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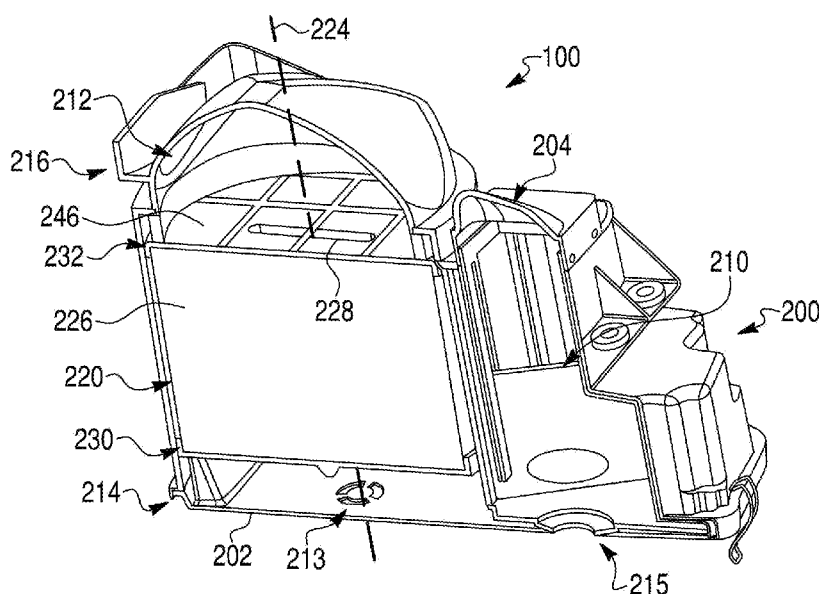
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**FIG. 2**

(57) **Abstract:** A fluid filtration system includes a shell housing having a first cavity and a second cavity, the first cavity upstream of the second cavity. The fluid filtration system further includes a housing closure configured to form a sealing engagement with the shell housing. The fluid filtration system further includes a filter element removably coupled to the shell housing and positioned within the second cavity. The filter element includes a first endcap, a second endcap, a media pack extending between and coupled to both of the first endcap and the second endcap, and a hydrophobic mesh coupled to the second endcap. The hydrophobic mesh is configured to prevent moisture from flowing out of the filter element and downstream of the filter element.



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AIR CLEANER WITH WATER SEPARATION

CROSS-REFERENCE TO RELATED PATENT APPLICATIONS

[0001] This application claims the benefit of and priority to Indian Provisional Patent Application No. 202041043381, filed October 6, 2020 and Indian Provisional Patent Application No 202041054207, Filed December 14, 2020. The contents of these applications are incorporated herein by reference in their entirety.

BACKGROUND

[0002] The present disclosure relates generally to fluid filtration systems. More specifically, the present disclosure relates to air filtration systems operating in wet environments.

SUMMARY

[0003] At least one embodiment of the present disclosure relates to a filter assembly. The filter assembly includes a housing and a filter element. The housing includes a housing body and a service cover. The housing body defines an interior volume, an inlet port, and an outlet port. The service cover is movable with respect to the housing body so as to provide access to the interior volume. The service cover includes a water collection sump that is at least partially axially aligned with the inlet port when the service cover is installed onto the housing body. The filter element is removably coupled to the housing body and disposed within the interior volume.

[0004] At least one embodiment relates to a fluid filtration system. The fluid filtration system includes a shell housing, a housing closure, and a filter element. The housing closure is configured to form a sealing engagement with the shell housing. The housing closure includes a drain opening that extends through the housing closure and is configured to selectively facilitate a flow of liquid out of the shell housing. The filter element is removably coupled to the shell housing and includes a first endcap, a second endcap downstream of the first endcap, a media pack, and a hydrophobic mesh. The media pack includes filter media that extends between both the first endcap and the second endcap. The hydrophobic mesh is coupled to one

of the first endcap and the second endcap and configured to prevent moisture from flowing out of the shell housing.

[0005] Another embodiment relates to a filter element. The filter element includes a media pack, a first endcap, a second endcap, and a hydrophobic mesh. The media pack defines a first end and a second end. The first endcap is coupled to the first end and the second endcap is coupled to the second end such that the second endcap is downstream of the first end. The second endcap includes a sealing member configured to form a sealing engagement with a shell housing. The filter element further includes a hydrophobic mesh that extends across the second end and is configured to prevent moisture from flowing downstream of the media pack.

[0006] This summary is illustrative only and should not be regarded as limiting.

BRIEF DESCRIPTION OF THE FIGURES

[0007] The disclosure will become more fully understood from the following detailed description, taken in conjunction with the accompanying figures, wherein like reference numerals refer to like elements, in which:

[0008] FIG. 1 is a perspective view of an example fluid filtration system.

[0009] FIG. 2 is a perspective cross-sectional view of the fluid filtration system of FIG. 1.

[0010] FIG. 3 is a perspective view of a filter element for use in a fluid filtration system, such as the fluid filtration system of FIG. 1.

[0011] FIG. 4 is a side cross-sectional view of the filter element of FIG. 3.

[0012] FIG. 5 is a top view of the filter element of FIG. 1.

[0013] FIG. 6 is a perspective view of another example filter assembly.

[0014] FIG. 7 is a partial perspective view of the filter assembly of FIG. 6.

[0015] FIG. 8 is a side cross-sectional view of a filter assembly, according to another embodiment.

[0016] FIG. 9 is a side cross-sectional view of a filter assembly, according to another embodiment.

[0017] FIG. 10 is a top perspective view of a service cover for the filter assembly of FIG. 9.

[0018] FIG. 11 is a side cross-sectional view of a filter assembly, according to another embodiment.

[0019] FIG. 12 is a side cross-sectional view of a filter assembly, according to another embodiment.

[0020] FIG. 13 is a top perspective view of a service cover for a filter assembly, according to another embodiment.

[0021] FIG. 14 is a top perspective view of a service cover for a filter assembly, according to still another embodiment.

[0022] Reference is made to the accompanying drawings throughout the following detailed description. In the drawings, similar symbols typically identify similar components, unless context dictates otherwise. The illustrative implementations described in the detailed description, drawings, and claims are not meant to be limiting. Other implementations may be utilized, and other changes may be made, without departing from the spirit or scope of the subject matter presented here. It will be readily understood that the aspects of the present disclosure, as generally described herein, and illustrated in the figures, can be arranged, substituted, combined, and designed in a wide variety of different configurations, all of which are explicitly contemplated and made part of this disclosure.

DETAILED DESCRIPTION

[0023] Embodiments described herein relate generally to air filtration assemblies for internal combustion engine systems. The various concepts introduced above and discussed in greater

detail below may be implemented in any of numerous ways, as the described concepts are not limited to any particular manner of implementation. Examples of specific implementations and applications are provided primarily for illustrative purposes.

[0024] Air filtration systems are used to filter particulate matter (e.g., dirt, oil, and or contaminants) from an incoming air stream and supplying the filtered air to an internal combustion engine. The filtration system may include a filter assembly (e.g., an air cleaner, etc.) that includes a removable filter element made from a pleated and/or corrugated media. The filter assembly may be disposed at various locations on or within a vehicle body (e.g., chassis). In some embodiments, the filter assembly may be positioned adjacent to a wheel well or in another position that is susceptible to water ingestion along the vehicle body. In these instances, the filter assembly may be exposed to water in rainy environments or when the streets are flooded with water, which may contaminate the fresh air stream and increase the risk of water ingestion into the engine. These issues are exacerbated in configurations that do not include pre-cleaners or water separation devices upstream of the filter assembly (e.g., within other parts of the air intake system). Pre-cleaners and water separation devices also add restriction to the air filtration system, which can reduce engine performance.

[0025] The present application generally relates to systems for water separation and removal within a filter assembly. In particular, the present application relates to a filter assembly that includes a water collection sump that is integrally formed into a service cover of the filter assembly. The filter assembly includes a two-piece housing having a housing body and the service cover. The housing body defines an enclosed interior volume of the housing and an inlet port and an outlet port that are fluidly coupled to the interior volume. A portion of the water collection sump is disposed beneath (in axial alignment) with the inlet port when the service cover is installed onto the housing body. Fresh air entering the inlet port is directed toward the water collection sump, which facilitates water removal via inertial separation from the incoming air stream. Among other benefits, the water collection sump allows for separation and removal of water from within the filter assembly, which may substantially eliminate the need for other pre-separation devices upstream of the inlet port (e.g., such as vortex tube, snorkel, and/or louver-type pre-cleaners).

[0026] Before turning to the figures, which illustrate certain exemplary embodiments in detail, it should be understood that the present disclosure is not limited to the details or methodology set forth in the description or illustrated in the figures. It should also be understood that the terminology used herein is for the purpose of description only and should not be regarded as limiting.

[0027] FIG. 1 is a perspective view of a first example fluid filtration system, shown as system 100. The system 100 may be used to filter a fluid that is provided to an internal combustion engine. The fluid may be, for example, air or a similar gaseous substance. The system 100 may be mounted to a vehicle chassis. In other embodiments, the system 100 is configured for mounting to an engine.

[0028] As shown in FIG. 1, the system 100 includes a shell housing (e.g., housing body) 200 and a housing closure (e.g., service cover) 202. The housing closure 202 is removably coupled to the shell housing 200 such that an operator may remove the housing closure 202 to service an interior of the shell housing 200. The housing closure 202 may be coupled to the shell housing 200 using one of latches, fasteners, adhesives, or the like.

[0029] The shell housing 200 includes an inlet 204 and an outlet 206. The inlet 204 is upstream of the outlet 206. The inlet 204 transfers a flow of fluid directly or indirectly to an engine. The outlet 206 expels the flow of fluid post-filtering.

[0030] Referring now to FIG. 2, a cross-sectional view of the system 100 is shown. The system 100 includes a first cavity 210 and a second cavity 212, the second cavity 212 being in fluid communication with the first cavity 210. The first cavity 210 includes the inlet 204 and the second cavity 212 includes the outlet 206. In some embodiments, the outlet 206 transfers the filtered fluid, directly or indirectly, to an engine. The second cavity 212 is positioned downstream of the first cavity 210. The shell housing 200 may be formed of a single body including both the first cavity 210 and the second cavity 212, the shell housing 200 being formed from casting, milling, die-casting, additive manufacturing, and the like. The housing closure 202 forms a sealing engagement with the shell housing 200 such that a substantially watertight and/or airtight seal is formed between the shell housing 200 and the housing closure

202. The housing closure 202 may include a drain opening 213 (e.g., opening, aperture, valve, etc.) extending through the housing closure 202 and configured to facilitate a flow of fluid out of the shell housing 200. In some embodiments, the drain opening 213 is a one-way valve configured to prevent a flow of fluid from entering the shell housing 200 via the drain opening 213 but configured to facilitate a flow of fluid or liquid (e.g., moisture, condensate, water, water vapor, etc.) out of the shell housing 200. The drain opening 213 is in fluid communication with the second cavity 212. The housing closure 202 may further include a second drain opening 215 in fluid communication with the first cavity 210.

[0031] The second cavity 212 defines a second cavity inlet 214 and a second cavity outlet 216. The second cavity outlet 216 is in fluid communication with the outlet 206. The second cavity inlet 214 is upstream of the second cavity outlet 216. The second cavity 212 facilitates a flow of fluid from the second cavity inlet 214 to the second cavity outlet 216. The second cavity 212 may define a substantially cylindrical cross-section configured to receive a substantially cylindrical filter element. In some embodiments, the second cavity 212 defines a racetrack cross-section (e.g., two semicircles separated by straight lines) and is configured to receive a filter element having a racetrack cross-section. In some embodiments, the second cavity 212 defines a substantially oval cross-section and is configured to receive a filter element having a substantially oval cross-section.

[0032] A filter element 220 is removably positioned within the second cavity 212. In some embodiments, the filter element 220 is removably coupled to the shell housing 200, for example by fasteners, latches, or friction, such that the filter element 220 may be removed from the shell housing 200 and replaced with a new filter element.

[0033] The filter element 220 is disposed within the second cavity 212 of the shell housing 200 such that a central longitudinal axis 224 of the second cavity 212 extends through the filter element 220. The filter element 220 may be cylindrically-shaped and may include a cylindrically-shaped media pack 226 wound around an element core 228. In some embodiments, a cross-section of the filter element 220 may define a shape being substantially circular, racetrack, obround (e.g., two curved ends joined by two straight ends), elliptical, and

the like. In some embodiments, a cross-section of the media pack 226 defines a shape being substantially circular, racetrack, obround, elliptical, and the like. The cross-sectional shape of the element core 228 may influence the cross-section of the media pack. For example, if the element core 228 defines an elliptical cross-section, the media pack 226 may define a similarly elliptical cross-section. The media pack 226 includes filter media configured to filter particulate matter from a fluid flowing therethrough so as to produce filtered fluid (e.g., clean fluid). The filter media may be pleated or formed into another desired shape to increase a flow area through the media pack 226, or to otherwise alter the particle removal efficiency of the filter element 220. According to one embodiment, the media pack 226 may include a variety of different types of filter media, including but not limited to pleated media, corrugated media, tetrahedral media, or variations thereof, such as any of the filter media disclosed in PCT Application No. PCT/US 2019/065259, the entirety of which is incorporated by reference. U.S. Patent No. 8,397,920, entitled "PLEATED FILTER ELEMENT WITH TAPERING BEND LINES," by Moy et al, filed on October 14, 2011, and issued on March 19, 2013, assigned to Cummins Filtration IP Inc., which is incorporated by reference in its entirety and for all purposes, describes a tetrahedral filter media that the media pack 226 may comprise. Some configurations of tetrahedral filter media may comprise a plurality of inlet tetrahedron flow channels and a plurality of outlet tetrahedron flow channels. The inlet tetrahedron merge in a central portion of the tetrahedral filter media thereby allowing axial cross-flow of air between the inlet tetrahedron channels prior to the air passing through the tetrahedral filter media. Such an arrangement provides for additional dust loading on the upstream side of the media, which increases a filter capacity of the filter media. In some embodiments, the filter media includes a porous material having a predetermined pore size, a paper-based filter media, a fiber-based filter media, a foam-based filter media, or the like. The filter element 220 may be arranged as an axial-flow filter element having a dirty side 230 and a clean side 232. The dirty side 230 is upstream of the clean side 232. Specifically, the filter element 220 is configured to filter fluid that flows axially through the filter element 220 from the dirty side 230 to the clean side 232.

[0034] Referring to FIG. 3, a perspective view of the filter element 220 is shown. The filter element 220 includes a first end 240 (e.g., dirty end) and a second end 242 (e.g., clean end). A

first endcap 245 is coupled to the first end 240 and a second endcap 249 is coupled to the second end 242. In some embodiments, both the first endcap 245 and the second endcap 249 are open endcaps. In some embodiments, one of the first endcap 245 and the second endcap 249 is a closed endcap. Extending between the first end 240 and the second end 242 are the media pack 226 (shown in FIG. 5) and the element core 228. In some embodiments, the media pack 226 is surrounded by a shell 227 (e.g., housing, casing, exoskeleton, etc.). The shell 227 extends between the first end 240 and the second end 242 and protects the media pack 226 from damage. In some embodiments, the shell 227 is potted into the first endcap 245 and the second endcap 249. Coupled to the filter element 220 proximate to the second end 242 is a sealing member 244. The sealing member 244 is configured to form a sealing engagement with the shell housing 200. The sealing member 244 extends about a perimeter of (e.g., circumferentially about) the second end 242 and defines a generally annular body. In some embodiments, the sealing member 244 is coupled to the second endcap 249, and the second endcap 249 is coupled to the media pack 226 proximate to the second end 242. In some embodiments, the sealing member 244 is positioned to form a radial seal against the inner surface of the shell housing 200. In some embodiments, the sealing member 244 is positioned to form an axial seal against the shell housing 200. For example, when the housing closure 202 is coupled to the shell housing 200, a portion of the housing closure 202 may interface with a portion of the filter element 220, such as the first endcap 245. The interaction between the housing closure 202 and the filter element 220 may compress the filter element 220, and thus the sealing member 244, against an internal feature of the shell housing 200 (e.g., internal surface, ledge, etc.) to form one of an axial seal or a radial seal.

[0035] The filter element 220 further includes a hydrophobic mesh 246 positioned on (e.g., about, over, etc.) the second end 242. The hydrophobic mesh 246 is configured to resist or prevent moisture (e.g., water) and debris from passing through the media pack 226 while allowing air and other gaseous elements to pass through the media pack 226. In other words, the hydrophobic mesh 246 prevents or resists passage of moisture downstream of the filter element 220. In some embodiments, the hydrophobic mesh 246 is formed of a polymeric, woven mesh with an optional surface coating. In some embodiments, the hydrophobic mesh

246 is a polymeric mesh fabric. In some embodiments, the hydrophobic mesh 246 is a woven fabric. For example, the hydrophobic mesh 246 may be woven in a variety of weave patterns, such as a satin weave, sateen weave, dobby weave, and bi-directional weave. In some embodiments, the hydrophobic mesh 246 is a non-woven fabric. In some embodiments, the hydrophobic mesh 246 is formed of a textile, such as cotton, wool, and nylon, and treated with a hydrophobic surface treatment. In some embodiments, the hydrophobic mesh 246 is formed of a polymeric thread (e.g., high-density polyethylene, low density polyethylene, nylon, polyester, etc.) and woven into a fabric. The polymeric thread may be a monofilament thread. In some embodiments, the hydrophobic mesh 246 is formed of a woven stainless steel mesh having a hydrophobic coating, such as a Polytetrafluoroethylene (e.g., PTFE, Teflon™) coating. In some embodiments, the hydrophobic mesh 246 is a screen, such as an extruded screen or an extruded mesh. The hydrophobic mesh 246 may be formed by perforating a material to form a desired pore structure. In some embodiments, the hydrophobic mesh 246 is formed by perforating a material and then expanding (e.g., stretching) that material to form a desired pore size. In some embodiments, the hydrophobic mesh 246 covers the entirety of the second end 242. The hydrophobic mesh 246 may be coupled to the sealing member 244.

[0036] In some embodiments, the filter element 220 includes a support structure 248 (in the form of a grid in FIG. 3) that extends across the second end 242 and is interposed between the hydrophobic mesh 246 and the media pack 226. The support structure 248 may be formed of plastic, metal, wood, a polymer, or a similar material. The support structure 248 is formed of thin structures extending perpendicularly relative to one another, forming a lattice structure (e.g., an open framework formed of strips of material in a crisscross pattern). In some embodiments, the support structure 248 is formed of thin structures extending radially away from the central longitudinal axis 224 and toward the perimeter of the endcap 245. In some embodiments, the support structure 248 defines a broken rib pattern so that lateral movement of fluid between the broken rib pattern is allowed. For example, the thin structures that define the support structure 248 may include apertures that allow fluid to pass through laterally (e.g., in a direction substantially perpendicular to the central longitudinal axis 224). In some

embodiments, the hydrophobic mesh 246 is coupled to the support structure 248. The support structure 248 is configured to allow fluids, air, and debris to pass through.

[0037] In some embodiments, the first end 240 includes a support structure 250 (also in the form of a grid in particular embodiments) similar to the support structure 248. The first end 240 further includes the first endcap 245 similar to the second endcap 249. The support structure 250 may be coupled to the first end 240 with fasteners, adhesives, or the like. In some embodiments, a hydrophobic mesh (e.g., the hydrophobic mesh 246) is coupled to both the first end 240 and the second end 242. In some embodiments, the hydrophobic mesh 246 is coupled to the first end 240 and not coupled to the second end 242.

[0038] In some embodiments, the system 100 includes a secondary filter element that is downstream from the filter element 220. The secondary filter element may include the hydrophobic mesh 246 on one of or both of a dirty side and a clean side. In some embodiments, the system 100 includes a tertiary filter element that is positioned upstream of the filter element 220. The tertiary filter element may include the hydrophobic mesh 246 on one of or both of a dirty side and a clean side. In some embodiments, such as with inside-out filters and outside-in filters, the hydrophobic mesh 246 is wrapped circumferentially about the media pack 226 and is potted into the first endcap 245 and the second endcap 249.

[0039] Referring now to FIG. 5, a top view of the second end 242 of the filter element 220 is shown. The filter element 220 is shown having a substantially racetrack cross-section. Similarly, the hydrophobic mesh 246 defines a substantially racetrack surface area. A perimeter of the hydrophobic mesh 246 is coupled to the sealing member 244. Interposed between the hydrophobic mesh 246 and the media pack 226 is the support structure 248. The support structure 248 includes a narrow support member that extends from a first point of the sealing member 244 to a second point of the sealing member 244. The hydrophobic mesh 246 may be coupled to the support structure 248 and to a plurality of points 252 about the support structure 248. In some embodiments, the hydrophobic mesh 246 is coupled to the media pack 226 and is not coupled to the sealing member 244. In some embodiments, the hydrophobic mesh 246 is interposed between the media pack 226 and the support structure 248 and the hydrophobic

mesh 246 is coupled to the media pack 226. In some embodiments, the hydrophobic mesh 246 is coupled to the shell 227 proximate to the second end 242. In some embodiments, the hydrophobic mesh 246 is separate from the filter element 220 and is positioned downstream of the filter element 220 when the filter element 220 is positioned within the shell housing 200. In some embodiments, the hydrophobic mesh 246 is coupled to the shell housing 200 downstream of the filter element 220.

[0040] In some embodiments, the cross-sectional shape of the media pack 226 is different from the cross-sectional shape of the sealing member 244. For example, the media pack 226 may define a cross-section having a racetrack shape while the sealing member 244 defines a cross-section having an elliptical shape (as shown in FIG. 3). Similarly, in some embodiments, the media pack 226 may define a cross-section having an obround shape while the sealing member 244 may define a cross-section having a racetrack shape. Each of the sealing member 244, the endcap 245, the shell 227, the media pack 226, the hydrophobic mesh 246, and the endcap 249 may define different cross-sectional shapes. In some embodiments, the second cavity 212 defines different cross-sectional shapes between the second cavity inlet 214 and the second cavity outlet 216. Similarly, the filter element 220 may define different cross-sectional shapes between the first end 240 and the second end 242.

[0041] Referring now to FIGS. 6 and 7, a filter assembly 300 is shown, according to another example embodiment. The filter assembly 300 includes a housing 400 (e.g., shell, etc.) that includes a housing body 402 and a service cover 404. The housing body 402 defines an interior volume 406 sized to receive a replaceable air filter element 500 therein. The housing body 402 also defines an inlet port 408 and an outlet port 410 that are fluidly coupled to the interior volume 406 for directing air flow into and out of the interior volume 406, respectively. The inlet port 408 and the outlet port 410 are both disposed on an upper end of the housing body 402 and are axially offset from one another. The service cover 404 is movable with respect to the housing body 402 so as to provide access to the interior volume 406. In one embodiment, the service cover 404 is hingedly (e.g., rotatably) coupled to the housing body 402 and can rotate between an open position (in which a user may access the interior volume 406 through an opening in the housing body 402) and a closed position that prevents access to the interior

volume 406. In another embodiment, the service cover 404 is removably (e.g., detachably) coupled to the housing body 402 and can be separated from the housing body 402 to gain access to the interior volume 406. The service cover 404 may be secured to the housing body 402 in a closed (e.g., installed) position using clips, latches, or another suitable fastener.

[0042] As shown in FIG. 7, the filter element 500 is removably installed into the housing body 402 proximate to the outlet port 410. In one embodiment, the filter element 500 is sealingly engaged with the housing body 402 proximate to the outlet port 410. The filter element 500 includes a media pack 502, a first (e.g., upper) endcap 504, and a second (e.g., lower) endcap 506. The first endcap 504 is coupled to the media pack 502 at an upper end of the media pack 502. The second endcap 506 is coupled to the media pack 502 at a lower end of the media pack 502 (e.g., at an opposite axial end of the media pack 502 as the first endcap 504). The first endcap 504 and the second endcap 506 may be frames that support the media pack 502 and ensure sealing between the filter element 500 and the housing body 402. The first endcap 504 and the second endcap 506 may be formed from plastic (e.g., hard polyurethane, etc.), metal, or another suitable material. The media pack 502 may include any fibrous or porous media used to remove solid particulates from an incoming air stream. The media may include a paper-based filter media, a fiber-based filter media, a foam-based filter media, or the like. In one embodiment, the media pack 502 includes a pleated filter media. For example, the media pack 502 may be defined by a plurality of interdigitated tetrahedral forms extending from an upstream and a downstream end of the media pack 502. Examples of tetrahedral forms are described in detail in International Patent Publication No. PCT/US2019/039876, filed June 28, 2019, and U.S. Patent No. 8,397,920, filed October 14, 2011, the entire disclosures of which are hereby incorporated by reference herein. In embodiments, the media pack 502 may comprise another form of pleated media or pleated media shape.

[0043] The service cover 404 is coupled to an opening at a lower end of the housing body 402, opposite from the upper end. Together, the housing body 402 and the service cover 404 substantially enclose the interior volume 406. As shown in FIG. 7, the service cover 404 defines a protrusion extending from an interior surface of the service cover 404 into the interior

volume 406. The protrusion includes a ramp 412 that extends along a sidewall of the protrusion toward the interior surface of the service cover 404. The ramp 412 may be a fillet (e.g., chamfer) along a lower edge of the protrusion. The radius of the fillet may be approximately equal to the height of the protrusion. In other embodiments, the radius of the fillet may be different. Among other benefits, the ramp 412 facilitates the transition of air flow from a substantially axial direction (e.g., vertical direction as shown in FIG. 7) from the inlet port 408 into the interior volume 406 to a horizontal direction across the interior volume 406 between the inlet port 408 and the outlet port 410. In some embodiments, the ramp 412 may reduce the pressure loss across the filter assembly by approximately 8% or greater. As shown in FIG. 7, the service cover 404 also includes a plurality of support members extending upwardly from the interior surface of the service cover 404 toward the filter element 500. When the service cover 404 is installed onto the housing body 402, an upper end of each support member contacts a lower end of the filter element 500 to support the filter element in position within the housing 400 and to ensure that the filter element remains sealingly engaged with the housing body 402.

[0044] Referring now to FIG. 8, a filter assembly 600 is shown, according to another example embodiment. The filter assembly 600 is similar to the filter assembly 300 of FIGS. 6 and 7. A difference between the filter assembly 600 and the filter assembly 300 is that the filter assembly 600 includes a water collection sump 714 that is integrated into the service cover 704. In one embodiment, the service cover 704 is a two-part design in which the water collection sump 714 is a separate part that connects to a second cover part (e.g., a flat second cover part that connects to the housing body 702) to form the service cover 704. In another embodiment, the water collection sump 714 is a separately accessible component from the service cover 704. In yet another embodiment, the water collection sump 714 is integrally formed with the service cover 704 so that the water collection sump 714 is not separable from the service cover 704. In still another embodiment, the water collection sump 714 is coupled to the housing body 702 separate from the service cover 704. The water collection sump 714 includes a partition 716 (e.g., a sidewall, perimeter wall, etc.) that extends upwardly from the lower wall (e.g., interior surface) of the service cover 704 and is in a substantially perpendicular orientation with respect

to the lower wall. The partition 716 defines a recessed area 718 that is at least partially axially aligned with the inlet port when the service cover 704 is installed onto the housing body 702. In other words, the inlet port defines a central axis, and the recessed area 718 is intersected by the central axis when the service cover 704 is coupled to the housing body 702. As shown in FIG. 8, the water collection sump 714 is located directly below the inlet port 708 and the duct (extending upwardly from the inlet port 708) such that incoming water from the inlet port 708 (and duct) can fall inside the water collection sump 714 and separate from the main air flow to reduce the overall water intrusion into the clean side of the filter assembly 600. In the embodiment of FIG. 8, the recessed area 718 is a substantially rectangular cavity. In other embodiments, the shape and/or size of the recessed area 718 may be different. The water collection sump 714 also includes a drain (e.g., port, opening, etc.) disposed along a lower wall of the recessed area 718 and configured to allow separated water to exit the interior volume 706. The drain may include a drain valve (e.g., a check valve, one way valve, solenoid valve, etc.) to selectively fluidly couple the interior volume to an environment surrounding the filter assembly 600. As shown in FIG. 8, a portion 720 of the partition 716 separates the water collection sump 714 from an area of the service cover 704 that is axially aligned with the filter element 500. This portion 720 of the partition 716 may also define the ramp 712 as described with reference to FIGS. 6 and 7.

[0045] As shown in FIG. 8, air entering the interior volume 706 from the inlet port 708 moves axially (e.g., vertically as shown in FIG. 8) downward toward the water collection sump 714 and then transitions to a lateral direction toward the filter element 500. Water is separated from the main air flow due to the higher inertia of water compared to the air (inertial separation). The separated water is collected inside the water collection sump 714.

[0046] The design and arrangement of components described with reference to FIG. 8 should not be considered limiting. Many alternatives and combinations are possible without departing from the inventive concepts disclosed herein. For example, FIGS. 9-13 show examples of different structures that can be used for the service cover (e.g., the housing closure 202; the service cover 404, 704) and housing body (e.g., the shell housing 200; the housing body 402, 702). FIGS. 9 and 10 show a housing body 902 that has an inlet duct 922 extending from the

inlet port 908 and axially toward the service cover 904. The inlet duct 922 is disposed within the interior volume 706 of the housing body 902 and directs incoming air axially toward the water collection sump 914 in the service cover 904 to improve separation of the water from the incoming air. As shown in FIG. 10, the partition 916 is contoured to match the profile (e.g., shape) of the inlet duct 922. In other words, the partition 916 extends at least partially laterally (e.g., horizontally as shown in FIG. 9) away from a first lateral end of the service cover 904 toward a second (e.g., opposite) lateral end of the service cover 904 in the vicinity of the inlet duct 922 (e.g., along a portion of the partition 916 that is aligned with the inlet duct 922).

[0047] As shown in FIG. 10, the water collection sump 914 includes a plurality of baffles 924 disposed within the recessed area. The baffles 924 extend away from a lower wall 926 of the service cover 904 in a substantially perpendicular orientation relative to the lower wall 926. Among other benefits, the baffles 924 reduce sloshing of any separated water within the recessed area. Water accumulated within the recessed area flows over the partition 916 toward a drain (e.g., port, opening, etc.) disposed along a drain floor 928 of the service cover 904, beneath the filter element 500. The drain may include a drain valve (e.g., check valve, one way valve, solenoid valve, etc.) configured to allow water to be ejected from the interior volume 706. In other embodiments, a drain may be disposed in the lower wall of the recessed area. As shown in FIG. 10, the service cover 904 additionally includes a plurality of angled ribs 930 extending upwardly from the drain floor 928 to further reduce flow interaction between the air stream and the water along the drain floor 928. The arrangement of baffles 924 and ribs 930 may be different in various embodiments.

[0048] FIG. 11 shows a housing configuration in which the housing body 1002 includes a bellmouth 1032 disposed at an outlet end of the inlet duct 1022. Among other benefits, the bellmouth 1032 reduces the pressure loss across the transition between the inlet duct 1022 and the interior volume 706. In other embodiments, the design of the inlet duct 1022 may be different. For example, FIG. 12 shows a housing body 1102 having a diffuser-shaped inlet duct 1122 having an inner diameter at an outlet end of the inlet duct that is greater than an inner diameter at an inlet end of the inlet duct. The diameter of the inlet duct 1122 increases

continuously from the inlet port 1108 toward the water collection sump 1114 to further reduce pressure loss across the inlet duct 1122 and filter assembly 300, 600.

[0049] The size and/or shape of the water collection sump may also be different in various embodiments. For example, FIG. 13 shows a service cover 1204 in which the volume of the water collection sump 1214 is increased by extending the partition 1216 along a circumferential portion of the drain floor 1228 (e.g., along an outside edge of the drain floor in a region of the drain floor 1228, in a dead flow zones between the outer perimeter of the filter element and the sidewalls of the housing body where the main air flow is not affected by the presence of the partition 1216).

[0050] FIG. 14 shows another example service cover 1304 that includes multiple drains (e.g., drain openings, ports, holes, etc.), including a first drain 1319 disposed in the water collection sump 1314, along a lower wall of the recessed area 1318, and a second drain 1321 disposed along a drain floor 1328 of the service cover 1304 outside of the water collection sump 1314. As shown, the first drain 1319 and the second drain 1321 are disposed at a central position along the recessed area 1318 and the drain floor 1328, respectively. In other embodiments, the position, size, and/or number of drains may be different. One or both of the first drain 1319 and the second drain 1321 may also include drain valves to control the draining of water from the filter assembly 300, 600.

[0051] As utilized herein with respect to numerical ranges, the terms “approximately,” “about,” “substantially,” and similar terms generally mean $\pm 10\%$ of the disclosed values, unless specified otherwise. As utilized herein with respect to structural features (e.g., to describe shape, size, orientation, direction, relative position, etc.), the terms “approximately,” “about,” “substantially,” and similar terms are meant to cover minor variations in structure that may result from, for example, the manufacturing or assembly process and are intended to have a broad meaning in harmony with the common and accepted usage by those of ordinary skill in the art to which the subject matter of this disclosure pertains. Accordingly, these terms should be interpreted as indicating that insubstantial or inconsequential modifications or alterations of

the subject matter described and claimed are considered to be within the scope of the disclosure as recited in the appended claims.

[0052] It should be noted that the term “exemplary” and variations thereof, as used herein to describe various embodiments, are intended to indicate that such embodiments are possible examples, representations, or illustrations of possible embodiments (and such terms are not intended to connote that such embodiments are necessarily extraordinary or superlative examples).

[0053] The term “coupled” and variations thereof, as used herein, means the joining of two members directly or indirectly to one another. Such joining may be stationary (e.g., permanent or fixed) or moveable (e.g., removable or releasable). Such joining may be achieved with the two members coupled directly to each other, with the two members coupled to each other using a separate intervening member and any additional intermediate members coupled with one another, or with the two members coupled to each other using an intervening member that is integrally formed as a single unitary body with one of the two members. If “coupled” or variations thereof are modified by an additional term (e.g., directly coupled), the generic definition of “coupled” provided above is modified by the plain language meaning of the additional term (e.g., “directly coupled” means the joining of two members without any separate intervening member), resulting in a narrower definition than the generic definition of “coupled” provided above. Such coupling may be mechanical, electrical, or fluidic.

[0054] References herein to the positions of elements (e.g., “top,” “bottom,” “above,” “below”) are merely used to describe the orientation of various elements in the FIGURES. It should be noted that the orientation of various elements may differ according to other exemplary embodiments, and that such variations are intended to be encompassed by the present disclosure.

WHAT IS CLAIMED IS:

1. A filter assembly, comprising:
 - a housing, comprising:
 - a housing body defining an interior volume, an inlet port, and an outlet port;
 - a service cover movable with respect to the housing body so as to provide access to the interior volume, the service cover having a water collection sump that is at least partially axially aligned with the inlet port when the service cover is installed onto the housing body;
 - and
 - a filter element disposed within the interior volume.
2. The filter assembly of claim 1, wherein the water collection sump includes a partition defining a recessed area, a portion of the partition defining a ramp.
3. The filter assembly of claim 2, wherein the partition separates the water collection sump from an area of the service cover that is axially aligned with the filter element.
4. The filter assembly of claim 2, wherein the water collection sump includes a plurality of baffles disposed within the recessed area, the plurality of baffles extending away from a lower wall of the service cover in substantially perpendicular orientation relative to the lower wall.
5. The filter assembly of claim 1, wherein the housing body comprises an inlet duct extending from the inlet port and toward the service cover.
6. The filter assembly of claim 5, wherein the housing body further comprises a bellmouth disposed at an outlet end of the inlet duct.
7. The filter assembly of claim 5, wherein the inlet duct is a diffuser-shaped inlet duct having an inner diameter at an outlet end of the inlet duct that is greater than an inner diameter at an inlet end of the inlet duct.
8. The filter assembly of claim 5, wherein the water collection sump includes a partition defining a recessed area, the partition extending at least partially laterally away from a first

lateral end of the service cover toward a second lateral end of the service cover in a portion of the partition that is aligned with the inlet duct.

9. The filter assembly of claim 1, wherein the water collection sump is movable with respect to other parts of the service cover.

10. The filter assembly of claim 1, further comprising a drain valve disposed in the water collection sump.

11. The filter assembly of claim 1, wherein the service cover further comprises a drain floor, the drain floor axially aligned with the filter element when the service cover is installed onto the housing body, the filter assembly further comprising a drain valve disposed in the drain floor.

12. A fluid filtration system comprising:

- a shell housing;

- a housing closure configured to form a sealing engagement with the shell housing, the housing closure comprising a drain opening extending through the housing closure and configured to selectively facilitate a flow of liquid out of the shell housing;

- a filter element removably coupled to the shell housing, the filter element comprising:

- a first endcap;

- a second endcap downstream of the first endcap;

- a media pack comprising filter media, the media pack extending between and coupled to both of the first endcap and the second endcap; and

- a hydrophobic mesh coupled to one of the first endcap and the second endcap and configured to prevent moisture from flowing out of the shell housing.

13. The fluid filtration system of claim 12, wherein:

- the shell housing includes a second cavity and a first cavity,

- the first cavity is upstream of the second cavity, and

- the drain opening is in fluid communication with the second cavity.

14. The fluid filtration system of claim 13, wherein the filter element is positioned within the second cavity and the hydrophobic mesh is coupled to the second endcap.
15. The fluid filtration system of claim 13, wherein the first cavity has a smaller volume than the second cavity.
16. The fluid filtration system of claim 12, wherein the drain opening is axially aligned with the inlet of the shell housing.
17. The fluid filtration system of claim 12, wherein the housing closure is rotatably coupled to the shell housing, the housing closure comprising a partition that defines a recessed area aligned with the filter element when the filter element is positioned within the shell housing.
18. A filter element comprising:
 - a media pack having a first end and a second end;
 - a first endcap coupled to the first end;
 - a second endcap coupled to the second end and positioned downstream of the first end, the second endcap comprising a sealing member configured to form a sealing engagement with a shell housing; and
 - a hydrophobic mesh extending across one of the first end and the second end, the hydrophobic mesh configured to substantially prevent moisture from flowing downstream of the media pack.
19. The filter element of claim 18, further comprising a support structure coupled to one of the first endcap and the second endcap and extending across one of the first end and the second end, the support structure coupled to the hydrophobic mesh.
20. The filter element of claim 19, wherein the hydrophobic mesh is coupled to the second endcap such that the hydrophobic mesh substantially prevents water from entering the media pack.

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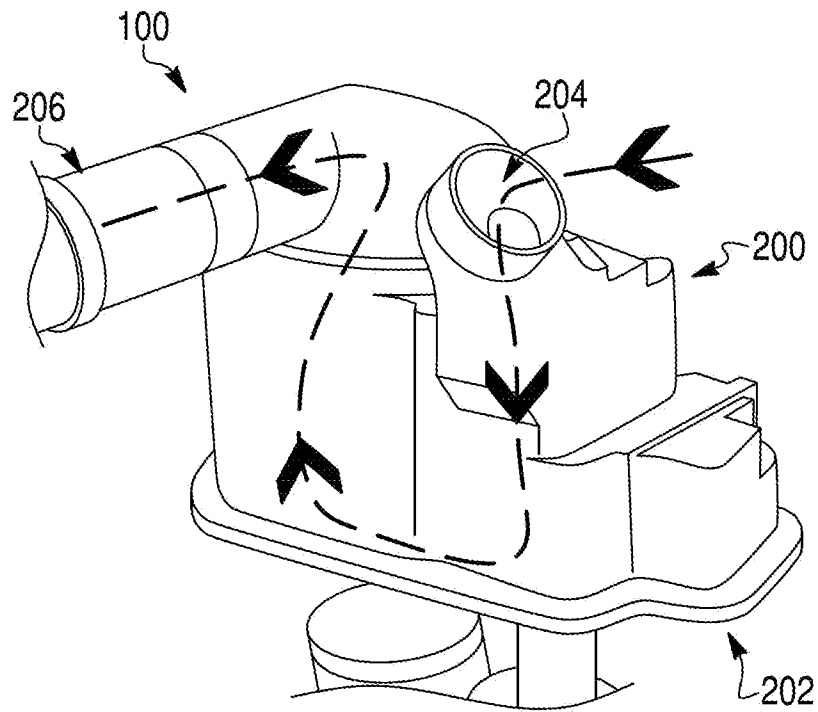


FIG. 1

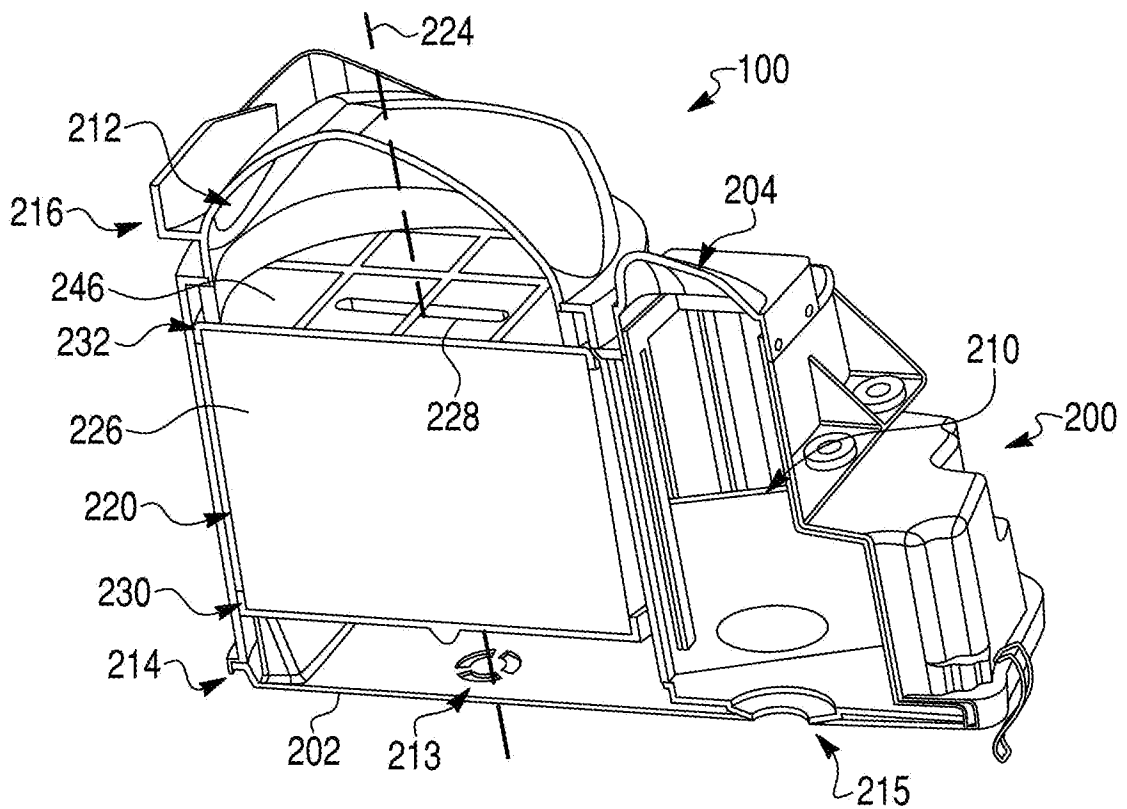


FIG. 2

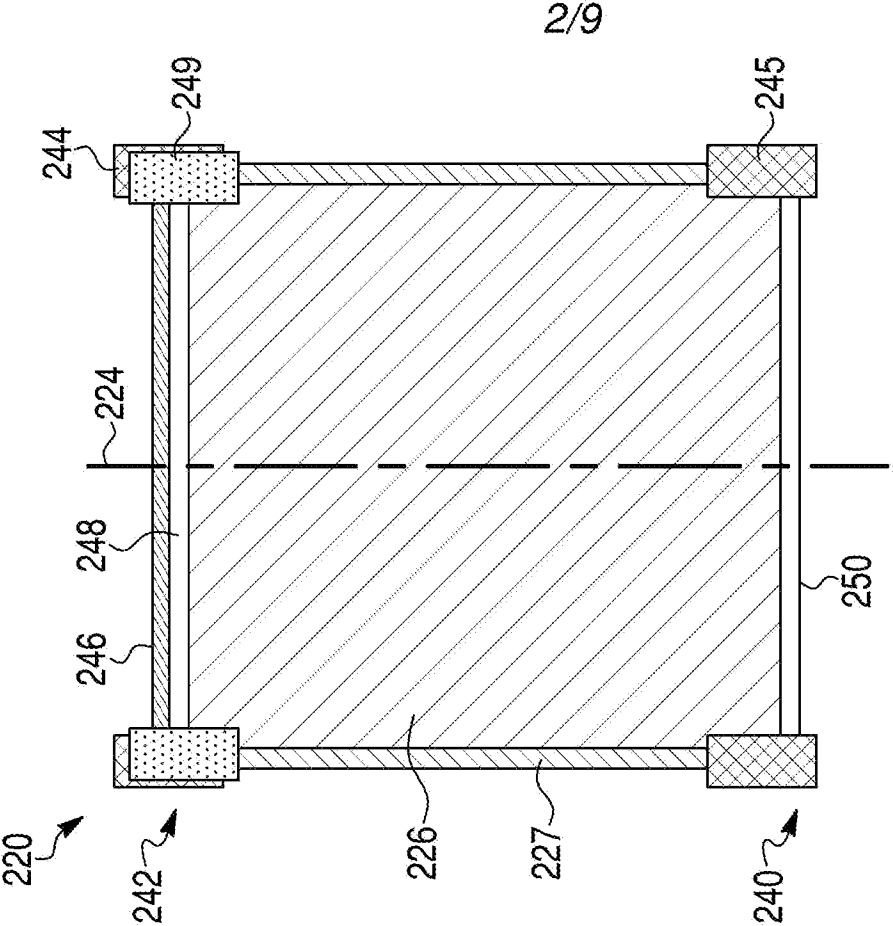


FIG. 4

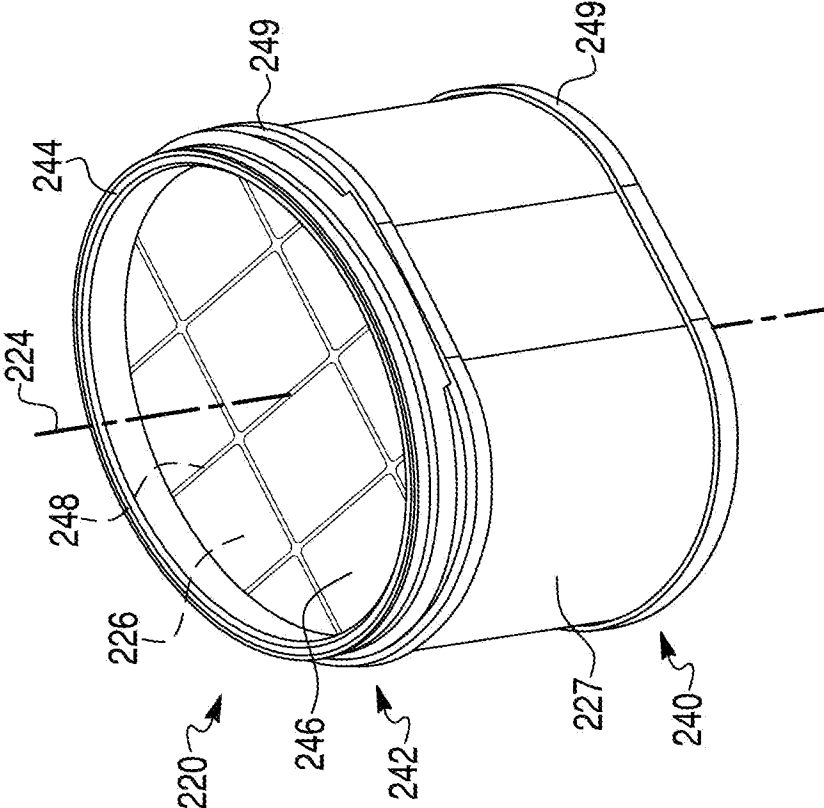


FIG. 3

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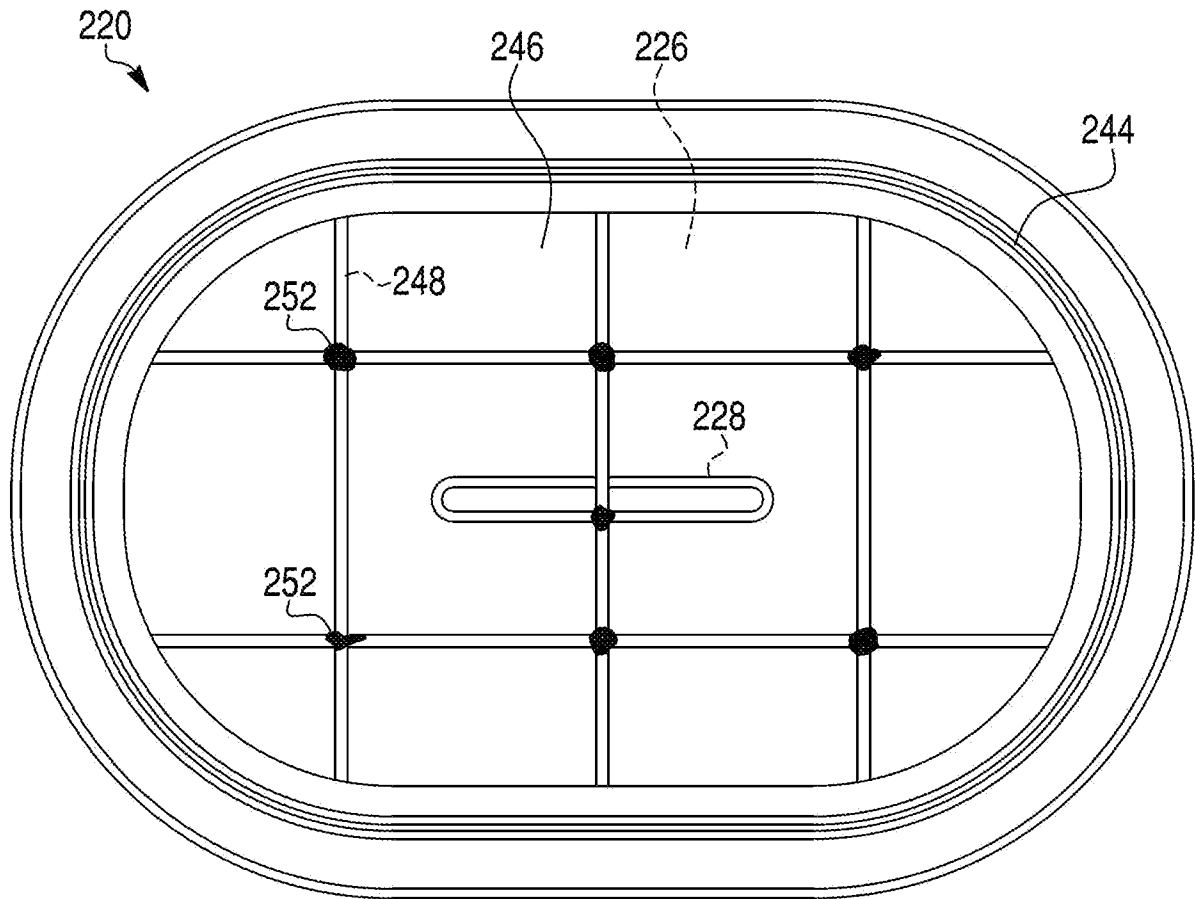


FIG. 5

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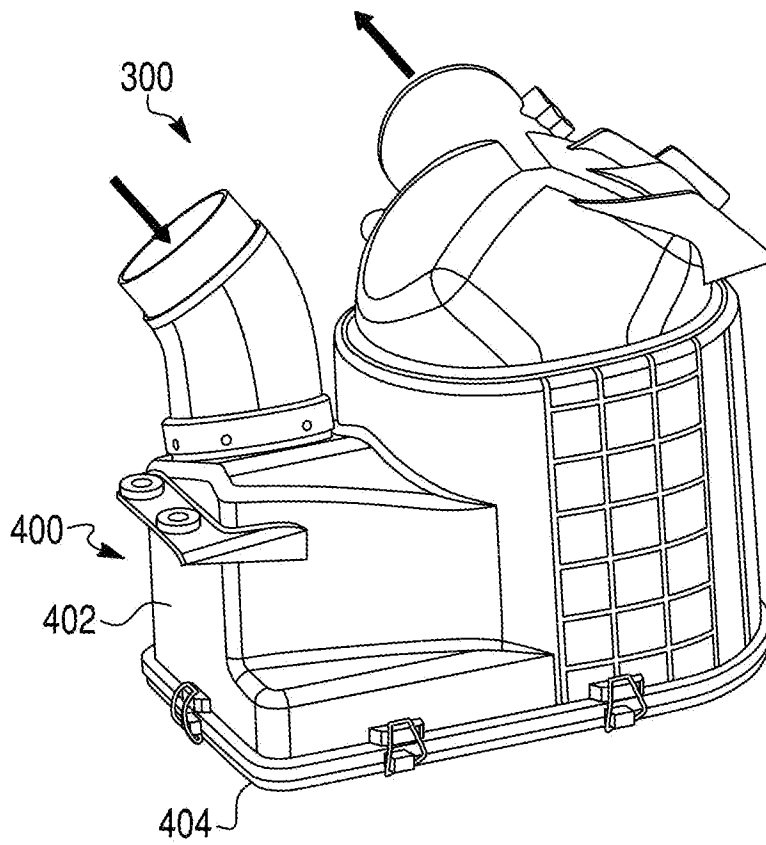
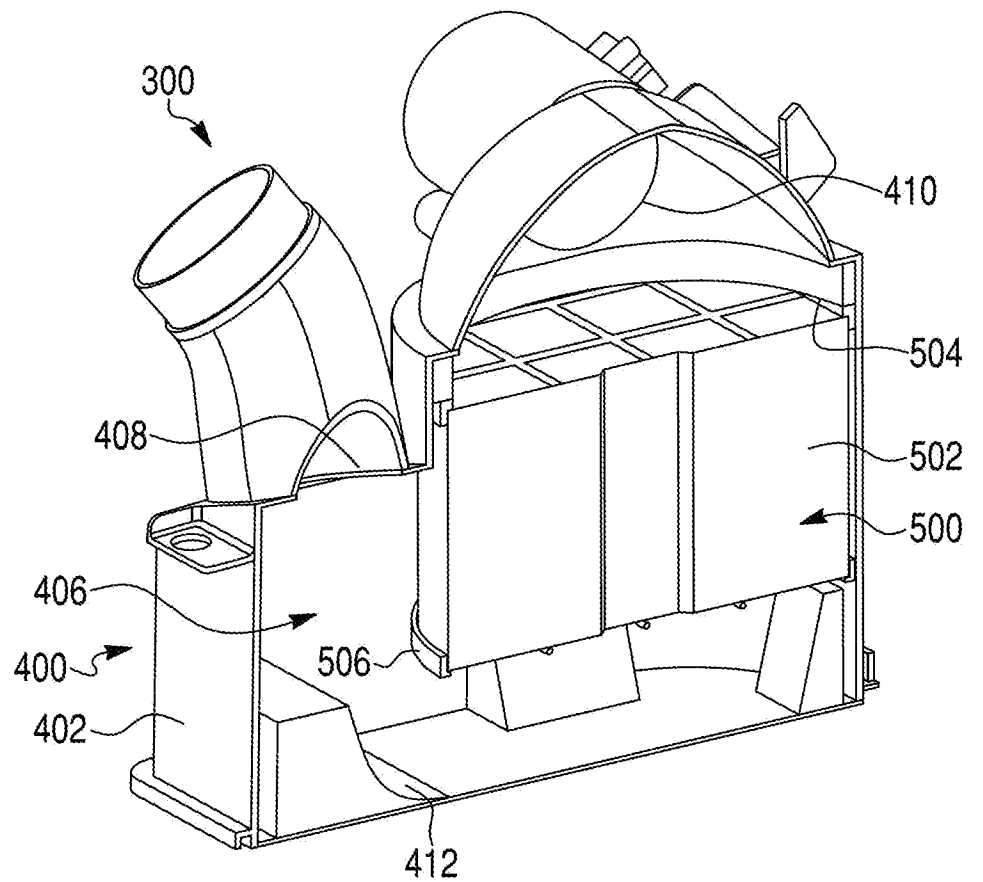


FIG. 6

FIG. 7



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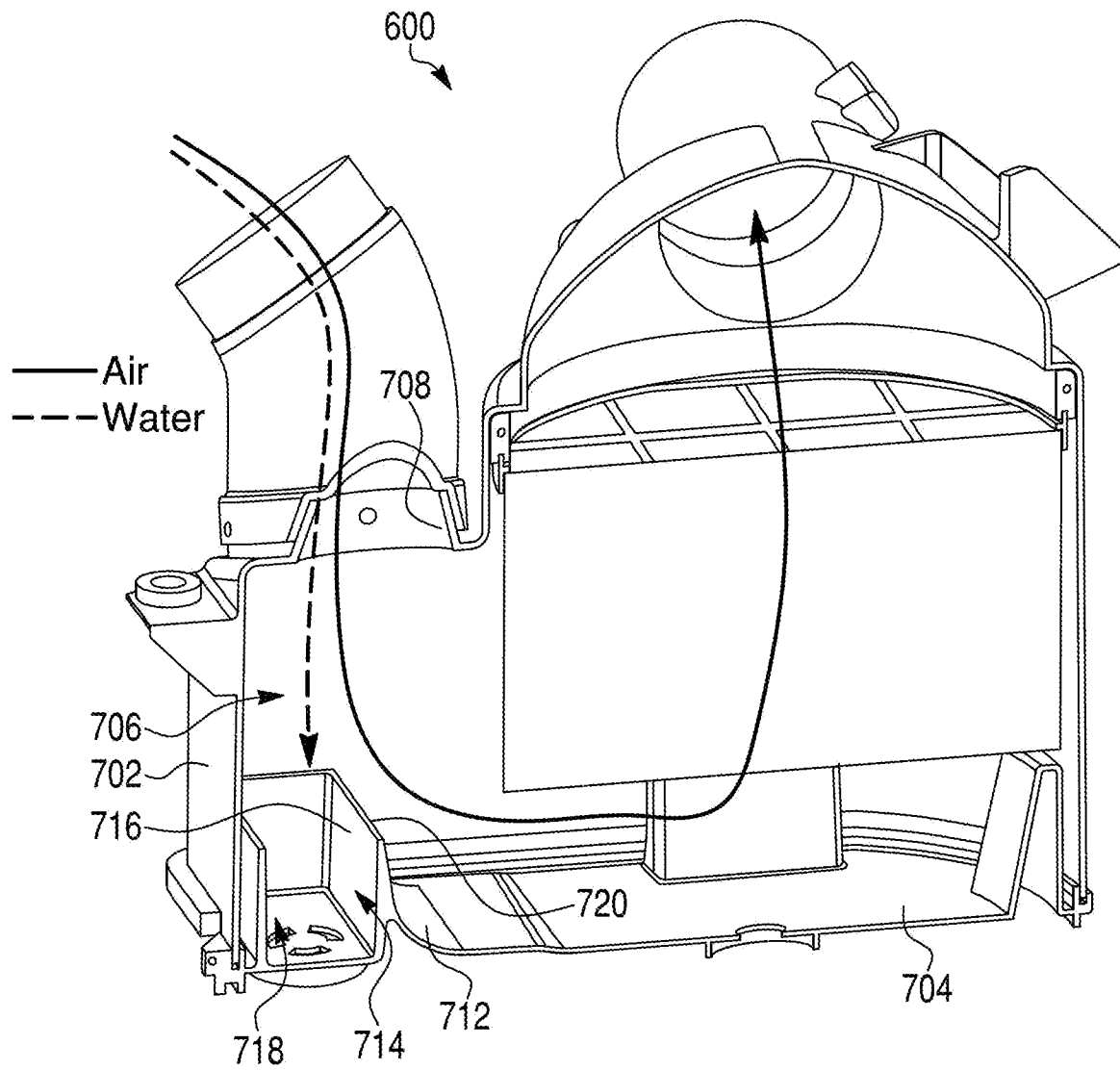


FIG. 8

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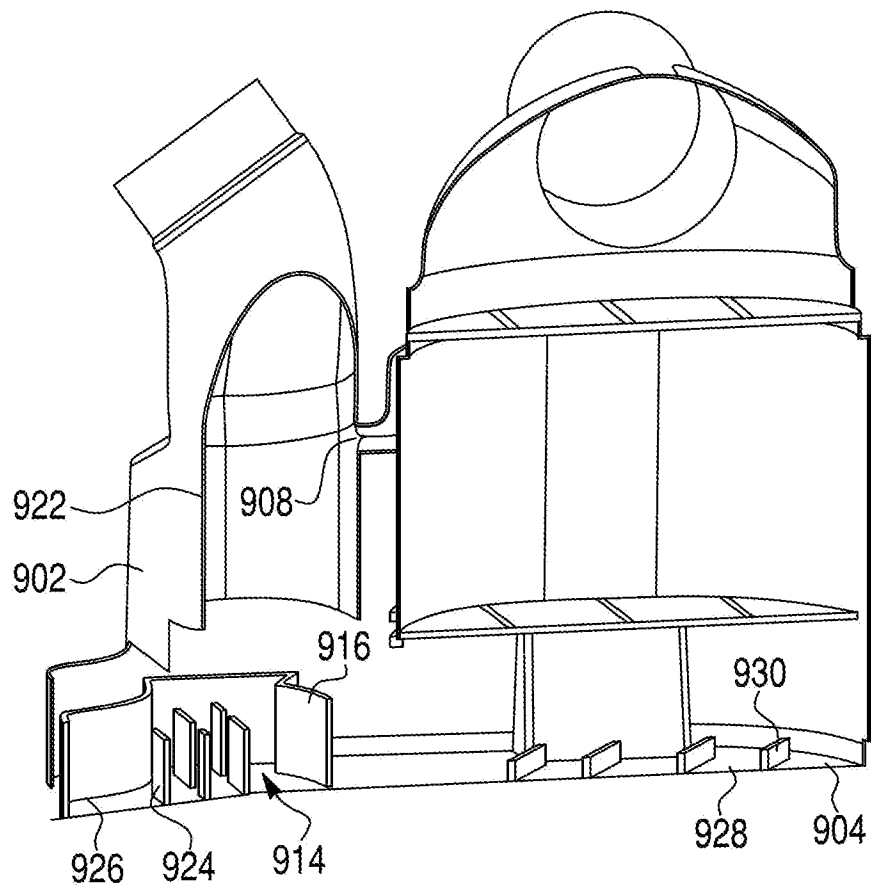


FIG. 9

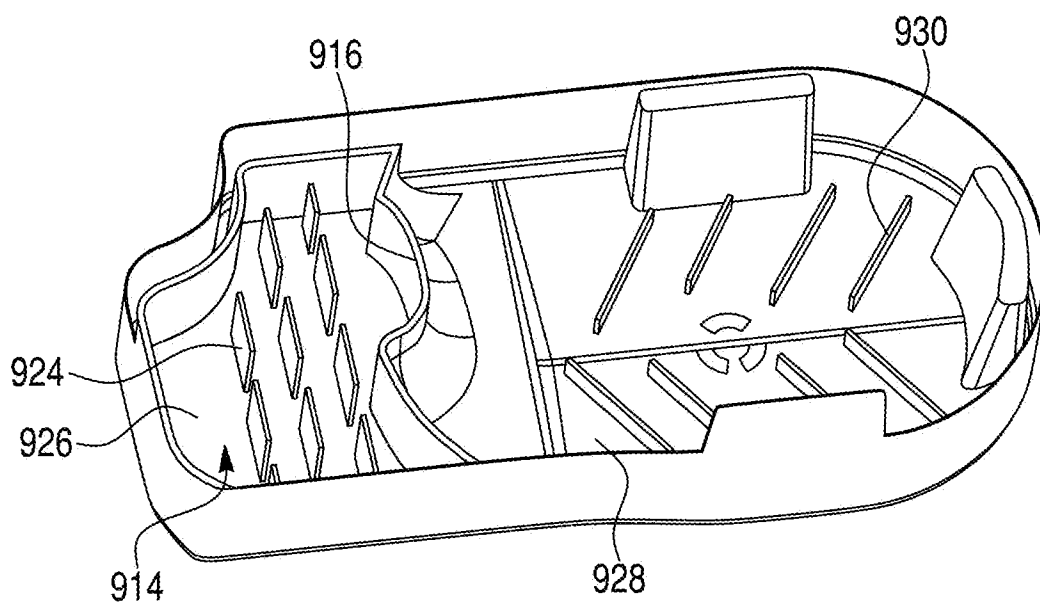


FIG. 10

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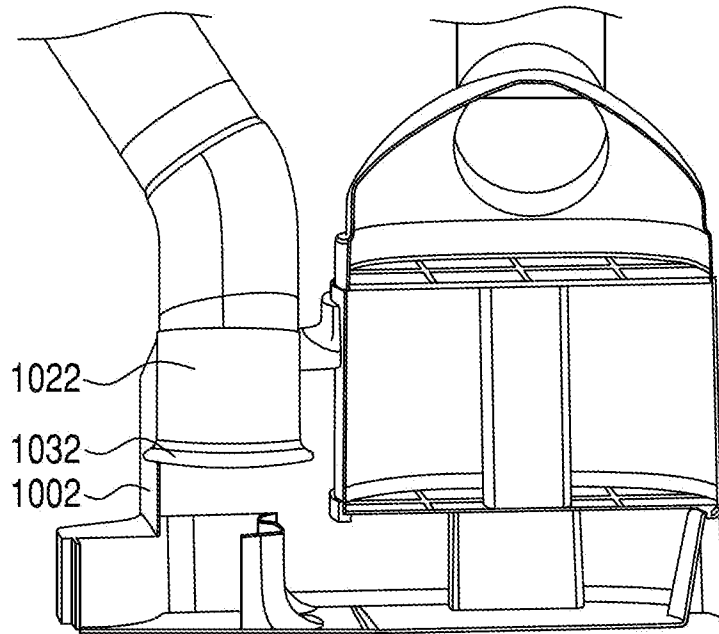


FIG. 11

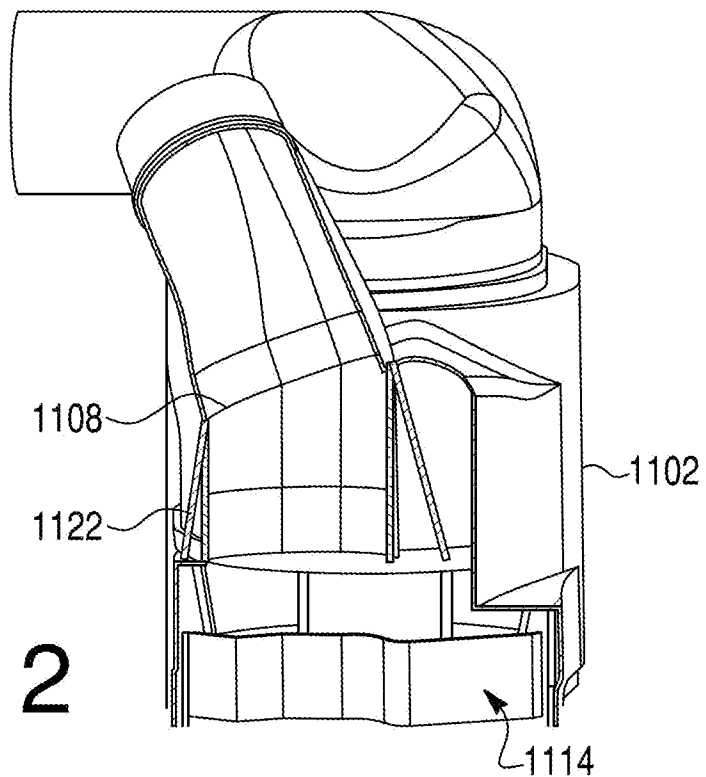


FIG. 12

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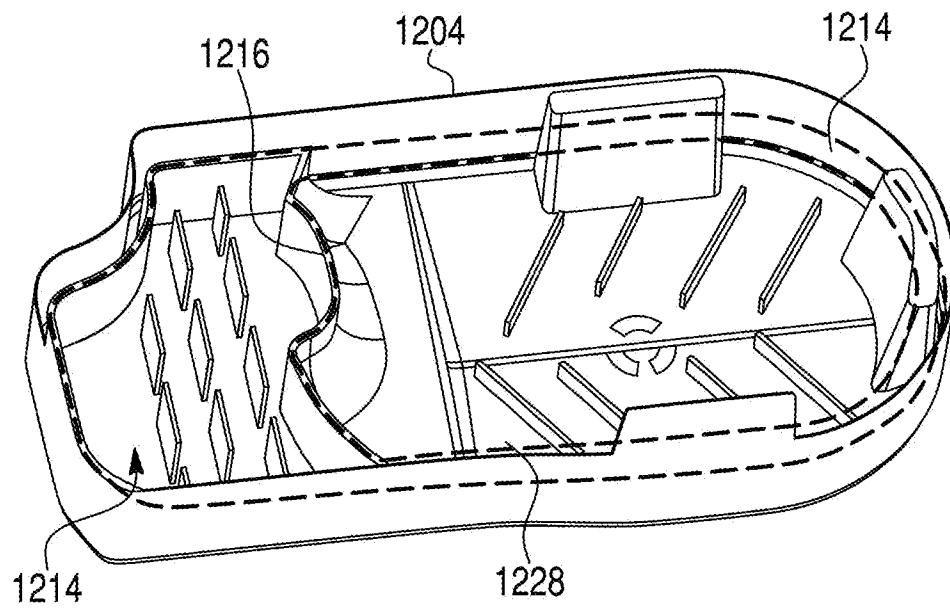


FIG. 13

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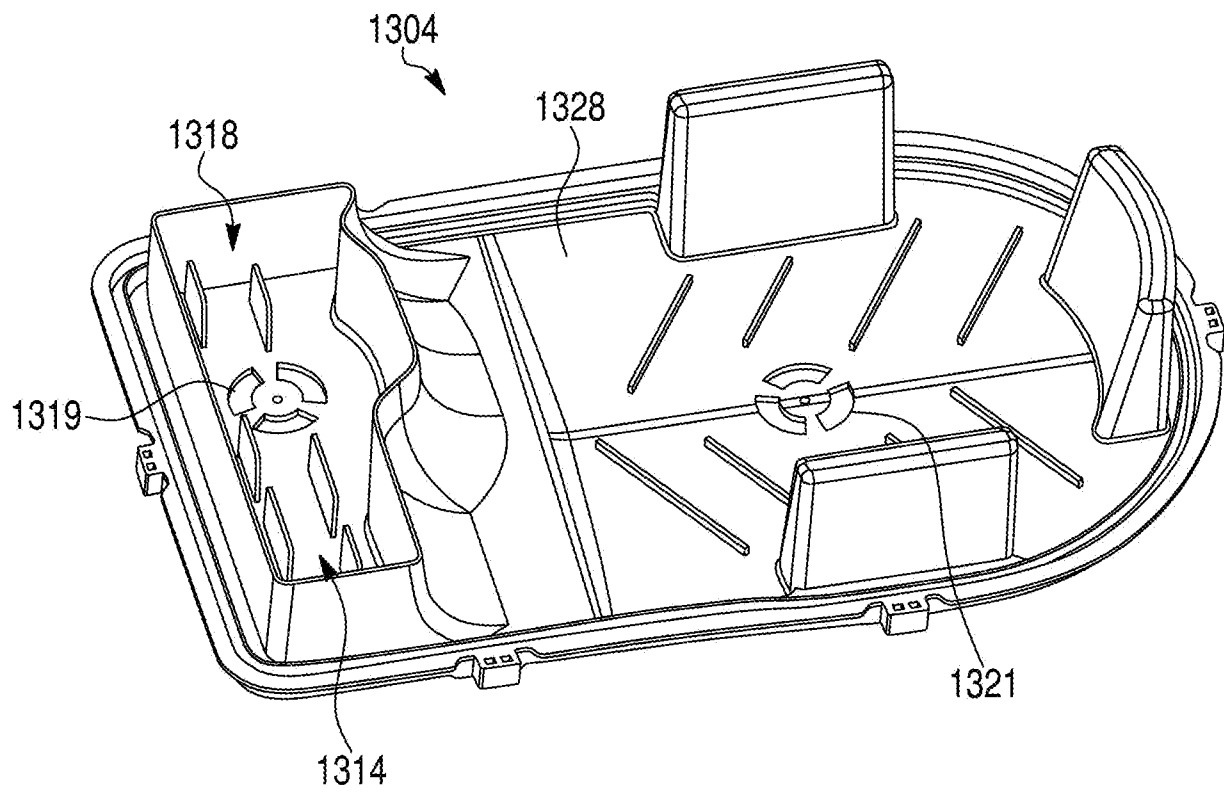


FIG. 14

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 21/53576

A. CLASSIFICATION OF SUBJECT MATTER

IPC - B01D 50/00 (2022.01)

CPC - B01D 50/00

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)

See Search History document

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

See Search History document

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

See Search History document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2008/0282654 A1 (MATSCHL et al.) 20 November 2008 (20.11.2008) Fig. 3; para [0040], [0042], [0043], [0044], [0049], [0051].	1-3, 5-6, 8
Y		4, 7, 9-11
Y	US 4,000,779 A (IRWIN) 04 January 1977 (04.01.1977) Fig. 1; col 2 ln 41-53; col 3 ln 32-44; col 4 ln 20-32; col 5 ln 16-24.	4
Y	US 6,540,802 B2 (TRAUTMANN et al.) 01 April 2003 (01.04.2003) Fig. 1; col 4 ln 25-39, 51-67; col 5 ln 1-10.	7
Y	US 5,022,479 A (KISER et al.) 11 June 1991 (11.06.1991) Fig. 1; col 2 ln 46-51; col 3 ln 7-16, 48-65.	9-11
A	US 3,298,149 A (SOBECK) 17 January 1967 (17.01.1967) Figs. 1-2; col 3 ln 3-12; col 4 ln 18-25, 59-61.	1-11
A	US 2005/0120686 A1 (NAKAGOME et al.) 09 June 2005 (09.06.2005) Figs. 1-3; para [0028], [0029], [0032], [0033].	1-11
A	US 3,147,100 (WILBER) 01 September 1964 (01.09.1964) Figs. 1-3; col 1 ln 65-col 2 ln 13; col 3 ln 3-18.	1-11
A	US 5,391,099 A (ALLAIN) 21 February 1995 (21.02.1995) Figs. 1-2; col 3 ln 19-42, 59-66; col 4 ln 15-49; col 5 ln 14-29.	1-11

☐ Further documents are listed in the continuation of Box C.☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"D" document cited by the applicant in the international application

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"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

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

09 February 2022

Date of mailing of the international search report

FEB 23 2022

Name and mailing address of the ISA/US

Mail Stop PCT, Attn: ISA/US, Commissioner for Patents

P.O. Box 1450, Alexandria, Virginia 22313-1450

Facsimile No. 571-273-8300

Authorized officer

Karl Rodriguez

Telephone No. PCT Helpdesk: 571-272-4300

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 21/53576

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

-*- See Extra Sheet -*-

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:
1-11

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 21/53576

-*- Box III - Observations where unity of invention is lacking -*-

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be searched, the appropriate additional search fees must be paid.

Group I: Claims 1-11, directed to a filter assembly comprising a service cover having a water collection sump

Group II: Claims 12-20, directed to a fluid filtration system or filter element comprising a media pack and a hydrophobic mesh.

The inventions listed as Groups I-II do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons:

-*- SPECIAL TECHNICAL FEATURES -*-

The invention of Group I includes the special technical feature of a service cover movable so as to provide access to an interior volume, the service cover having a water collection sump that is at least partially axially aligned with the inlet port, an inlet port, and an outlet port not required by the claims of Group II.

The invention of Group II includes the special technical features of a media pack comprising a filter media, a hydrophobic mesh, at least one endcap, not required by the claims of Group I.

-*- COMMON TECHNICAL FEATURES -*-

Groups I-II share the common technical feature of a filter apparatus comprising a housing and a filter element.

However, this shared technical feature does not represent a contribution over prior art as being anticipated by US 2014/0158590 A1 to GENERAL ELECTRIC COMPANY (hereinafter "General Electric").

General Electric teaches a filter apparatus (120, Fig. 1; para [0028], [0029], [0030]) comprising a housing (136, Fig. 2; para [0031]) and a filter element (filter media structure assembly 134, Fig. 2; para [0031]).

As the common technical features were known in the art at the time of the invention, these cannot be considered special technical feature that would otherwise unify the groups.

Therefore, Groups I-II lack unity under PCT Rule 13 because they do not share a same or corresponding special technical feature.