

LIQUID RECOVERY FILTER

BACKGROUND OF THE DISCLOSURE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. Serial No. 13/460,583 filed April 30, 2012, the contents of which are incorporated in their entirety herein by reference.

1. FIELD OF THE DISCLOSURE

[0002] The present disclosure relates generally to filtration devices and systems, and particularly to a liquid recovery filter assembly having an inlet and outlet, vent and purge ports for the drainage and recovery of unfiltered and filtered liquids from the filter housing and enclosed filter after filtering operations.

2. DESCRIPTION OF THE RELATED ART

[0003] Innumerable filtration devices and systems have been developed for the cleaning and purification of a wide range of gases and liquids. One area that requires extremely high quality filtration is in the field of pharmaceutical manufacture, where a number of different liquids are involved in the manufacturing processes of a large number of drugs and medications. These various liquids are often quite costly to produce, and as a result, much effort is expended to recover such liquids in a sterile manner during the manufacturing process, insofar as practicable for reuse.

[0004] One of the means used to recover such liquids is through the use of various filter assemblies. The liquid is passed through the filter assembly(s) and the purified liquid is recovered from the downstream or outlet side of the enclosed filter element. In one type of filter element used, the filter element conventionally has a generally toroidal configuration, the unfiltered liquid passing through the filter element from the outside and through the filter material to a hollow inner core, although other filter element configurations are certainly feasible. One problem with such filter configurations is that when the filter element is replaced, there is a volume

of purified, filtered liquid still resident in the filter element within the filter housing or shell, as well as unfiltered liquid remaining within the filter housing and outside the filter element. These liquids are often quite valuable, as noted further above, and discarding these liquids when the filter element and/or entire filter assembly is periodically removed and replaced results in the loss of a considerable amount of valuable reusable liquid over some period of time.

[0005] One way to remove the resident filtered and unfiltered liquids is to introduce pressurized gas into the system to force the liquids out of the filter assembly. This approach, although effective, is problematic due to the relatively high bubble points of the filter materials used for specific applications, such as pharmaceutical uses. Filter materials with about 0.1 and 0.2 micron pore sizes have relatively high bubble points that require relatively high gas pressures to be used to evacuate the fluids. The introduction of high pressure gas can compromise the physical and functional integrity of the filter element and filter assembly by, for example, causing the filter element to separate from its attachment points, or causing the filter element to physically break that can lead subsequently to the unfiltered and the filtered liquids mixing downstream, which would compromise the intended sterility of the filtered fluid. In addition, assemblies using, for example, barbed connectors for hoses can experience hose breakage or separation from the barbed connectors due to the introduction of gas at a relatively high pressure.

[0006] What is needed is a filter recovery system that provides a means to removed valuable filtered and unfiltered liquids from a filter apparatus in a sterile manner. What is also needed is a filter recovery system that permits the use of a gas applied at a relatively low pressure to effectively remove resident filtered and unfiltered fluids while maintaining the sterility of the fluids in both upstream and downstream locations within a filter assembly. These and other problems are solved by the disclosed liquid recovery filter apparatus as described in the following disclosure summary.

SUMMARY OF THE DISCLOSURE

[0007] The liquid recovery filter assembly disclosed herein comprises a number of embodiments, each of the embodiments including a filter housing or shell

containing a filter element therein. All of the embodiments have an inlet port extending into the upstream or inlet side of the shell, and an outlet extending from the core for some filter element configurations, or from a downstream portion of the filter element. The terms "inlet," "inlet side," "upstream," "upstream side," and similar terms all refer to the portion or volume of the filter assembly located on the inlet portion of the apparatus, i.e., between the filter housing or shell and the outer surface of the filter element containing unfiltered liquid during operation of the filter assembly. The terms "outlet," "outlet side," "downstream," "downstream side," and similar terms all refer to the volume of the filter assembly located within the core of the filter element for filter elements having a core, or located at a downstream end or side of the filter element containing filtered liquid that has passed through the filter element during operation of the filter assembly. The filter element defines the liquid permeable barrier between the upstream or inlet side and the downstream or outlet side of the assembly. Thus, all liquid must pass through the filter element from the designated inlet port to the designated outlet port of the filter assembly.

[0008] The filter housing or shell also has an upstream or inlet side vent or purge port or passage, and an upstream or inlet side drain port or passage. These two upstream ports or passages allow the outer portion of the filter shell or housing to be drained of unfiltered liquid, i.e., liquid that has not passed through the filter element from the upstream or inlet side to the downstream or outlet side of the filter.

[0009] Each of the liquid recovery filter embodiments further includes a downstream or outlet side vent or purge port or passage that communicates fluidly with the interior or downstream core or downstream end/side of the filter element. This downstream or outlet purge port is normally closed during filtering operations, but is opened when the filtration operation has been completed. The opening of this downstream vent or purge port allows air or other gas to flow into the core or downstream end/side of the filter element, thus "breaking the seal" or hydraulic lock formed within the core, or downstream end/side, of the filter element when the inlet and outlet valves or ports are closed. This allows the valuable filtered liquid contained within the core or downstream end/side of the filter element to flow from the filter assembly for recovery and reuse.

[0010] Two basic configurations of the liquid recovery filter are disclosed herein, one having a downstream or outlet port disposed at the bottom of the filter assembly, and the other having its downstream or outlet port disposed at or near the

top of the assembly. The second of these configurations includes an additional downstream drain port or passage at the bottom of the assembly to allow liquid to flow from the core or downstream end of the filter element by gravity. The first basic configuration, i.e., having the main outlet port or passage disposed below the filter element, includes three different embodiments, which differ due to the different locations or arrangements of the primary inlet and outlet ports or passages. The second basic configuration, i.e., having the main outlet port or passage extending from the top or upper portion of the filter assembly, includes two additional embodiments, which also differ due to the different arrangements of the primary inlet and outlet ports or passages. However, each of the embodiments disclosed herein includes means for draining filtered liquid from the core or downstream end/side of the filter element.

[0011] Also disclosed are port/valve configurations and settings that permit fluid to be introduced into the filter assemblies in a reverse direction with the reassignment of vent and purge ports to remove the resident unfiltered and filtered fluids in a sterile manner from the apparatus after a filtering event. These and other features of the present disclosure will become readily apparent upon further review of the following drawings and detailed disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] Fig. 1 is a front elevation view of a first embodiment of a liquid recovery filter according to one aspect of the disclosure, illustrating its general external configuration.

[0013] Fig. 2 is an elevation view in section of a liquid recovery filter according to another aspect of the disclosure having a generally inline flow path, illustrating its internal configuration.

[0014] Fig. 3 is an elevation view in section of a liquid recovery filter according to a further aspect of the disclosure having a generally C-shaped flow path, illustrating its internal configuration.

[0015] Fig. 4 is an elevation view in section of a liquid recovery filter according to a still further aspect of the disclosure having a generally L-shaped flow path, illustrating its internal configuration.

[0016] Fig. 5 is an elevation view in section of a liquid recovery filter according to yet another aspect of the disclosure having a generally T -

shaped flow path, illustrating its internal configuration.

[0017] Fig. 6 is an elevation view in section of a liquid recovery filter according to another aspect of the disclosure having a generally S-shaped flow path, illustrating its internal configuration.

[0018] It should be understood that similar reference characters denote corresponding features consistently throughout the attached drawings.

DETAILED DESCRIPTION OF THE DISCLOSURE

[0019] The liquid recovery filter comprises several embodiments, each configured for the recovery of liquids within the filter shell or housing and filter element after the completion of filtration operations, e.g., when a batch has been filtered and/or the filter element is to be changed, etc. While the filter shells or housings of the various liquid recovery filter embodiments are shown in the drawings as being permanently sealed structures (with the exception of their various inlet and outlet ports or passages), it should be understood that the filter shells or housings may be constructed as reusable units, permitting access to the filter element therein for replacement or cleaning and reuse.

[0020] Referring to FIG. 1, a liquid recovery filter assembly is shown designated generally as **110**. The liquid recovery filter or filter assembly **110** includes an outer filter shell or housing **112** having an upper or inlet end **114** and an opposite lower or outlet end **116**, in addition to the outer cylindrical wall **112**. Filter assembly **110** will normally be oriented as shown in FIG. 1, with the inlet end **114** disposed above the outlet end **116**. Filter assembly **110** includes an upstream or inlet passage or port **118**, a generally opposite downstream or outlet passage or port **120** for the flow of filtered liquid from the device, an outlet vent passage **122** serving as a vent to the outlet side of the filter assembly, i.e., to the internal volume of the filter element contained within the housing or shell **112**, an upstream vent passage **124** communicating with the internal volume of the device between the shell or housing **112** and the filter element therein, and an upstream drain passage **126** for draining liquids from the internal volume between the shell **112** and the internal filter.

[0021] All of the embodiments of the liquid recovery device include these various vents, ports, and passages. However, the relationship and

orientation of the various vents, ports, and passages are arranged differently in different embodiments. Some embodiments also include an additional port or passage to accommodate the specific arrangement or orientation of the other ports and passages. Moreover, the operational states and settings of the ports and associated valves may be varied and ports reassigned function to permit the reverse flow of fluid through the assemblies. The locations and orientations of the various ports and passages **118** through **126** of the liquid recovery filter assembly **110** of FIG. 1 most closely resemble the configuration of the liquid recovery filter embodiment of FIG. 4, discussed in detail below. Moreover, while the filter assembly **110** is shown having a relatively tall and narrow configuration, it should be understood that other configurations may be provided, depending upon the shape and configuration of the filter element contained therein, the placement of the various inlet and outlet ports or passages, and other factors. The various fittings and connectors, illustratively barbed connectors and quick connects, for the various ports and passages of the filter assembly **110** are conventional in the industry.

[0022] Referring now to FIG. 2, another aspect of the liquid recovery filter is shown designated generally as filter assembly **210**. It should be understood that while filter assembly **210** is considerably shorter and somewhat wider than filter assembly **110** of FIG. 1, the length and width of any of the filter embodiments shown in the drawings are by way of illustration and not limitation, and will depend upon the configuration of the filter element installed therein according to the intended use and operating environment. Filter assembly **210** includes a housing or shell **212** having an inlet end **214** and an opposite outlet end **216**. An inlet passage **218** extends from the inlet end **214** of the shell **212** axially parallel to the length of the filter, as defined by its inlet and outlet ends. An outlet passage **220** extends coaxially (with the filter) from the opposite lower outlet end **216** of shell **212**. An outlet vent passage **222** extends from upper inlet end **214** of filter shell or housing **212**.

[0023] Outlet vent passage **222** communicates with the outlet portion or core of the filter disposed within housing or shell **212**, as described in more detail below. An upstream vent passage **224** also extends from inlet end **214** of shell **212** for the purpose of venting the internal volume of filter shell **212**

that surrounds the filter element therein. Lastly, an upstream drain passage **226** extends from outlet end **216** of shell **212** for draining liquids from the internal volume between shell **212** and the internal filter. This general external configuration is similar to filter assembly **110** of FIG. 1, with the exception of the orientation of inlet passage **218** and upstream drain passage **226**.

[0024] Filter shell or housing **212** defines an internal volume **228** having a filter element **230** disposed therein. The filter element preferably has a generally toroidal configuration and a hollow outlet core **232**. It should be understood that filter element **230** may conform to any regular or irregular geometric shape and configuration, e.g., pleated, hollow fiber, tubular, stacked disc, and may be formed from a variety of materials, e.g., polymeric, ceramic, or metallic membranes, hydrophobic membrane, hydrophilic membrane and combinations thereof, with varying porosities and still be within the scope and spirit of the disclosed and claimed filter assembly embodiments. It should be understood for filter elements made from, for example, hollow fiber and tubular materials, there is no "core", but a series of lumen that collectively function as a core disclosed herein. It should be further understood that filter **230** may be secured in any of the disclosed filter housings via thermal or sonic bonding, adhesive, O-ring seals and any combination of these methods as well any another other method used to secure filters in housings as are well known in the art.

[0025] Filter shell or housing **212** and filter element **230** contained therein define an upstream or inlet volume portion **234** between the filter shell **212** and the outer surface of the liquid permeable filter element **230**. Unfiltered liquid enters upstream volume **234** of filter assembly **210** via upstream or inlet passage **218** and passes through liquid permeable filter element **230** to hollow outlet core **232** of filter element **230**, and then exits filter **210** through outlet port **220** as filtered liquid.

[0026] It should further be noted that each of the various passages or ports **218** through **226** includes a valve therein. The valves are designated as valves **218v** through **226v**, respectively. The valves **218v** through **226v** are shown schematically in FIG. 2, and may be any suitable type of valve known and used in the art. During normal filtering operations, only inlet valve

218v and outlet valve 220v will be open, the other three valves 222v, 224v, and 226v remain closed. With this port configuration, liquid passing through filter assembly 210 must pass from upstream or inlet volume 234 through permeable filter element 230, and into hollow core 232 of filter element 230 as filtered liquid before leaving filter assembly 210 through the downstream or outlet port or passage 220.

[0027] The above-described operation presents no problems with liquid recovery, as long as the operation is essentially continuous. However, when the liquid stream must be interrupted for some reason, e.g., to clean the liquid delivery lines or passages, to change batches of liquid, to replace the filter or filter element, etc., the flow of liquid through filter assembly 210 must be shut off. This is easily accomplished by closing the inlet and outlet passage valves 218v and 220v. This, however, leaves some quantity of both unfiltered and filtered liquid within the filter housing or shell 212. As this liquid is often quite valuable, particularly in the pharmaceutical industry, it represents a fairly substantial financial cost or loss if it is discarded when filter assembly 210 is removed or replaced. Moreover, there may be additional costs associated with disposing of a filter containing such a liquid, if the liquid is considered to be a biohazard or requires special handling to contain and/or discard.

[0028] The various aspects and embodiments of the liquid recovery filter assemblies disclosed herein are configured to address this problem by providing structural means to drain the filter housing or shell of resident liquid in a sterile manner when the filtering operation is terminated. This permits the recovery of the valuable liquid within the filter for reuse. This is accomplished by means of opening one, some or all of the outlet vent passage 222, the upstream or inlet volume vent passage 224, and the upstream or inlet volume drain passage 226 in sequentially and/or concurrently. When filtering operations are terminated and the remaining liquid trapped within filter assembly 210 is to be drained, the primary inlet passage valve 218v is closed to terminate liquid flow through filter assembly 210. Filtration of the unfiltered liquid remaining within the unfiltered upstream or inlet side volume portion 234 of filter assembly 210 is accomplished by forcing it through the filter element 230 to drain as processed or filtered liquid from the filter outlet passage 220.

[0029] A brief discussion of the characteristics of a conventional filter

element, similar to element 230 is warranted. Filter elements used in many areas of the pharmaceutical industry, and likewise for other industries and operations, often utilize extremely fine filtration membranes having porosities on the order of fractional micron sizes. The level or degree of filtration is often quantified according to the "bubble point" of the filter, i.e., the differential pressure required to force air (or other gas) through the wetted filter element. In general, the smaller the filter porosity, the greater the bubble point. This pressure is equal to the pressure required to force the liquid through the pores of the wetted filter. Finer porosity requires a greater differential pressure between the inlet and the outlet of a filter assembly. The bubble point test also serves as a test or check of the integrity of the filter element. The bubble point of many filters used in the pharmaceutical industry may be 45 psi, or even higher, so that the pressure required to force a liquid of higher viscosity through a relatively small porosity filter during operating conditions is even greater.

[0030] With this explanation in mind, with respect to the disclosed filter assemblies, it is not sufficient merely to open the upstream vent passage valve 224v to break the suction of filter assembly 210. Instead, air (or other gas) must be applied to the open upstream vent passage 224 at sufficient pressure to force the residual unfiltered liquid through the filter element 230 and out the outlet passage 220 of filter assembly 210. Upstream vent passage 224 may include an inline filter 225 therein to preclude contamination of the liquid being forced through the filter element 230 by the air or gas introduced through the upstream vent passage 224. In this manner, most of the unfiltered liquid within the filter assembly 210 is filtered and recovered as filtered and processed liquid, as is accomplished during standard filter operation.

[0031] Once recovery of unfiltered liquid has been accomplished as just described, any remaining unfiltered liquid in filter housing 212, outside filter element 230 is removed from the filter assembly by opening lower upstream volume drain passage valve 226v while maintaining open counterpart upstream volume vent passage valve 224v per the liquid recovery method disclosed above. This relieves any partial vacuum or suction that may impede the flow of the liquid from the upstream volume drain passage 226, and permits any remaining residual unfiltered liquid to flow freely from filter housing

or shell 212.

[0032] The valuable filtered liquid remaining in core 232 of filter element 230 is recovered by opening the outlet vent passage valve 222v at the opposite end of the filter 210. Outlet passage 220 and its associated valve 220v are maintained in an open condition as in the initial liquid recovery operation disclosed above. This allows the remaining filtered liquid within core 232 of filter element 230 to drain from filter assembly 210 for recovery. A gas (air, nitrogen, carbon dioxide, etc., as appropriate), may be introduced into filter core 232 through outlet vent passage 222 to assist in the removal of liquid from the core, particularly if the liquid is relatively viscous. Due to the use of the accessory drain and vent ports, the pressure of the introduced gas needed to evacuate the resident fluid will be lower than what would be needed if the accessory drain and vent ports were not incorporated into the disclosed filter assemblies. To ensure sterile recovery of the downstream fluids, outlet vent passage 222 is fitted with an inline filter 236 to preclude contamination of the filtered liquid being removed from filter core 232 by the air or gas introduced through vent passage 222.

[0033] The configuration of filter assembly 210 may also perform the intended fluid filter and recovery functions when the fluid flow is reversed through the assembly. In this functional configuration, outlet port 220 is reassigned as an inlet port and upstream drain passage port 226 is reassigned as a downstream outlet port. Downstream vent port 222 is maintained in a closed condition during the main filtering operation. When used in this manner, fluid introduced into port 220 (with valve 220v open), flows into core 232 (or the lumen of the filter element if constructed from, for example, hollow fiber or tubular material), and radially outwardly through filter element 230 into internal volume 228 and out of the filter assembly through port 226 as processed fluid. In this functional configuration, inlet 218 is maintained in a closed condition by closing inlet valve 218v. Once the intended volume of fluid is filtered through assembly 210, valve 220v is closed to cease flow.

[0034] To remove the resident unfiltered fluid (resident in core 232), pressurized gas is introduced into the filter assembly via vent passage port 222 (reassigned as an upstream vent passage port), by connecting a gas supply to port 222 and opening valve 222v. Reassigned upstream vent passage 222 may include an inline filter 236 therein to preclude contamination of the liquid being forced

through the filter element 230 by the air or gas introduced through the reassigned upstream vent passage 222. Once the resident unfiltered fluid is forced through filter element 230, and removed from the filter assembly as processed fluid via port 226, valve 222v is closed. This reversed functional use of the filter assembly will result in filtered fluid remaining in internal volume 228, upstream vent port 224 may be reassigned as a purge port or downstream vent passage port made operational by opening valve 224v. Pressurized gas is again introduced into the filter assembly's internal volume 228 via port 224, purging filtered fluid out of the port 226 for recovery. Reassigned downstream vent passage 224 may include an inline filter 225 therein to preclude contamination of the filtered liquid being forced out of the filter assembly via the port 226 by the air or gas introduced through the reassigned downstream vent passage 224. Once the purge function is completed and the introduction of pressurized gas is ceased by closing valve 224v, valve 226v may be closed to prepare for another filter cycle.

[0035] Referring now to FIG. 3, in another aspect of the disclosure, an alternative embodiment of the liquid recovery filter assembly is shown designated generally as 310. Filter assembly 310 includes all of the components and elements disclosed above for filter assembly 210, i.e., a filter housing or shell 312 having mutually opposed first or upper and second or lower ends 314 and 316 defining an interior volume 328, and a toroidal filter element 330 secured therein. Filter element 330 and surrounding housing or shell 312 define an upstream or inlet volume 334 therebetween. Filter element 330 has a hollow core 332. An upstream vent passage 324 and its associated valve 324v extend from the upper or inlet end 314 of shell 312. An opposite upstream or inlet side drain passage 326 and its associated valve 326v extend from the lower or downstream or outlet end 316 of filter housing or shell 312.

[0036] The difference between filter assembly 210 of FIG. 2 and filter assembly 310 of FIG. 3 lies in the orientation of their respective inlet and outlet ports or passages. It will be seen in FIG. 3 that an upstream or inlet port or passage 318 and its associated valve 318v extend radially from upper end 314 of filter housing or shell 312. A downstream or outlet port or passage 320 and its associated valve 320v extend from filter core 332 radially from lower or outlet end 316 of filter shell or housing 312. This configuration may be more readily installed in certain processing systems than the inline configuration of filter assembly 210 of FIG. 2. The liquid flow

paths through filter assembly 310 during normal filtering operations and during the draining or purging of filter assembly 310 are essentially the same as those disclosed above for filter assembly 210.

[0037] An outlet vent passage valve 322v secured in line with outlet vent passage 322, upstream vent passage valve 324v, and upstream drain passage valve 326v are closed during normal filtering operations, i.e., when the upstream or inlet and downstream or outlet valves 318v and 320v are open to permit flow through the filter 310. Draining or purging of liquid from filter 310 is accomplished in the same manner as disclosed above for filter assembly 210, i.e., inlet valve 318v is closed and upstream vent passage and upstream drain passage valves 324v and 326v are opened to drain unfiltered liquid from the upstream volume portion 334 of filter housing 312 through filter element 330. The pressurized gas may pass through an inline filter 325 installed in an upstream vent passage 324. Once all of the liquid that can be purged through filter element 330 has been recovered, any remaining unfiltered liquid in filter housing 312, but outside filter element 330 may be removed from the filter assembly by opening lower upstream volume drain passage valve 326v while maintaining open counterpart upstream volume vent passage valve 324v as per the liquid recovery operation disclosed above. This permits any remaining residual unfiltered liquid to flow freely from filter housing or shell 312. Upstream volume vent passage valve 324v and upstream volume drain passage valve 326v are then closed and outlet vent passage valve 322v is opened to allow the remaining filtered liquid to drain or to be purged or flushed from filter core 332. To ensure sterile recovery of the downstream fluids, outlet vent passage 322 is fitted with an inline filter 336 to preclude contamination of the filtered liquid being removed from filter core 332 by the air or gas introduced through vent passage 322.

[0038] The configuration of filter assembly 310 may also perform the intended fluid filter and recovery functions when the fluid flow is reversed through the assembly. In this functional configuration, outlet port 320 is reassigned as an inlet port and upstream drain passage port 326 is reassigned as a downstream outlet port. Downstream vent port 322 is maintained in a closed condition during the main filtering operation. When used in this manner, fluid introduced into port 320 (with valve 320v open), flows into core 332 (or the lumen of the filter element if constructed from, for example, hollow fiber or tubular material), and radially outwardly through filter element 330 into internal volume 328 and out of the filter

assembly through port 326 as processed fluid. In this functional configuration, inlet 318 is maintained in a closed condition by closing inlet valve 318v. Once the intended volume of fluid is filtered through assembly 310, valve 320v is closed to cease flow.

[0039] To remove the resident unfiltered fluid (resident in core 332), pressurized gas is introduced into the filter assembly via vent passage port 322 (reassigned as an upstream vent passage port), by connecting a gas supply to port 322 and opening valve 322v. Reassigned upstream vent passage 322 may include an inline filter 336 therein to preclude contamination of the liquid being forced through the filter element 330 by the air or gas introduced through the reassigned upstream vent passage 322. Once the resident unfiltered fluid is forced through filter element 330, and removed from the filter assembly as processed fluid via port 326, valve 322v is closed. This reversed functional use of the filter assembly will result in filtered fluid remaining in internal volume 328, upstream vent port 324 may be reassigned as a purge port or downstream vent passage port made operational by opening valve 324v. Pressurized gas is again introduced into the filter assembly's internal volume 328 via port 324, purging filtered fluid out of the port 326 for recovery. Reassigned downstream vent passage 324 may include an inline filter 325 therein to preclude contamination of the filtered liquid being forced out of the filter assembly via the port 326 by the air or gas introduced through the reassigned downstream vent passage 324. Once the purge function is completed and the introduction of pressurized gas is ceased by closing valve 324v, valve 326v may be closed to prepare for another filter cycle.

[0040] Referring now to Fig. 4, another alternative embodiment of the liquid recovery filter assembly is shown designated generally as 410. Filter assembly 410 includes all of the components and elements disclosed above for filter assemblies 210 and 310, i.e., a filter housing or shell 412 having mutually opposed first or upper and second or lower ends 414 and 416 defining an interior volume 428, and a toroidal filter element 430 secured therein. Filter element 430 and surrounding housing or shell 412 define an upstream or inlet volume 434 therebetween. Filter element 430 has a hollow core 432. An upstream vent passage 424 and its associated valve 424v extend from upper or inlet end 414 of shell 412. An opposite upstream or inlet side drain passage 426 and its associated valve 426v extend from lower or downstream or outlet end 416 of filter housing or shell 412.

[0041] Filter assembly 410 may be considered a hybrid of filter assemblies 210 and 310. An upstream or inlet passage 418 of filter assembly 410 extends radially from upper end 414 of filter housing or shell 412 in essentially the same orientation as the corresponding component 318 of filter assembly 310. However, a downstream or outlet passage 420 extends coaxially from filter shell 412 in the manner of outlet passage 220 of filter housing 210. This configuration provides further installation options.

[0042] The liquid flow paths through filter assembly 410 during normal filtering operations and during the draining or purging of filter assembly 410 are essentially the same as those disclosed above for filter assemblies 210 and 310. An outlet vent passage valve 422v connected to an outlet vent passage 422, the upstream vent passage valve 424v, and the upstream drain passage valve 426v are closed during normal filtering operations, i.e., when the upstream or inlet and downstream or outlet valves 418v and 420v, respectively, are open to permit flow through the filter assembly 410.

[0043] Draining or purging of liquid from the filter assembly 410 is accomplished in the same manner as disclosed above for filter assemblies 210 and 310, i.e., inlet valve 418v is closed and upstream vent passage valve is opened to allow pressurized gas to force unfiltered liquid from upstream volume portion 434 of filter housing 412 through filter element 430. The pressurized gas may pass through an inline filter 425 installed in upstream vent passage 424. Once all the liquid that can be purged through filter element 430 has been recovered, any remaining unfiltered liquid in filter housing 412 and outside filter element 430 is removed from the filter assembly by opening lower upstream volume drain passage valve 426v while maintaining open counterpart upstream volume vent passage valve 424v per the liquid recovery operation disclosed above. This allows any remaining residual unfiltered liquid to flow freely from filter housing or shell 412. Upstream volume vent passage valve 424v and upstream volume drain passage valve 426v are then closed and outlet passage valve 422v is opened to allow the remaining filtered liquid to drain or to be purged or flushed from filter core 432. To ensure sterile recovery of the downstream fluids, outlet vent passage 422 is fitted with an inline filter 436 to preclude contamination of the filtered liquid being removed from filter core 432 by the air or gas introduced through vent passage 422.

[0044] The configuration of filter assembly 410 may also perform the intended

fluid filter and recovery functions when the fluid flow is reversed through the assembly. In this functional configuration, outlet port 420 is reassigned as an inlet port and upstream drain passage port 426 is reassigned as a downstream outlet port. Downstream vent port 422 is maintained in a closed condition during the main filtering operation. When used in this manner, fluid introduced into port 420 (with valve 420v open), flows into core 432 (or the lumen of the filter element if constructed from, for example, hollow fiber or tubular material), and radially outwardly through filter element 430 into internal volume 428 and out of the filter assembly through port 426 as processed fluid. In this functional configuration, inlet 418 is maintained in a closed condition by closing inlet valve 418v. Once the intended volume of fluid is filtered through assembly 410, valve 420v is closed to cease flow.

[0045] To remove the resident unfiltered fluid (resident in core 432), pressurized gas is introduced into the filter assembly via vent passage port 422 (reassigned as an upstream vent passage port), by connecting a gas supply to port 422 and opening valve 422v. Reassigned upstream vent passage 422 may include an inline filter 436 therein to preclude contamination of the liquid being forced through the filter element 430 by the air or gas introduced through the reassigned upstream vent passage 422. Once the resident unfiltered fluid is forced through filter element 430, and removed from the filter assembly as processed fluid via port 426, valve 422v is closed. This reversed functional use of the filter assembly will result in filtered fluid remaining in internal volume 428, upstream vent port 424 may be reassigned as a purge port or downstream vent passage port made operational by opening valve 424v. Pressurized gas is again introduced into the filter assembly's internal volume 428 via port 424, purging filtered fluid out of the port 426 for recovery. Reassigned downstream vent passage 424 may include an inline filter 425 therein to preclude contamination of the filtered liquid being forced out of the filter assembly via the port 426 by the air or gas introduced through the reassigned downstream vent passage 424. Once the purge function is completed and the introduction of pressurized gas is ceased by closing valve 424v, valve 426v may be closed to prepare for another filter cycle.

[0046] Referring now to FIGS. 5 and 6, additional embodiments of the liquid recovery filter assemblies are shown designated generally as 510 and 610, respectively. It will be seen that each of the filter embodiments of FIGS. 5 and 6

includes an additional drain passage or port communicating with the downstream or outlet core volume of the filter element. This is due to the placement of the downstream or outlet passage away from the filter core, which is relatively high in the filter housing.

[0047] FIG. 5 shows a liquid recovery filter assembly 510 having an additional drain passage, as described briefly above. For the most part, filter assembly 510 includes corresponding components to those disclosed above for filter assemblies 210 through 410, i.e., a filter housing or shell 512 having mutually opposed first or upper and second or lower ends 514 and 516, respectively, defining an interior volume 528, and a toroidal filter element 530 secured therein. Filter element 530 and surrounding housing or shell 512 define an upstream or inlet volume 534 therebetween. Filter element 530 has a hollow core 532. An upstream vent passage 524 and its associated valve 524v extend from upper or inlet end 514 of shell 512. An opposite upstream or inlet side drain passage 526 and its associated valve 526v extend radially from lower or downstream or outlet end 516 of filter housing or shell 512.

[0048] The placement of a downstream or outlet passage or port 520 extending substantially radially from upper end 514 of filter housing or shell 512 requires that the liquid passing through filter assembly 510 flows upward from the lower portions of filter core 532 to exit the filter. Otherwise, liquid flow through filter assembly 510 is substantially as disclosed above for the other filter assembly embodiments, i.e., an outlet vent passage valve 522v, upstream vent passage valve 524v, and upstream drain passage valve 526v are closed during normal filtering operations, and upstream or inlet and downstream or outlet valves 518v and 520v, respectively, are open to permit flow through filter assembly 510. However, it will be seen that a sixth port or passage 538 and its associated valve 538v extend from lower end 516 of filter shell or housing 512, in fluid communication with filter core 532. Port or passage 538 serves as an outlet drain passage for draining filter core 532. Its valve 538v must be closed during normal filtering operations. Liquid flow during normal filtering operations initially passes through radially disposed upstream or inlet passage 518 and its normally open valve 518v at upper end 514 of filter housing or shell 512, and enters interior volume 534 between filter housing or shell 512 and filter element 530. The liquid then passes through filter element 530 and into filter core 532, and then upward and out of core 532 to flow from radially disposed

downstream or outlet passage 520 and its normally open valve 520v at upper end 514 of filter housing or shell 512.

[0049] Draining or purging of liquid from filter assembly 510 is accomplished in a procedure similar to the procedure disclosed above for the other filter assembly embodiments, but with some differences due to the presence of upwardly disposed outlet passage 520. Inlet valve 518v is closed and upstream vent passage valve 524v is opened to allow pressurized gas to force unfiltered liquid from upstream volume portion 534 of filter housing 512 through filter element 530. The pressurized gas may pass through an inline filter 525 installed in upstream vent passage 524.

[0050] Once all the liquid that can be purged through filter element 530 has been recovered, any remaining unfiltered liquid in filter housing 512 and outside filter element 530 is removed from the filter housing by opening lower upstream volume drain passage valve 526v while maintaining open counterpart upstream volume vent passage valve 524v per the liquid recovery operation disclosed above. This permits any remaining residual unfiltered liquid to flow freely from filter housing or shell 512. Upstream volume vent passage valve 524v and upstream volume drain passage valve 526v are then closed and outlet vent passage valve 522v is opened to allow the remaining filtered liquid to drain or to be purged or flushed from filter core 532. To ensure sterile recovery of the downstream fluids, outlet vent passage 522 is fitted with an inline filter 536 to preclude contamination of the filtered liquid being removed from filter core 532 by the air or gas introduced through vent passage 522.

However, it will be seen that due to the high position of downstream or outlet passage 520, the introduction of a purging gas through vent passage 522 cannot flush liquid from filter core 532. Accordingly, outlet passage valve 520v is closed and outlet drain passage valve 538v in fluid communication with filter core 532 is opened to allow any liquid contained in filter core 532 to flow downward, i.e., in the reverse direction of its flow during normal filtering operations, and out through outlet drain passage 538 and its associated valve 538v.

[0051] The configuration of filter assembly 510 may also perform the intended fluid filter and recovery functions when the fluid flow is reversed through the assembly. In this functional configuration, outlet port 520 is reassigned as an inlet port and upstream drain passage port 526 is reassigned as a downstream outlet port. Downstream vent port 522 is maintained in a closed condition during the main filtering operation. When used in this manner, fluid introduced into port 520 (with

valve 520v open), flows into core 532 (or the lumen of the filter element if constructed from, for example, hollow fiber or tubular material), and radially outwardly through filter element 530 into internal volume 528 and out of the filter assembly through port 526 as processed fluid. In this functional configuration, inlet 518 is maintained in a closed condition by closing inlet valve 518v. In addition, port 538 is also maintained in a closed condition by closing inlet valve 538v. Once the intended volume of fluid is filtered through assembly 510, valve 520v is closed to cease flow.

[0052] To remove the resident unfiltered fluid (resident in core 532), pressurized gas is introduced into the filter assembly via vent passage port 522 (reassigned as an upstream vent passage port), by connecting a gas supply to port 522 and opening valve 522v. Reassigned upstream vent passage 522 may include an inline filter 536 therein to preclude contamination of the liquid being forced through the filter element 530 by the air or gas introduced through the reassigned upstream vent passage 522. Once the resident unfiltered fluid is forced through filter element 530, and removed from the filter assembly as processed fluid via port 526, valve 522v is closed. This reversed functional use of the filter assembly will result in filtered fluid remaining in internal volume 528, upstream vent port 524 may be reassigned as a purge port or downstream vent passage port made operational by opening valve 524v. Pressurized gas is again introduced into the filter assembly's internal volume 528 via port 524, purging filtered fluid out of the port 526 for recovery. Reassigned downstream vent passage 524 may include an inline filter 525 therein to preclude contamination of the filtered liquid being forced out of the filter assembly via the port 526 by the air or gas introduced through the reassigned downstream vent passage 524. Once the purge function is completed and the introduction of pressurized gas is ceased by closing valve 524v, valve 526v may be closed to prepare for another filter cycle.

[0053] Referring now to FIG. 6, a yet further aspect of the liquid recovery filter assembly designated generally as 610 has a configuration similar to that of filter assembly 510, i.e., with a filter outlet passage extending radially from an upper end portion 614 of a housing or shell 612. Filter assembly 610 includes components corresponding to those disclosed above for filter assembly 510, i.e., filter housing or shell 612 having mutually opposed first or upper and second or lower ends 614 and 616, respectively, defining an interior volume 628, and a toroidal filter element 630

secured therein. Filter element 630 and surrounding housing or shell 612 define an upstream or inlet volume 634 therebetween. Filter element 630 has a hollow core 632. An upstream vent passage 624 and its associated valve 624v extend from upper or inlet end 614 of shell 612. An opposite upstream or inlet side drain passage 626 and its associated valve 626v extend radially from lower or downstream or outlet end 616 of filter housing or shell 612.

[0054] Liquid flow through filter housing 610 is essentially as disclosed above for filter assembly 510. An outlet vent passage valve 622v connected to an outlet vent passage 622, upstream vent passage valve 624v, and upstream drain passage valve 626v are closed during normal filtering operations, and upstream or inlet and downstream or outlet valves 618v and 620v, respectively, are open to permit flow through filter assembly 610. An outlet drain passage valve 638v is also closed during normal filtering operations. Liquid flow during normal filtering operations initially passes through radially disposed upstream or inlet passage 618 and its normally open valve 618v at lower end 616 of filter housing or shell 612, and then enters the interior volume 634 between filter housing or shell 612 and filter element 630. The liquid then passes through filter element 630 and into filter core 632, and upward out of core 632 to flow from radially disposed downstream or outlet passage 620 and its normally open valve 620v at upper end 614 of filter housing or shell 612.

[0055] Draining or purging of liquid from the filter 610 is accomplished essentially as disclosed above for liquid recovery filter assembly 510. Inlet valve 618v is closed, and upstream vent passage valve 624v is opened to allow pressurized gas to force unfiltered liquid from upstream volume portion 634 of filter housing 612v through filter element 630. The pressurized gas may pass through an inline filter 625 installed in upstream vent passage 624.

[0056] Once all the liquid that can be purged through filter element 630 has been recovered, any remaining unfiltered liquid in filter housing 612 and outside filter element 630 is removed from the filter housing by opening lower upstream volume drain passage valve 626v while maintaining open counterpart upstream volume vent passage valve 624v per the liquid recovery operation disclosed above. This permits any remaining residual unfiltered liquid to flow freely from filter housing or shell 612. Upstream volume vent passage valve 624v and upstream volume drain passage valve 626v are then closed and outlet vent passage valve 622v is opened to allow the remaining filtered liquid to drain or to be purged or flushed from filter core 632.

To ensure sterile recovery of the downstream fluids, outlet vent passage 622 is fitted with an inline filter 636 to preclude contamination of the filtered liquid being removed from filter core 632 by the air or gas introduced through vent passage 622.

However, it will be seen that due to the high position of downstream or outlet passage 620, the introduction of a purging gas through vent passage 622 cannot flush liquid from filter core 632. Accordingly, outlet passage valve 620v is closed and outlet drain passage valve 638v in fluid communication with filter core 632 is opened to allow any liquid contained in filter core 632 to flow downward, i.e., in the reverse direction of its flow during normal filtering operations, and out through outlet drain passage 638 and its associated valve 638v.

[0057] The configuration of filter assembly 610 may also perform the intended fluid filter and recovery functions when the fluid flow is reversed through the assembly. In this functional configuration, outlet port 620 is reassigned as an inlet port and upstream drain passage port 626 is reassigned as a downstream outlet port. Downstream vent port 622 is maintained in a closed condition during the main filtering operation. When used in this manner, fluid introduced into port 620 (with valve 220v open), flows into core 632 (or the lumen of the filter element if constructed from, for example, hollow fiber or tubular material), and radially outwardly through filter element 630 into internal volume 628 and out of the filter assembly through port 626 as processed fluid. In this functional configuration, inlet 618 is maintained in a closed condition by closing inlet valve 618v. In addition, port 638 is also maintained in a closed condition by closing inlet valve 638v. Once the intended volume of fluid is filtered through assembly 610, valve 620v is closed to cease flow.

[0058] To remove the resident unfiltered fluid (resident in core 632), pressurized gas is introduced into the filter assembly via vent passage port 622 (reassigned as an upstream vent passage port), by connecting a gas supply to port 622 and opening valve 622v. Reassigned upstream vent passage 622 may include an inline filter 636 therein to preclude contamination of the liquid being forced through the filter element 630 by the air or gas introduced through the reassigned upstream vent passage 622. Once the resident unfiltered fluid is forced through filter element 630, and removed from the filter assembly as processed fluid via port 626, valve 622v is closed. This reversed functional use of the filter assembly will result in filtered fluid remaining in internal volume 628, upstream vent port 624 may be

reassigned as a purge port or downstream vent passage port made operational by opening valve 624v. Pressurized gas is again introduced into the filter assembly's internal volume 628 via port 624, purging filtered fluid out of the port 626 for recovery. Reassigned downstream vent passage 624 may include an inline filter 625 therein to preclude contamination of the filtered liquid being forced out of the filter assembly via the port 626 by the air or gas introduced through the reassigned downstream vent passage 624. Once the purge function is completed and the introduction of pressurized gas is ceased by closing valve 624v, valve 626v may be closed to prepare for another filter cycle.

[0059] Accordingly, the various embodiments of the disclosed liquid recovery filter apparatus provide an effective means to recover costly liquids used in filtering operations particularly in the pharmaceutical as well as in other industries. It should be understood that the various axial and radial configurations of the various inlet and outlet passages or ports illustratively depicted in the drawings and disclosed herein are merely exemplary, and that various other arrangements of these ports or passages are within the contemplation of the disclosure that provide a means for the drainage or removal of liquid from the filter housing or shell, and particularly for the drainage or removal of filtered liquid from the core of the filter.

[0060] It is to be understood that the present disclosure is not limited to the embodiments disclosed herein, but encompasses any and all embodiments and equivalents thereof within the scope of the following claims. What I claim as new and desire to secure by letters patent is

1. A liquid recovery filter comprising:

a filter having an upper end, a lower end opposite the upper end, and a cylindrical outer wall extending between the upper end and the lower end, the shell defining an internal volume;

a filter element disposed within the filter shell, the filter element having an inlet side and an outlet core, the inlet side of the filter element communicating fluidly with the internal volume of the filter shell between the filter shell and the filter element;

an inlet passage disposed through the filter shell, the inlet passage communicating fluidly with the internal volume of the filter shell between the filter shell and the filter element;

an outlet passage disposed through the filter shell, the outlet passage communicating fluidly with the outlet core of the filter element;

an outlet vent passage disposed through the filter shell, the outlet vent passage communicating fluidly with the outlet core of the filter element,

an upstream vent passage disposed through the filter shell, the upstream vent passage communicating fluidly with the internal volume of the filter shell between the filter shell and the filter element; and,

an upstream drain passage disposed through the filter shell, the upstream drain passage communicating fluidly with the internal volume of the filter shell between the filter shell and the filter element.

2. The liquid recovery filter according to claim 1 wherein the outlet passage is disposed through the lower end of the filter shell, and wherein the outlet vent passage is disposed through the upper end of the filter shell.

3. The liquid recovery filter according to claim 1 wherein the outlet passage is disposed through the upper end of the filter shell, wherein the outlet vent passage is disposed through the upper end of the filter shell, and wherein an outlet drain passage is disposed through the lower end of the filter shell, the outlet drain passage communicating fluidly with the outlet core of the filter element.

4. The liquid recovery filter according to claim 1 wherein the inlet passage is disposed substantially axially through the upper end of the filter shell, and wherein

the outlet passage is disposed through the lower end of the filter shell and extends substantially coaxially with the filter element.

5. The liquid recovery filter according to claim 1 wherein the inlet passage is disposed substantially radially through the upper end of the filter shell, and wherein the outlet passage is disposed substantially radially through the lower end of the filter shell.

6. The liquid recovery filter according to claim 1 wherein the inlet passage is disposed substantially radially through the upper end of the filter shell, and wherein the outlet passage is disposed through the lower end of the filter shell and extends substantially coaxially with the filter element.

7. The liquid recovery filter according to claim 1 wherein the inlet passage is disposed substantially radially through the upper end of the filter shell, and wherein the outlet passage is disposed substantially radially through the upper end of the filter shell, substantially opposite the inlet passage, and wherein an outlet drain passage is disposed through the lower end of the filter shell, the outlet drain passage communicating fluidly with the outlet core of the filter element.

8. The liquid recovery filter according to claim 1 wherein the inlet passage is disposed substantially radially through the lower end of the filter shell, wherein the outlet passage is disposed substantially radially through the upper end of the filter shell, generally diametrically opposite the inlet passage, and wherein an outlet drain passage is disposed through the lower end of the filter shell, the outlet drain passage communicating fluidly with the outlet core of the filter element.

9. The liquid recovery filter according to claim 1 further comprising:
an inline gas filter disposed in the outlet vent passage; and,
an inline gas filter disposed in the upstream vent passage.

10. The liquid recovery filter comprising:

- a filter shell having an upper end, a lower end opposite the upper end, and a cylindrical wall extending between the upper end and the lower end, the shell defining an internal volume;

- a filter element disposed within the filter shell, the filter element having an inlet side and an outlet core, the inlet side of the filter element communicating fluidly with the internal volume of the filter shell between the filter shell and the filter element;

- an inlet passage disposed through the filter shell, the inlet passage communicating fluidly with the internal volume of the filter shell between the filter shell and the filter element;

- an outlet passage disposed through the lower end of the filter shell, the outlet passage communicating fluidly with the outlet core of the filter element; and,

- an outlet vent passage disposed through the upper end of the filter shell, the outlet vent passage communicating fluidly with the outlet core of the filter element.

11. The liquid recovery filter according to claim 10 further comprising:

- an upstream vent passage disposed through the filter shell, the upstream vent passage communicating fluidly with the internal volume of the filter shell between the filter shell and the filter element; and,

- an upstream drain passage disposed through the filter shell, the upstream drain passage communicating fluidly with the internal volume of the filter shell between the filter shell and the filter element.

12. The liquid recovery filter according to claim 10 wherein the inlet passage is disposed substantially axially through the upper end of the filter shell, and wherein the outlet passage is disposed through the lower end of the filter shell and extends substantially coaxially with the filter element.

13. The liquid recovery filter according to claim 10 wherein the inlet passage is disposed substantially radially through the upper end of the filter shell, and wherein the outlet passage is disposed substantially radially through the lower end of the filter shell.

14. The liquid recovery filter according to claim 10 wherein the inlet passage is disposed substantially radially through the upper end of the filter shell, and wherein the outlet passage is disposed through the lower end of the filter shell and extends substantially coaxially with the filter element.

15. The liquid recovery filter according to claim 10 further comprising:

an inline gas filter disposed in the outlet vent passage; and,

an inline gas filter disposed in the upstream vent passage.

16. The liquid recovery filter comprising:

a filter shell having an upper end, a lower end opposite the upper end, and a cylindrical wall extending between the upper end and the lower end, the shell defining an internal volume;

a filter element disposed within the filter shell, the filter element having an inlet side and an outlet core, the inlet side of the filter element communicating fluidly with the internal volume of the filter shell between the filter shell and the filter element;

an inlet passage disposed through the filter shell, the inlet passage communicating fluidly with the internal volume of the filter shell between the filter shell and the filter element;

an outlet passage disposed through the upper end of the filter shell, the outlet passage communicating fluidly with the outlet core of the filter element;

an outlet vent passage disposed through the upper end of the filter shell, the outlet vent passage communicating fluidly with the outlet core of the filter element; and,

an outlet drain passage disposed through the lower end of the filter shell, the outlet drain passage communicating fluidly with the outlet core of the filter element.

17. The liquid recovery filter according to claim 16 further comprising:

an upstream vent passage disposed through the filter shell, the upstream vent passage communicating fluidly with the internal volume of the filter shell between the filter shell and the filter element; and,

an upstream drain passage disposed through the filter shell, the upstream

drain passage communicating fluidly with the internal volume of the filter shell between the filter shell and the filter element.

18. The liquid recovery filter according to claim 16 wherein the inlet passage is disposed substantially radially through the upper end of the filter shell, and wherein the outlet passage is disposed substantially radially through the upper end of the filter shell, substantially opposite the inlet passage.

19. The liquid recovery filter according to claim 16 wherein the inlet passage is disposed substantially radially through the lower end of the filter shell, and wherein the outlet passage is disposed substantially radially through the upper end of the filter shell, generally diametrically opposite the inlet passage.

20. The liquid recovery filter according to claim 16 further comprising:
an inline gas filter disposed in the outlet vent passage; and,
an inline gas filter disposed in the upstream vent passage.