 October 1967 (1967-10-03) figures 1-3	1-31
A	DE 19 55 791 A1 (PUROLATOR FILTER GMBH) 13 May 1971 (1971-05-13) figure 1	1-31
A	US 3 291 307 A (ROSAEN NILS O) 13 December 1966 (1966-12-13) figures 1-3	1-31
A	US 5 723 044 A (GLEASON ET AL) 3 March 1998 (1998-03-03) figure 4	1-31

☐ Further documents are listed in the continuation of box C.☒ Patent family members are listed in annex.

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- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

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