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(71) Applicant: **FILTRATION SOLUTIONS, INC.** [US/US]; 432 Sand Shore Road, Unit 8, Hackettstown, New Jersey 07840 (US).

(72) Inventor: **JEN, Change-Wei**; 16 Jordanna Court, Bedminster, New Jersey 07921 (US).

(74) Agent: **GRELL, Mathew L.**; Grell & Watson Patent Attorneys LLC, 3770 Halyard Court, Acworth, Georgia 30102 (US).

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(54) Title: UNHOUSED FILTRATION DEVICE AND METHODS OF USE

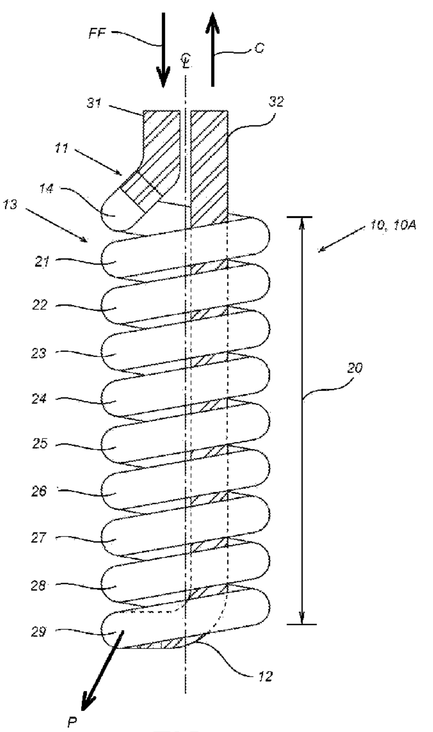

FIG. 4

(57) Abstract: A porous tube or conduit formed in a series of loops coiled around a center line, the series of loops having a first loop, the first loop having a first extension configured with a first open end in fluid communication with the first loop, the series of loops having an end loop, the end loop having a second extension configured with a second open end in fluid communication with the end loop, wherein the first open end and the second open end are positioned proximate the center line and the first loop, and, thus, functions to provide a more efficient filter having less plugging or clogging of the filtration membrane, reduced the need for self-cleaning of the porous tube, minimize the effects of pressure drop across a porous tube, installed inside a tank, accommodating shipping, handling, and storage, simplified system arrangement, thereby provide a more efficient filtration device, system, process.

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TITLE OF THE INVENTION

UNHOUSED FILTRATION DEVICE AND METHODS OF USE

CROSS-REFERENCE TO RELATED APPLICATIONS

To the full extent permitted by law, the present United States Non-provisional Patent Application hereby claims priority to and the full benefit of United States Provisional Application entitled "UNHOUSED FILTRATION DEVICE," having assigned serial number 62/388,659, filed on February 4, 2016, incorporated herein by reference in its entirety.

FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

None

PARTIES TO A JOINT RESEARCH AGREEMENT

None

REFERENCE TO A SEQUENCE LISTING

None

BACKGROUND OF THE INVENTION

Technical Field of the Invention

This disclosure relates generally to tubular membrane filtration and, more specifically, to unhoused filtration.

Description of the Related Art

The art has seen various filtration devices employing different methods for removing particulate or impurities from a feed fluid. For example, so-called dead end filtration systems force all of the feed fluid through a filter to separate impurities therefrom. Dead end filters designs may place a filter either directly across a flow path or at an oblique angle to the flow path. One disadvantage to this approach is that all of the fluid must pass through the filter and the velocity of the fluid about the filter will continuously decrease eventually to zero unless the filter is cleared or replaced.

Other traditional treatment systems include chemical treatments followed by filtration and separation technologies such as sedimentation tanks (clarifiers), sand/media filters, various microfiltration (MF) and ultrafiltration technologies (UF), such as hollow fiber and reverse osmosis (RO) systems, to name a few.

Some filter designs employ a spiral fluid flow path to separate heavier particulate from the fluid medium. These centrifugal particulate separation devices employ a spiral path to generate centrifugal forces which force the heavier particulate to the outside of the spiral flow path.

Another approach shown in **FIG. 1** is tubular membrane filtration is a pressure driven, cross-flow filtration process using a micro-porous membrane to separate suspended solids, such as chemicals or metals, from liquids such as water. Tubular filtration device **100.1** includes a hollow permeable conduit, such as membrane tube **110.1** enclosed within tubular housing **112.1,** such as a pipe, conduit, or tube, shown in **FIG. 1**. The ends of the tubes are sealed with for example epoxy directly against housing **112.1** to form end plates **114.1**. During the filtration process, pressurized effluent, such as feed **121.1** is fed into the membrane tube **110.1** from one end, such as first end **110.1**. As feed **121.1** flows in through membrane tube **110.1**, particles **Pt** are separated by membrane tube **110.1** and particles **Pt** remain inside or within interior **I** of membrane tube **110.1**. The pressurized feed **121.1** is pressurized to force permeate **P** (a clean fluid with little or no particles **Pt**) through the filter media, such as to penetrate or pass through openings (pores **Po**) therein membrane tube **110.1,** whereby permeate **P** is then collected inside housing **112.1** and directed to a manifold or a tank through discharge port such as fluid out (permeate **P)** through outlet **116.1**. As the fluid flows through the filter media, particles **Pt** are trapped by the fibers that make up the filter media. Particles **Pt** or contaminants separated by the membrane, such as membrane tube **110.1** remain inside membrane tube **110.1** and are carried away by the remainder of the feed fluid **F** (**121.1**), as retentate fluid, such as concentrate **C** (**122.1**). One disadvantage to this approach is that backwashing is routinely applied in this filtration process to alleviate membrane plugging or clogging, such as membrane tube **110.1**. During backwashing, the pressure that feeds feed **121.1** to membrane tube **110.1** is isolated and alternatively pressure is applied or built up in housing **112.1** reversing flow of permeate **P,** and thus, forces particles **Pt** that are lodged therein pores **Po** of membrane tube **110.1** to be removed or dislodge therein to interior **I** of membrane tube **110.1** to alleviate membrane plugging or clogging and prepare membrane tube **110.1** for further filtration.

Moreover, **FIG. 2** illustrate an alternative tubular membrane filtration device **100A.1** includes a plurality of hollow permeable conduits, such as membrane tubes **110A.1** configured therein housing **112.1.** Similar to **FIG. 1** with both ends of membrane tubes **110A.1** potted to allow thru-flow of fluid pathways for feed **121.1** and Concentrate **122.1** while encapsulating membrane tubes **110A.1** with for example epoxy directly against housing **112.1** to form seals at the ends **114.1**. During the filtration process, pressurized effluent, such as feed **121.1** is fed into the membrane tubes **110A.1** from one end, such as first end **114.1**. As feed **121.1** flows through membrane tubes **110A.1**, particles **Pt** are separated by each membrane tube **110.1** and particles **Pt** remain inside or within interior **I** of each of membrane tubes **110A.1**. The filtered fluid **F** that penetrates or pass through openings (pores **Po**) of membrane tubes **110A.1** (the "filtrate" or "permeate **P**") is then collected inside housing **112.1** and directed to a manifold or a tank through discharge port such as outlet **116.1**. Moreover as in **FIG. 1** particles **Pt** or contaminants separated by the membrane, such as membrane tubes **110A.1** remain inside membrane tubes **110A.1** and are carried away by the remainder of the feed **F**, as concentrate **C** (**122.1**). Like **FIG. 1,** one disadvantage to this approach is that backwashing is routinely applied in this filtration process to alleviate membrane plugging or clogging, such as membrane tube **110.1**. During backwashing, the pressure that feeds feed **121.1** to membrane tubes **110A.1** is isolated and alternatively pressure is applied or built up in housing **112.1** reversing flow of permeate **P,** and thus, forces particles **Pt** that are lodged therein pores **Po** of membrane tubes **110A.1** pores to be removed or dislodge therein to interior **I** of membrane tubes **110A.1** to alleviate membrane plugging or clogging and prepare membrane tubes **110A.1** for further filtration.

In this prior art filtration process, housing **112.1** provides the function for membrane tube protection, permeate **P** collection, and serves as a pressure vessel in backwashing. Moreover, filter media removes and retains larger particles **Pt** passing through openings or pores **Po** of the filter media, but allows the carrier fluid (the filtrate or permeate **P**) to pass through filter media and exit via outlet **116.1**.

In this prior art filtration process, an elongate annular gap is formed therebetween membrane tube **110/110A.1,** an elongate porous filter mounted in an elongated cavity of housing **112.1.** The elongate annular gap is formed between the outer filter surface of membrane tube **110/110A.1** and the interior surface of the housing **112.1** so as to define a fluid flow passageway or guide. Moreover the filter includes an open first end, an opposed closed second end.

One disadvantage and inherent weakness common to the traditional cross-flow designs of the prior art, including they all exhibit a pressure drop from the feed inlet to the outlet. The result is that more fouling tends to occur at the inlet end, which has a higher trans-membrane pressure drop than is present at the outlet end. Another disadvantage of the prior art is concentration polarization. Concentration polarization is a phenomenon commonly found in a membrane separation process, in which the non-permeating or slowly permeating components in the solution (feed flow) accumulate adjacent to the membrane surface, elevating osmotic pressure above that which would exist in the absence of polarization. The effect of concentration polarization is to reduce the membrane flux rate and its selectivity.

Therefore, it is readily apparent there is a recognizable unmet need for an unhoused filtration device and methods of use that is configured to address at least some aspects of the problems discussed above common to the traditional cross-flow designs, which specifically functions with less membrane plugging or clogging of the filtration membrane and reduces the need for self-cleaning of the filter, minimizes uneven fouling, reduces concentration polarization and thus increase the membrane flux rate, minimizes the effects of pressure drop across a filter media, and thereby provide a more efficient filtration device, system, and/or process.

SUMMARY

Briefly described, in an example embodiment, the present disclosure overcomes the above-mentioned disadvantages and meets the recognized need for unhoused filtration device and methods of use, that generally includes a porous tube or conduit formed in a series of loops coiled around a center line, the series of loops having a first loop, the first loop having a first extension configured with a first open end in fluid communication with the first loop, the series of loops having an end loop, the end loop having a second extension configured with a second open end in fluid communication with the end loop, wherein the first open end and the second open end are positioned proximate the center line and the first loop, and, thus, functions to provide a more efficient filter having less plugging or clogging of the filtration membrane, reduced the need for self-cleaning of the porous tube, minimize the effects of pressure drop across a porous tube, and thereby provide a more efficient filtration device, system, and/or process.

According to its major aspects and broadly stated, the disclosure of the unhoused filtration system and methods of use that generally includes one or more porous tube unhoused filtration device formed in a coil or series of loops in fluid communication with a pressurized feed fluid, wherein permeate is pushed through pores therein one or more porous tube and collected in a container and concentrate with particles are continually lifted from the interior surface via Dean Flow eddy currents and together discharged therefrom unhoused filtration device and, thus, functions to provide a more efficient filter having less plugging or clogging of the filtration membrane, reduced the need for self-cleaning of the porous tube, minimize the effects of pressure drop across a porous tube, and thereby provide a more efficient filtration device, system, and/or process.

In an exemplary embodiment, a filter for filtering a pressurized feed fluid with suspended particles therethrough and discharging a concentrate fluid with suspended particles, the filter includes a filtration tube, the filtration tube configured in a series of loops coiled around a center line having a first loop and an end loop, wherein the first loop includes a first extension in fluid communication with the first loop, wherein the end loop includes a second extension in fluid communication with the end loop.

In still a further exemplary embodiment of a method of filtering includes the steps of providing one or more filtration tube, the filtration tube configured in a series of loops coiled around a center line having a first loop and an end loop, wherein the first loop includes a first extension in fluid communication with the first loop, wherein the end loop includes a second extension in fluid communication with the end loop, and a pump in fluid communication with the first extension of one or more the filtration tube and a container, generating Dean Flow currents therein the feed fluid in at least opposing pairs of corkscrew vortices, collecting a permeate filtered therethrough the one or more filtration tube, and discharging a concentrate fluid with suspended particles.

Accordingly, a feature of the unhoused filtration device and methods of use is the ability of the series of loops coiled around a center line to provide a secondary flow current to fluid flowing therethrough.

Another feature of the unhoused filtration device and methods of use is the ability to the series of the porous tube to be of dimension so as to impart Dean Flow currents to fluid flowing therethrough.

Still another feature of the unhoused filtration loops coiled around a center line to enable Dean Flow currents to form therein. Dean Flow currents are opposing pairs of corkscrew vortices formed in the fluid flowing therethrough, which travel along the device and methods of use is its ability of the series of loops coiled and provide a shear cleaning current across the interior surface of the porous tube (filter media) so as to conduct away and prevent particles being entrapped by the filter media, i.e. to prevent concentration polarization.

Yet another feature of the unhoused filtration device and methods of use is its ability to minimized uneven fouling and the filtration performance can be enhanced by the Dean Flow in this unhoused filtration device disclosed.

Yet another feature of the unhoused filtration device and methods of use is its ability to provide a mass transport advantage in the unhoused version greatly reduces the concentration polarization issue in the prior art.

Yet another feature of the unhoused filtration device and methods of use is its ability to enable backwashing that is commonly used in a filtration process. The backwashing can be performed by evacuating, pulling vacuum in the tube (i.e. from the permeate side) to achieve the same purpose.

Yet another feature of the unhoused filtration device and methods of use is its ability to provide a porous tube filter without opposed first and second open ends and an elongated straight porous filter, which requires a large foot print.

Yet another feature of the unhoused filtration device and methods of use is its ability to not provide an elongated porous tube filter mounted in an elongated housing positioned therearound the porous tube, wherein the outer filter surface and the interior surface of the housing wall define an elongate annular gap therebetween, which requires a large foot print.

Yet another feature of the unhoused filtration device and methods of use is its ability to provide coiled membrane tube in a spiral form, it not only provides a flow path that generates Dean Flow in the tube, but also significantly shortens the length of membrane modules with the same membrane areas. For example, a six (6) linear foot tube can be made into a coil with a two (2) inch inside diameter that is less than seven (7) inches in length. Thus, the shortened length of membrane tubes make unhoused membrane modules practical with regards to size of filter installation footprint.

Yet another feature of the unhoused filtration device and methods of use is its ability to provide coiled membrane tube in a spiral form rather than a passageway or channel or groove integrated therein a gap between the filter media and its housing whether the passageway is formed therein the filter membrane, the housing, or a combination thereof. A coiled membrane tube configuration enables more efficient cleaning of the filter membrane via pulling a vacuum only on the filter membrane versus a vacuum spread over the filter membrane and housing.

Yet another feature of the unhoused filtration device and methods of use is its ability to provide coiled tubular membrane filter making shipping and handling more manageable compared to straight tubular membrane filters with the same linear length. The unhoused membrane modules have the advantage of minimum size and weight. The coiled form allows a significant reduction of tube length for a compact design.

Yet another feature of the unhoused filtration device and methods of use is its ability to provide coiled tubular membrane filters which can be mounted under a tank cover and installed inside a tank. This not only makes a design compact but also minimizes piping and fittings, which results in significant cost savings.

Yet another feature of the unhoused filtration device and methods of use is its ability to provide coiled tubular membrane filters, wherein backwashing of the filter membrane may be performed by pulling a vacuum from the inside of membrane tubes instead of applying a positive pressure from the outside of membrane tubes.

Yet another feature of the unhoused filtration device and methods of use is its ability to utilize secondary flow currents developed by the spiral flow path therein coiled tubular membrane filter, Dean Flow currents. Dean Flow currents describe a particular flow pattern developed when fluid is forced through a spiraling fluid flow path. It can occur in a very wide flow regime from laminar to high turbulent flow. Dean Flow currents are developed in opposing pairs of corkscrew vortices which travel along the spiral fluid flow path and provide a shear cleaning current across the filter media surface so as to conduct away particles entrapped by the filter media to extend the operating period of a filter unit between required backwashing or maintenance.

Yet another feature of the unhoused filtration device and methods of use is its ability to provide for filtration using an efficient and low-energy process due to less clogging – controls cake layer formation and effective membrane self-cleaning at low flow velocities, and longevity of filter.

Yet another feature of the unhoused filtration device and methods of use is its ability to integrate one or more unhoused filtration device therein an industrial or surface wastewater treatment system.

Yet another feature of the unhoused filtration device and methods of use is its ability to eliminate the cost of the tubular housing of conventional straight TMF (tubular membrane filter).

Yet another feature of the unhoused filtration device and methods of use is its ability to be mounted under a tank cover or above a collection tank.

Yet another feature of the unhoused filtration device and methods of use is during the flow process, clean fluid (permeate) will penetrate the membrane tube wall leaving dirty flow trapped inside the tube. The permeate generated by the filters can be collected by a holding tank or any convenient collecting device.

Yet another feature of the unhoused filtration device and methods of use is its ability to provide an unhoused membrane filtration device that is to have tubular membranes in a coiled form allowing a secondary flow (called Dean Flow) to be generated, which can minimize membranes from fouling.

Yet another feature of the unhoused filtration device and methods of use is its ability to provide a sterilizing device into a compact system, e.g. a UV light bulb insert into the inside space of a coiled tubular membrane.

Yet another feature of the unhoused filtration device and methods of use is its ability to be integral with a sterilizing device to provide potable water at the point of use.

These and other features of the unhoused filtration device and methods of use will become more apparent to one skilled in the art from the prior Summary and following Brief Description of the Drawings, Detailed Description of exemplary embodiments thereof, and Claims when read in light of the accompanying Drawings or Figures.

BRIEF DESCRIPTION OF THE DRAWINGS

The present unhoused filtration device and methods of use thereof will be better understood by reading the Detailed Description of the Preferred and Selected Alternate Embodiments with reference to the accompanying drawing Figures, in which like reference numerals denote similar structure and refer to like elements throughout, and in which:

FIG. 1 is a cross-sectional side view of a prior art housed cross flow filtration assembly;

FIG. 2 is a side view of a prior art housed cross flow filtration assembly with a partial cross-sectional view of an assembly with a plurality of hollow permeable conduits;

FIG. 3 is a partial cross-sectional of the filtration assembly of **FIG. 1** and **FIG. 2** showing detail;

FIG. 4 is a front side view of an exemplary embodiment of the unhoused filtration device;

FIG. 5 is a top view of an exemplary embodiment of the unhoused filtration device, according to **FIG. 4**;

FIG. 6 is a side view of an exemplary embodiment of the unhoused filtration device according to **FIG. 4** enclosed in a meshed sleeve;

FIG. 7A is a side view of a UV light or other representative radiation source;

FIG. 7B is a side view of another exemplary embodiment of the unhoused filtration device in combination with a UV light of **FIG. 7A**;

FIG. 8 is a cross-sectional perspective view of the filtration tube of an exemplary embodiment of the unhoused filtration device;

FIG. 9A is a front side view of a filtration system having one or more exemplary embodiments of the unhoused filtration devices;

FIG. 9B is a perspective view of an exemplary embodiment of a manifold used in the unhoused filtration devices of **FIG. 9A**;

FIG. 9C is a side view of a filtration system having one or more exemplary embodiments of the unhoused filtration devices;

FIG. 9D is a top view of a filtration system having two exemplary embodiments of the unhoused filtration devices;

FIG. 9E is a top block diagram of a filtration system having two manifolds to connect two exemplary embodiments of the unhoused filtration devices;

FIG. 10A is a front side view of a filtration system having one or more alternative exemplary embodiments of the unhoused filtration devices;

FIG. 10B is a perspective view of an alternate exemplary embodiment of a manifold used in the unhoused filtration devices of **FIG. 10A**;

FIG. 10C1 is a top view of a filtration system having two alternative exemplary embodiments of the unhoused filtration devices;

FIG. 10C2 is a top block diagram of a filtration system having two alternative manifolds to connect two exemplary embodiments of the unhoused filtration devices;

FIG. 11 is an exemplary chart of permeate flux rate from exemplary embodiments of the unhoused filtration devices in gallons per square foot of filtration tube per day; and

FIG. 12 is a flow diagram of a method of use of one or more unhoused filtration devices to filter a portion of suspended substances from an effluent.

DETAILED DESCRIPTION

In describing the exemplary embodiments of the present disclosure, as illustrated in **FIGS. 1-12**, specific terminology is employed for the sake of clarity. The present disclosure, however, is not intended to be limited to the specific terminology so selected, and it is to be understood that each specific element includes all technical equivalents that operate in a similar manner to accomplish similar functions. Embodiments of the claims may, however, be embodied in many different forms and should not be construed to be limited to the embodiments set forth herein. The examples set forth herein are non-limiting examples, and are merely examples among other possible examples.

Referring now to the **FIGS. 4** and **5**, there is illustrated a unhoused filtration device and process for removing suspended substance from an effluent, such as feed fluid **FF** entering a filter, such as unhoused filtration device **10, 10A.** Unhoused filtration device **10, 10A** may include an elongated membrane or conduit or tube filter, such as filtration tube **13** partially configured in a series of loops **20** in fluid communication and coiled around a center line **CL.** Preferably series of loops **20** may include a spiral or coiled tube, such as one or more or plurality of loops **20** in fluid communication and coiled around a center line **CL,** such as first loop **21,** second loop **22,** third loop **23,** fourth loop **24,** fifth loop **25,** sixth loop **26,** seventh loop **27,** eighth loop **28,** and ninth loop or end loop **29.** Moreover, first loop **21** may include a coupler or extension, such as first extension **11** configured having first tube end **31** and first open end **41** in fluid communication with first loop **21.** Furthermore, end loop **29** may include second extension **12** configured having second tube end **32** and second open end **42** in fluid communication with end loop **29**.

In one exemplary embodiment of unhoused filtration device **10, 10A,** first tube end **31** and first open end **41** and second tube end **32** and second open end **42** may terminate at opposite ends of plurality of loops **20**.

In another exemplary embodiment of unhoused filtration device **10, 10A,** first tube end **31** and first open end **41** and second tube end **32** and second open end **42** may terminate at one end of plurality of loops **20** via elongated second extension **12,** wherein first tube end **31** is in fluid communication with first open end **41** and second tube end **32** (which may be configured as a linear extension therebetween or within plurality of loops **20,** more specifically extends therefrom end loop **29** to first loop **21**) is in fluid communication with second open end **42** and second open end **42** may be positioned proximate center line **CL** and may extend proximate first loop **21**.

It is contemplated herein that first tube end **31** and second tube end **32** may be positioned parallel to center line **CL,** wherein first open end **41** and second open end **42** may be positioned proximate one another.

It is contemplated herein that plurality of loops **20** may be configured circular, oval, curved, arcing, angled or any like manner to generate secondary flow current therein.

Filtration tube **13** may be formed of any porous or semi permeable, or permeable, or hollow fiber or other material, capable of directing feed fluid **FF** through coiled form, such as plurality of loops **20**. Moreover, filtration tube **13** may preferably be constructed of permeable materials with tightly controlled pore sizes that are available in a variety of natural and synthetic fiber, composites, laminated composite material, cast materials, polymers as these materials (filter media) offers a variety of forms and shapes. It is contemplated herein that other suitable permeable materials may be utilized or the like, whether formed of multiple layers with different materials, or the like, may be utilized, provided such material has sufficient strength, pore sizes, supports backwashing, exhibits outstanding chemical resistance, offers long service life, high water recovery rates, pH tolerance, small system footprint, and/or durability as would meet the purpose described herein.

Referring now to the **FIG. 5**, there is illustrated an exemplary embodiment of top view of unhoused filtration device **10, 10A.** Unhoused filtration device **10, 10A** may include first loop **21** which may further include first angled extension **11** in fluid communication with first loop **21** and configured having first tube end **31** and first open end **41.** Unhoused filtration device **10, 10A** may further include second extension **12** in fluid communication with end loop **29** and configured having second tube end **32** and second open end **42.**

It is contemplated herein that first extension **11** (first tube end **31**) and second extension **12** (second tube end **32**) may be positioned (or extend a position) proximate one another or proximate center line **CL.**

It is contemplated herein that first open end **41** and second open end **42** may be positioned proximate one another or proximate center line **CL.**

In use during the filtration process, pressurized effluent, such as feed fluid **FF** may be fed into filtration tube **13** from one end, such as first open end **41** of first tube end **31** wherein feed fluid **FF** traverses therethrough plurality of loops **20.** As feed fluid **FF** flows through filtration tube **13**, particles **Pt** are separated by filtration tube **13** and particles **Pt** remain inside or within interior **I** of filtration tube **13**. The pressurized feed fluid **FF** is pressurized to force liquid or fluid, such as permeate **P** through the filter media of filtration tube **13**, such as to penetrate or pass through openings (pores **Po**) therein filter media of filtration tube **13,** whereby filtered fluid, such as permeate **P** is then pushed outside filtration tube **13**, such as to an exterior **Ex** of filtration tube **13.** Moreover, as feed fluid **FF** flows through the filter media of filtration tube **13**, particles **Pt** are trapped by the fibers that make up the filter media of filtration tube **13**. Particles **Pt** or contaminants separated by filter media of filtration tube **13** remain inside or within interior **I** of filtration tube **13** and are carried by plurality of loops **20** thereto end loop **29** in fluid communication with second extension **12** having second tube end **32** and second open end **42.** Remaining feed fluid **FF** and particles **Pt** exit filtration tube **13** via second tube end **32** in fluid communication with second open end **42,** as concentrate **C**.

Referring now to the **FIG. 6**, there is illustrated an exemplary embodiment of a side view of unhoused filtration device **10, 10A.** Unhoused filtration device **10, 10A** may include a porous sleeve, such as meshed sleeve **50.** Meshed sleeve **50** may be utilized to form or encase first loop **21,** second loop **22,** third loop **23,** fourth loop **24,** fifth loop **25,** sixth loop

26, seventh loop **27,** eighth loop **28,** and ninth loop or end loop **29** therein a spiral configuration coiled around center line **CL** and may be slid over plurality of loops **20** to retain the coil shape. Meshed sleeve **50** may be utilized to protect plurality of loops **20** from impact or puncture as well as meshed sleeve **50** may be utilized to maintain or hold plurality of loops **20** in a spiral formation coiled around center line **CL.**

Referring now to the **FIG. 7A** and **7B**, there is illustrated an exemplary embodiment of a side view of unhoused filtration device **10, 10B.** Unhoused filtration device **10, 10B** may include an enclosed linear conduit, such as filtration tube **13** partially configured in a series of loops **20** in fluid communication and coiled around a center line **CL.** Preferably series of loops **20** may include one or more or plurality of loops **20** in fluid communication and coiled around a center line **CL,** such as first loop **21,** second loop **22,** third loop **23,** fourth loop **24,** fifth loop **25,** sixth loop **26,** seventh loop **27,** eighth loop **28,** and ninth loop or end loop **29.** Moreover, first loop **21** may include first extension **11** configured having first tube end **31** and first open end **41** in fluid communication with first loop **21.** Furthermore, end loop **29** may include second extension **12** configured having second tube end **32** and second open end **42** in fluid communication with end loop **29**.

In an exemplary embodiment of unhoused filtration device **10, 10B,** first tube end **31** and first open end **41** and second tube end **32** and second open end **42** may terminate at one end of plurality of loops **20** via elongated second extension **12,** wherein first tube end **31** is in fluid communication with first open end **41** and second tube end **32** (which may be configured as a linear extension outside or exterior to plurality of loops **20,** more specifically extends therefrom end loop **29** to first loop **21**) is in fluid communication with second open end **42** and second open end **42** may be positioned proximate center line **CL** and may extend proximate first loop **21**.

It is contemplated herein that first tube end **31** and second tube end **32** may be positioned parallel to center line **CL,** wherein first open end **41** and second open end **42** may be positioned proximate one another.

In another exemplary embodiment, unhoused filtration device **10, 10B** may include a radiation source, such as ultraviolet light **70** having one or more power terminals **71.** Ultraviolet light **70** may be positioned approximate plurality of loops **20** and more specifically ultraviolet light **70** may be inserted within one or more plurality of loops **20** or therebetween first loop **21,** second loop **22,** third loop **23,** fourth loop **24,** fifth loop **25,** sixth loop **26,** seventh loop **27,** eighth loop **28,** and ninth loop or end loop **29,** wherein ultraviolet light **70** may be positioned proximate or parallel to center line **CL** to form a compact filtration design with an integrated sterilizing function.

It is further contemplated herein that one or more filtration tube **13** of **FIG. 4, 6** and **7** having series of loops **20** in fluid communication or coiled around a center line **CL** may be utilized to form unhoused filtration device **10.**

Referring now to the **FIG. 8**, there is illustrated an exemplary embodiment of a cross-sectional view of filtration tube **13** of unhoused filtration device **10.** Filtration tube **13** is preferably configured as one or more or plurality of loops **20** in fluid communication and coiled around a center line **CL,** such as first loop **21,** second loop **22,** third loop **23,** fourth loop **24,** fifth loop **25,** sixth loop **26,** seventh loop **27,** eighth loop **28,** and ninth loop or end loop **29** enables unhoused filtration device **10** to produce Dean Flow currents therein filtration tube **13.**

It is contemplated herein that cross-sectional view of filtration tube **13** may be configured as hollow in other cross-sectional shapes other than circular, such as oval**,** rectangle, triangle, multi-angled or the like capable of providing Dean Flow currents.

It is further contemplated herein that pressurized feed fluid **FF** is pressurized to force the filtrate, or permeate **P** through the filter media of filtration tube **13**, wherein permeate **P** pass through openings (pores **Po**) therein filtration tube **13.** During the flow process, clean fluid permeate **P** will penetrate the filter media of filtration tube **13** leaving dirty flow captured inside filtration tube **13**.

Dean Flow currents are developed therein feed fluid **FF** as at least opposing pairs of corkscrew vortices, such as first corkscrew vortex **CC1** and second corkscrew vortex **CC2,** which travel along the spiral fluid flow path therein filtration tube **13** and provide a shear cleaning current across the filter media interior surface **82** so as to conduct away particles **Pt** entrapped by the filter media and to maintain or hold particles **Pt** to the interior **I** of filtration tube **13** away from interior surface **82**. Experimenters have reported that the vortex (flow first corkscrew vortex **CC1** and second corkscrew vortex **CC2)** exists in both the laminar flow and turbulent flow region, and the vortex structure persists up to 1000 times the critical flow rate, which is the transition between laminar and turbulent flow. Fluid flowing through a spiral flow path at less than the Dean Flow critical velocity will not develop the opposing corkscrew currents therein while fluid flowing too quickly through a spiral flow path degenerates into a purely turbulent flow regime. Dean Flow currents have been demonstrated to better maintain the flux rate across a filter media so as to extend the operating period of a filter unit between required backwashing or maintenance.

The movement of these vortices, such as first corkscrew vortex **CC1** and second corkscrew vortex **CC2,** creates micro-backwashing events that continually move across the filter media interior surface **82**, allowing the filter to operate essentially indefinitely without plugging (i.e. these backwashing events continuously clean the filter surface). Because very little energy is lost in the creation and maintenance of these vortices, embodiments of a filtration system of the present disclosure can operate over a broad pressure range in any practical application. Embodiments of the present disclosure thus provide for filtration using an efficient, low-energy process.

It is still further contemplated herein in **FIGs. 4-8** that pressurized feed fluid **FF** may be sourced from or positioned exterior **Ex** of filtration tube **13** and permeate **P** may pass through openings (pores **Po**) therein filtration tube **13** passing through the filter media of filtration tube **13** and into the Interior **I** of filtration tube **13.** Herein the filtration process is reversed from inside out flow of permeate **P** through filter media of filtration tube **13** (leaving dirty flow captured inside or interior **I** of filtration tube **13**) to an outside in flow of permeate **P** passing through filter media of filtration tube **13** (leaving dirty flow outside filtration tube **13**).

Referring now to the **FIG. 9A, 9B**, **9C**, **9D** and **9E** there is illustrated an exemplary embodiment of filtration system **900**. Filtration system **900A** may include one or more unhoused filtration device **10, 10C** may include a linear conduit, such as filtration tube **13** partially configured in a series of loops **20** in fluid communication and coiled around a center line **CL.** Preferably series of loops **20** may include a spiral or coiled tube, such as one or more or plurality of loops **20** in fluid communication and coiled around a center line **CL,** such as first loop **21**, second loop **22**, third loop **23**, fourth loop **24**, fifth loop **25**, sixth loop **26**, seventh loop **27**, (eighth loop **28**) and end loop **28/29.** Moreover, first loop **21** may include a connector **90**, such as first connector tube **90, 91** configured in fluid communication with first loop **21.** Furthermore, end loop **28/29** may include second connector tube **90**, **92** configured in fluid communication with end loop **28/29**. Furthermore, filtration system **900** may include one or more manifolds **100** having two or more ports, such as first port **111** in fluid communication with second port **112** and third port **113.** First port **111,** second port **112,** and third port **113** may include one or more quick disconnector, hose barbs, or manifold connectors **120,** such as first manifold connector **121** and second manifold connector **122** to provide fluid communication therebetween unhoused filtration device **10, 10C** and manifold **100.** More specifically, first manifold **101** having second port **112** with first manifold connector **121** connected thereto and first connector tube **91** configured to connect first loop **21** of unhoused filtration device **10C** thereto first manifold connector **121,** wherein second port **112** of first manifold **101,** first connector tube **91,** and first loop **21** of unhoused filtration device **10C** are in fluid communication therewith one another. Moreover, second manifold **102** having second port **112** with second manifold connector **122** connected thereto and second connector tube **92** configured to connect end loop **28/29** of unhoused filtration device **10C** thereto second manifold connector **122,** wherein second port **112** of second manifold **102,** second connector tube **92,** and end loop **28/29** of unhoused filtration device **10C** are in fluid communication therewith one another. Furthermore, pressurized effluent, such as fluid feed **FF** via pump **130** may flow from intake conduit 131 through pump **130** and therethrough outtake conduit **132,** which is in fluid communication therewith first port **111** of first manifold **101.**

Referring now to **FIG. 9C** pressurized feed **124** is pressurized to force permeate **P** through the filter media, filtration tube **13,** such as to permeate **P** to pass through openings (pores **Po**) therein filtration tube **13,** whereby permeate **P** is then collected in a collection device, tank, basin, or pan, such as container **140.** Container **140** may include a discharge port, such as outlet **116** with or without valve **150** to discharge permeate **P**. Moreover as in **FIG. 1** particles **Pt** or contaminants separated by the membrane, such as filtration tube **13** remain inside filtration tube **13** and are carried away by the remainder of pressurized feed **124**, as concentrate **C** and exit first port **111** of second manifold **102.**

Referring now to **FIG. 9D** and **9E** there is illustrated another exemplary embodiment of filtration system **900B.** Filtration system **900B** may include one or more filtration tube **13,** as first unhoused filtration device **10C1** (configured similar to **FIG. 9A**) and second unhoused filtration device **10C2.** More specifically, second unhoused filtration device **10C2** may include first manifold **101** having third port **113** with first manifold connector **121B** connected thereto and first connector tube **91B** configured to connect first loop **21B** of unhoused filtration device **10C2** thereto first manifold connector **121B,** wherein third port **113** of first manifold **101,** first connector tube **91B,** and first loop **21B** of unhoused filtration device **10C2** are in fluid communication therewith one another. Moreover, second manifold **102** having third port **113** with second manifold connector **122B** connected thereto and second connector tube **92B** configured to connect end loop **28B/29B** of unhoused filtration device **10C2** thereto second manifold connector **122B,** wherein third port **113** of second manifold **102,** second connector tube **92B,** and end loop **28B/29B** of unhoused filtration device **10C2** are in fluid communication therewith one another. Furthermore, pressurized effluent, such as fluid feed **FF** via pump **130** may flow from intake conduit **131** through pump **130** and therethrough outtake conduit **132,** which is in fluid communication therewith first port **111** of first manifold **101.**

Referring again to **FIG. 9C** pressurized feed **124** is pressurized to force permeate **P** through the filter media, filtration tube **13A** of first unhoused filtration device **10C1** (configured similar to **FIG. 9A**) and filtration tube **13B** of second unhoused filtration device **10C2,** such as permeate **P** to penetrate or pass through openings (pores **Po**) therein filtration tube **13A/B,** whereby permeate **P** is then collected in a tank, basin, or pan, such as container **140.** Container **140** may include a discharge port, such as outlet **116** with or without valve **150** to discharge permeate **P**. Moreover as in **FIG. 1** particles **Pt** or contaminants separated by the membrane, such as filtration tube **13A/B** remain inside filtration tube **13A/B** and are carried away by the remainder of pressurized feed **124**, as concentrate **C** and exit first port **111** of second manifold **102.**

Referring now to the **FIG. 10A, 10B**, and **10C1/10C2** there is illustrated an exemplary embodiment of filtration system **1000**. Filtration system **1000** may include one or more unhoused filtration device **10, 10B** may include a linear conduit, such as filtration tube **13** partially configured in a series of loops **20** in fluid communication and coiled around a center line **CL** as shown in **FIGs. 7.** Preferably series of loops **20** may include one or more or plurality of loops **20** in fluid communication and coiled around a center line **CL,** such as first loop **21,** second loop **22,** third loop **23,** fourth loop **24,** fifth loop **25,** sixth loop **26,** seventh loop **27,** eighth loop **28,** and ninth loop or end loop **28/29.** Moreover, first loop **21** may include a connector **90**, such as first connector tube **90, 91** configured in fluid communication with first loop **21.** Furthermore, end loop **28/29** may include second connector tube **90, 92** configured in fluid communication with end loop **28/29**. Furthermore, filtration system **1000** may include input manifold, such as one or more manifolds **100B** having two or more ports, such as first port **111** in fluid communication with second port **112** and third port **113** and fourth port **114** and fifth port **115.** First port **111,** second port **112,** third port **113,** fourth port **114** and fifth port **115** may include one or more quick disconnector, hose barbs, or manifold connectors **120,** such as first manifold connector **121,** second manifold connector **122,** and third manifold connector **123** to provide fluid communication therebetween unhoused filtration device **10B** and manifold **100B.**

Unhoused filtration device **10B1**

More specifically, first manifold **101A** having second port **112A** with first manifold connector **121** connected thereto and first connector tube **91** configured to connect first loop **21** of unhoused filtration device **10B1** thereto first manifold connector **121,** wherein second port **112A** of first manifold **101A,** first manifold connector **121,** first connector tube **91,** and first loop **21** of unhoused filtration device **10B1** are in fluid communication therewith one another. Moreover, an output manifold, such as third manifold **103** having second port **112** with second manifold connector **122** connected thereto and second connector tube **92** configured to connect end loop **28/29** of unhoused filtration device **10B1** thereto second manifold connector **122,** wherein second port **112** of third manifold **103,** second manifold connector **122,** second connector tube **92,** and end loop **28/29** of unhoused filtration device **10B1** are in fluid communication therewith one another.

Furthermore, pressurized effluent, such as fluid feed **FF** via pump **130** may flow from intake conduit **131** through pump **130** and therethrough outtake conduit **132,** which is in fluid communication therewith first port **111** of first manifold **101A.**

<u>Unhoused filtration device **10B3**</u>

Still more specifically, first manifold **101A** having third port **113A** with first manifold connector **121** connected thereto and first connector tube **91** configured to connect first loop **21** of unhoused filtration device **10B3** thereto first manifold connector **121**, wherein third port **113A** of first manifold **101A**, first manifold connector **121**, first connector tube **91**, and first loop **21** of unhoused filtration device **10B3** are in fluid communication therewith one another. Moreover, third manifold **103** having third port **113** with second manifold connector **122** connected thereto and second connector tube **92** configured to connect end loop **28/29** of unhoused filtration device **10B3** thereto second manifold connector **122**, wherein third port **113** of third manifold **103**, second manifold connector **122**, second connector tube **92**, and end loop **28/29** of unhoused filtration device **10B3** are in fluid communication therewith one another.

<u>Unhoused filtration device **10B2**</u>

More specifically, second manifold **101B** having second port **112B** with first manifold connector **121** connected thereto and first connector tube **91** configured to connect first loop **21** of unhoused filtration device **10B2** thereto first manifold connector **121**, wherein second port **112B** of second manifold **101B**, first manifold connector **121**, first connector tube **91**, and first loop **21** of unhoused filtration device **10B2** are in fluid communication therewith one another. Moreover, third manifold **103** having fourth port **114** with second manifold connector **122** connected thereto and second connector tube **92** configured to connect end loop **28/29** of unhoused filtration device **10B2** thereto second manifold connector **122**, wherein fourth port **114** of third manifold **103**, second manifold connector **122**, second connector tube **92**, and end loop **28/29** of unhoused filtration device **10B2** are in fluid communication therewith one another.

Furthermore, pressurized effluent, such as fluid feed **FF** via pump **130** may flow from intake conduit **131** through pump **130** and therethrough outtake conduit **132,** which is in fluid communication therewith first port **111** of second manifold **101B.**

<u>Unhoused filtration device **10B4**</u>

Still more specifically, second manifold **101B** having third port **113B** with first manifold connector **121** connected thereto and first connector tube **91** configured to connect first loop **21** of unhoused filtration device **10B4** thereto first manifold connector **121,** wherein third port **113B** of second manifold **101B,** first manifold connector **121,** first connector tube **91,** and first loop **21** of unhoused filtration device **10B4** are in fluid communication therewith one another. Moreover, third manifold **103** having fifth port **115** with second manifold connector **122** connected thereto and second connector tube **92** configured to connect end loop **28/29** of unhoused filtration device **10B4** thereto second manifold connector **122,** wherein fifth port **115** of third manifold **103,** second manifold connector **122,** second connector tube **92,** and end loop **28/29** of unhoused filtration device **10B5** are in fluid communication therewith one another.

In another exemplary embodiment, unhoused filtration device **10B1, 10B2, 10B3, 10B4** may include a radiation source, such as ultraviolet light **70** having one or more power terminals **71.** Ultraviolet light **70** may be positioned approximate plurality of loops **20** and more specifically ultraviolet light **70** may be inserted therebetween one or more plurality of loops **20** or therebetween first loop **21,** second loop **22,** third loop **23,** fourth loop **24,** fifth loop **25,** sixth loop **26,** seventh loop **27,** eighth loop **28,** and ninth loop or end loop **28/29,** wherein ultraviolet light **70** may be positioned proximate or parallel to center line **CL.**

Referring now to **FIG. 9C** (and similar in **FIGs. 10A, 10C2**) pressurized feed **124** is pressurized to force permeate **P** through the filter media, filtration tube **13,** such as to penetrate or pass through openings (pores **Po**) therein filtration tube **13,** whereby permeate **P** is then collected in a tank, basin, or pan, such as container **140.** Container **140** may include a discharge port, such as outlet **116** with or without valve **150** to discharge permeate **P**. Moreover as in **FIG. 1** particles **Pt** or contaminants separated by the membrane, such as filtration tube **13** remain inside filtration tube **13** and are carried away by the remainder of pressurized feed **124**, as concentrate **C** and exit first port **111** of third manifold **103.**

Referring now to **FIG. 10C1/10C2** there is illustrated another exemplary embodiment of filtration system **1000.** Furthermore, pressurized effluent, such as fluid feed **FF** via pump **130** may flow from intake conduit **131** through pump **130** and therethrough outtake conduit **132A/132B,** which is in fluid communication therewith first port **111** of first manifold **101A** and second manifold **101B,** respectively in fluid communication with one or more filtration tube **13.** First manifold **101A** distributes fluid feed **FF** thereto second port **112A** with first manifold connector **121** connected thereto and first connector tube **91** configured to connect first loop **21** of unhoused filtration device **10B1** and third port **113A** with first manifold connector **121** connected thereto and first connector tube **91** configured to connect first loop **21** of unhoused filtration device **10B3.** Second manifold **101B** distributes fluid feed **FF** thereto second port **112B** with first manifold connector **121** connected thereto and first connector tube **91** configured to connect first loop **21** of unhoused filtration device **10B2** and third port **113B** with first manifold connector **121** connected thereto and first connector tube **91** configured to connect first loop **21** of unhoused filtration device **10B4.** Likewise, third manifold **103** receives concentrate **C** from second port **112** with second manifold connector **122** connected thereto and second connector tube **92** configured to connect end loop **28/29** of unhoused filtration device **10B1,** fourth port **114** with second manifold connector **122** connected thereto and second connector tube **92** configured to connect end loop **28/29** of unhoused filtration device **10B2,** third port **113** with second manifold connector **122** connected thereto and second connector tube **92** configured to connect end loop **28/29** of unhoused filtration device **10B3,** and fifth port **115** with second manifold connector **122** connected thereto and second connector tube **92** configured to connect end loop **28/29** of unhoused filtration device **10B4,** whereby concentrate **C** may be aggregated from unhoused filtration device **10B1,** unhoused filtration device **10B2,** unhoused filtration device **10B3,** and unhoused filtration device **10B4** and discharged therefrom third manifold **103** via first port **111.**

Referring again to **FIG. 9C** (and similar in **FIGs. 10A, 10C2**) pressurized feed **124** is pressurized to force permeate **P** through the filter media, filtration tube **13** of unhoused filtration device **10B1,** unhoused filtration device **10B2,** unhoused filtration device **10B3,** and unhoused filtration device **10B4** (configured similar to **FIG. 9A**), such as permeate **P** to penetrate or pass through openings (pores **Po**) therein filtration tube **13,** whereby permeate **P** is then collected in a tank, basin, or pan, such as container **140.** Container **140** may include a discharge port, such as outlet **116** with or without valve **150** to discharge permeate **P**. Moreover as in **FIG. 1** particles **Pt** or contaminants separated by the membrane, such as filtration tube **13** remain inside filtration tube **13** and are carried away by the remainder of pressurized feed **124**, as retentate or concentrate **C** and exit first port **111** of third manifold **103.**

Referring now to the **FIG. 11** there is illustrated an exemplary chart of permeate **P** flow rate from filtration tube **13** of **FIG. 4** and **7B** coiled TMF (cTMF) flux (gallons per square foot of interior surface **82** of filtration tube **13** per day - gfd) verses conventional straight TMF (tubular membrane filter) running side-by-side under a feed rate of 2.65 gpm and a trans-membrane pressure of 5.8 psi, processing fluid feed **FF,** a highly concentrated fluid (well water loaded with 1000 ppm fine ISO test dust, particles **Pt**) from a common tank was circulated through both filters. As shown in **FIG. 11**, the initial flux rate of permeate **P** began to differentiate once a cake of test dust was formed on the interior membrane surface, interior surface **82** of filtration tube **13** by the end of week one. By allowing particles **Pt** in the processed fluid, fluid feed **FF,** to settle on the membrane surface, (stop the operation for two days between Week 1 and Week 2) the test data indicates that more than 20% difference in flux rate (Note that both filters showed a significant drop of flux at the onset of Week 2. However, the flux of cTMF was able to resume and follow the original curve after several hours into operation. The straight TMF had very limited improvement and remained gap-down in the curve.), permeate **P** flow rate, between filtration tube **13** of **FIG. 4** and **7B** coiled TMF (cTMF) as compared to conventional straight TMF (tubular membrane filter). Moreover, the flux rate, permeate **P** flow rate, of filtration tube **13** of **FIG. 4** and **7B** coiled TMF (cTMF) degrade less over time as compared to conventional straight TMF (tubular membrane filter and indicates the effectiveness of secondary flow currents, particularly Dean Flow currents, in clearing the filter media of filtration tube **13** when filtration tube **13** is configured in a series of loops **20** and coiled around a center line **CL**.

Unhoused filtration device **10** exhibits superior flux-rate, permeate **P** flow rate, across the filter media of filtration tube **13** for a longer period of time when Dean Flow currents are induced in filtration tube **13**. Dean Flow filtration thus provides for a longer mean-time between required backwashing of filtration tube **13** and better permeate

P flow rate through filtration tube **13**. Previous tests of conventional straight TMF without filtration tube **13** configured in a series of loops **20** and/or coiled around a center line **CL** demonstrated a significant build-up of particulate towards the inlet end of the filter media while tests employing the addition of filtration tube **13** with configured in a series of loops **20** and/or coiled around a center line **CL** and secondary flow generation have demonstrated significant reduction in particulate build-up on filter media of filtration tube **13**.

Moreover, the data set forth in the chart of the **FIG. 11** shows filtration tube **13** configured in a series of loops **20** and/or coiled around a center line **CL** and having secondary flow generation has an extended service life compared to conventional straight TMF. For example, if 20 gfd is set as the end of the filter service life, the conventional straight TMF (round dots) reaches the end of the service life in about 43 hours. The flux rate, permeate **P**, of filtration tube **13** configured in a series of loops **20** and/or coiled around a center line **CL** (square dots) reaches a steady operating state at 23 gfd, which means it will be in service for a longer duration of time.

With respect to the above description then, it is to be realized that the optimum dimensional relationships, to include variations in size, materials, shape, form, position, function and manner of operation, assembly and use, are intended to be encompassed by the present disclosure.

Referring now to **FIG. 12**, there is illustrated a flow diagram **1200** of a method of use of one or more unhoused filtration device **10** in a filtration system. In block or step **1210**, providing one or more unhoused filtration device **10** and a collection device, tank, basin, or pan, such as container **140.** In block or step **1215** pressurizing effluent, such as fluid feed **FF** via pump **130** via intake conduit **131** through pump **130** and therethrough outtake conduit **132.** In block or step **1220,** connecting outtake conduit **132** thereto first tube end **31** in fluid communication with filtration tube **13** of unhoused filtration device **10.** In block or step **1225** generating Dean Flow currents therein feed fluid **FF,** at least opposing pairs of corkscrew vortices, such as first corkscrew vortex **CC1** and second corkscrew vortex **CC2,** which travel along the spiral fluid flow path therein filtration tube **13.** In block or step **1230,** providing a shear cleaning current across the filter media interior surface **82** of filtration tube **13,** so as to conduct away particles **Pt** entrapped by the filter media. In block or step **1235,** providing a shear cleaning current across the filter media interior surface **82** of filtration tube **13,** so as to maintain or hold particles **Pt** to the interior **I** of filtration tube **13** away from interior surface **82** of filtration tube **13.** In block or step **1240,** discharging penetrate **P** via openings pores **Po** therein filtration tube **13,** whereby permeate **P** is then collected in container **140.**

The foregoing description and drawings comprise illustrative embodiments of the present disclosure. Having thus described exemplary embodiments, it should be noted by those ordinarily skilled in the art that the within disclosures are exemplary only, and that various other alternatives, adaptations, and modifications may be made within the scope of the present disclosure. Merely listing or numbering the steps of a method in a certain order does not constitute any limitation on the order of the steps of that method. Many modifications and other embodiments of the disclosure will come to mind to one ordinarily skilled in the art to which this disclosure pertains having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Although specific terms may be employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation. Moreover, the present disclosure has been described in detail, it should be understood that various changes, substitutions and alterations can be made thereto without departing from the spirit and scope of the disclosure as defined by the appended claims. Accordingly, the present disclosure is not limited to the specific embodiments illustrated herein, but is limited only by the following claims.

CLAIMS

WHAT IS CLAIMED IS:

1. A filter for filtering a pressurized feed fluid with suspended particles therethrough and discharging a concentrate fluid with suspended particles, the filter comprising:

a filtration tube, said filtration tube configured in a series of loops coiled around a center line having a first loop and an end loop;

wherein said first loop includes a first extension in fluid communication with said first loop;

wherein said end loop includes a second extension in fluid communication with said end loop.

2. The filter of Claim 1, further comprising a pump in fluid communication with said first extension of one or more said filtration tube and a container configured to collect a permeate filtered therethrough said filtration tube.

3. The filter of Claim 2, further comprising two or more manifold, each said manifold having two or more ports, said two or more ports includes a first port in fluid communication with a second port and a third port.

4. The filter of Claim 3, wherein said filtration tube further comprises two or more of said filtration tube including at least a first filtration tube and at least a second filtration tube.

5. The filter of Claim 4, wherein said two or more manifold includes a first manifold and a second manifold, wherein said pump is in fluid communication with said first port of said first manifold and said second port is in fluid communication with said first extension of said first filtration tube and said third port of said first manifold is

in fluid communication with said first extension of said second filtration tube.

6. The filter of Claim 5, wherein said second port of said second manifold is in fluid communication with said second extension of said first filtration tube and said third port of said second manifold is in fluid communication with said second extension of said second filtration tube.

7. The filter of Claim 6, wherein said first port of said second manifold is configured to discharge the concentrate fluid with the suspended particles.

8. The filter of Claim 1, wherein said second extension may extend to a position proximate said first extension and said first loop.

9. The filter of Claim 8, wherein said first extension is positioned within said series of loops proximate said center line.

10. The filter of Claim 9, further comprising a meshed sleeve configured to encase said filtration tube.

11. The filter of Claim 9, wherein said second extension is positioned within said series of loops.

12. The filter of Claim 9, wherein said second extension is positioned exterior to said series of loops.

13. The filter of Claim 12, further comprising a pump in fluid communication with said first extension of one or more said filtration tube and a container configured to collect a permeate filtered therethrough said filtration tube.

14. The filter of Claim 13, further comprising two or more input manifold, each said input manifold having two or more ports, said two or more ports includes a first port in fluid communication with a second port and a third port.

15. The filter of Claim 14, wherein said filtration tube further comprises two or more of said filtration tube including at least a first filtration tube and at least a second filtration tube.

16. The filter of Claim 15, wherein said one or more input manifold includes a first manifold and a second manifold, wherein said pump is in fluid communication with said first port of said first input manifold and said second port is in fluid communication with said first extension of said first filtration tube and said third port of said first manifold is in fluid communication with said first extension of said second filtration tube.

17. The filter of Claim 16, wherein said second port of said second input manifold is in fluid communication with said second extension of said first filtration tube and said third port of said second input manifold is in fluid communication with said second extension of said second filtration tube.

18. The filter of Claim 17, wherein said first port of said second manifold is configured to discharge the concentrate fluid with the suspended particles.

19. The filter of Claim 13, further comprising two or more input manifold and one or more output manifold, each said input manifold having two or more ports, said two or more ports includes a first port in fluid communication with a second port and a third port and each said output manifold having two or more ports, said two or more ports includes a

first port in fluid communication with a second port, a third port, a fourth port, and a fifth port.

20. The filter of Claim 19, wherein said filtration tube further comprises four or more of said filtration tube including at least a first filtration tube, at least a second filtration tube, at least a third filtration tube, and a fourth filtration tube.

21. The filter of Claim 20, wherein said one or more manifold includes a first input manifold and a second input manifold, wherein said pump is in fluid communication with said first port of said first manifold and said second input manifold, said second port of said first input manifold is in fluid communication with said first extension of said first filtration tube, said second port of said second input manifold is in fluid communication with said first extension of said second filtration tube, said third port of said first input manifold is in fluid communication with said first extension of said third filtration tube and said third port of said second input manifold is in fluid communication with said first extension of said fourth filtration tube.

22. The filter of Claim 21, wherein said second port of said output manifold is in fluid communication with said second extension of said first filtration tube, said third port of said output manifold is in fluid communication with said second extension of said second filtration tube, said fourth port of said output manifold is in fluid communication with said second extension of said third filtration tube, and said fifth port of said output manifold is in fluid communication with said second extension of said fourth filtration tube.

23. The filter of Claim 22, wherein said first port of said output manifold is configured to discharge the concentrate fluid with the suspended particles.

24. The filter of Claim 1, wherein said series of loops of said filtration tube is configured to produce one or more Dean Flow currents in the pressurized feed fluid therein said filtration tube.

25. The filter of Claim 1, wherein said one or more Dean Flow currents includes opposing pairs of corkscrew vortices.

26. A method of filtering a pressurized feed fluid with suspended particles therethrough, said method comprising the steps of:

providing one or more filtration tube, said filtration tube configured in a series of loops coiled around a center line having a first loop and an end loop, wherein said first loop includes a first extension in fluid communication with said first loop, wherein said end loop includes a second extension in fluid communication with said end loop, and a pump in fluid communication with said first extension of one or more said filtration tube and a container;

generating Dean Flow currents therein the feed fluid in at least opposing pairs of corkscrew vortices;

collecting a permeate filtered therethrough said one or more filtration tube; and

discharging a concentrate fluid with suspended particles.

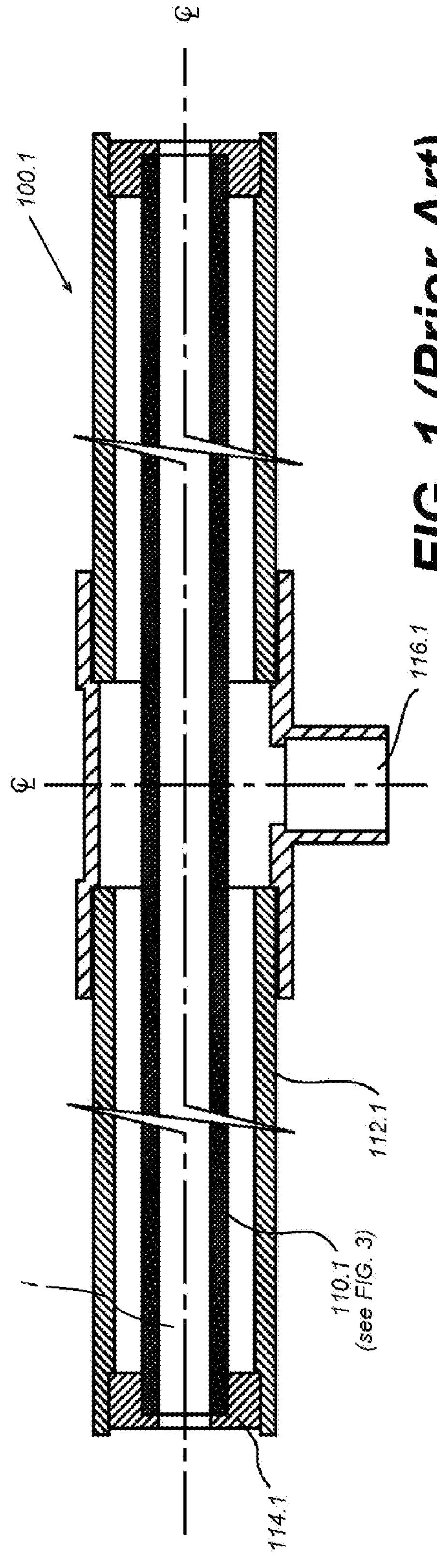


FIG. 1 (Prior Art)

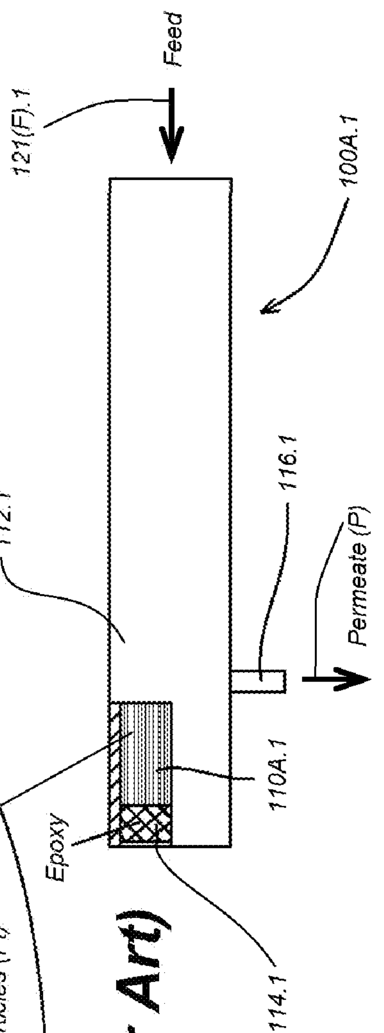


FIG. 2 (Prior Art)

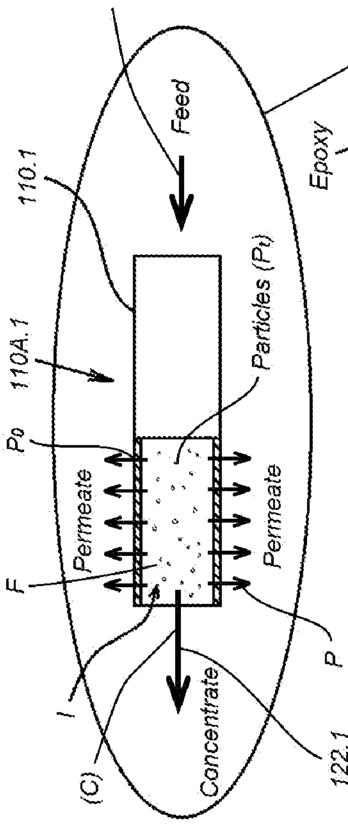


FIG. 3 (Prior Art)

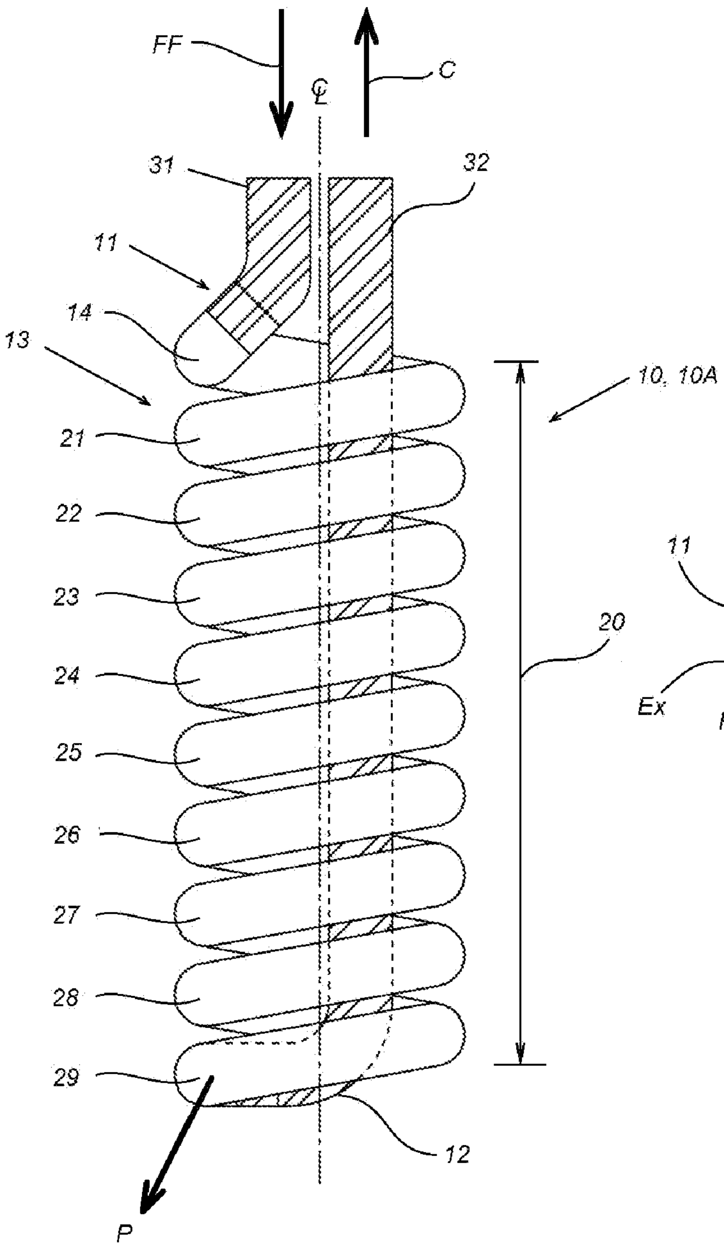
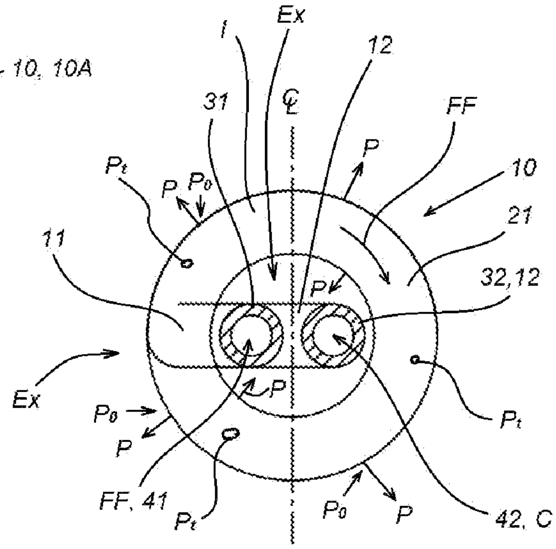

FF
C
℄
31
32
11
14
13
10, 10A
21
22
23
24
25
26
27
28
29
20
12
P

FIG. 4


I
Ex
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Pt
P0
P
FF, 41
Pt
P0
P
42, C

FIG. 5

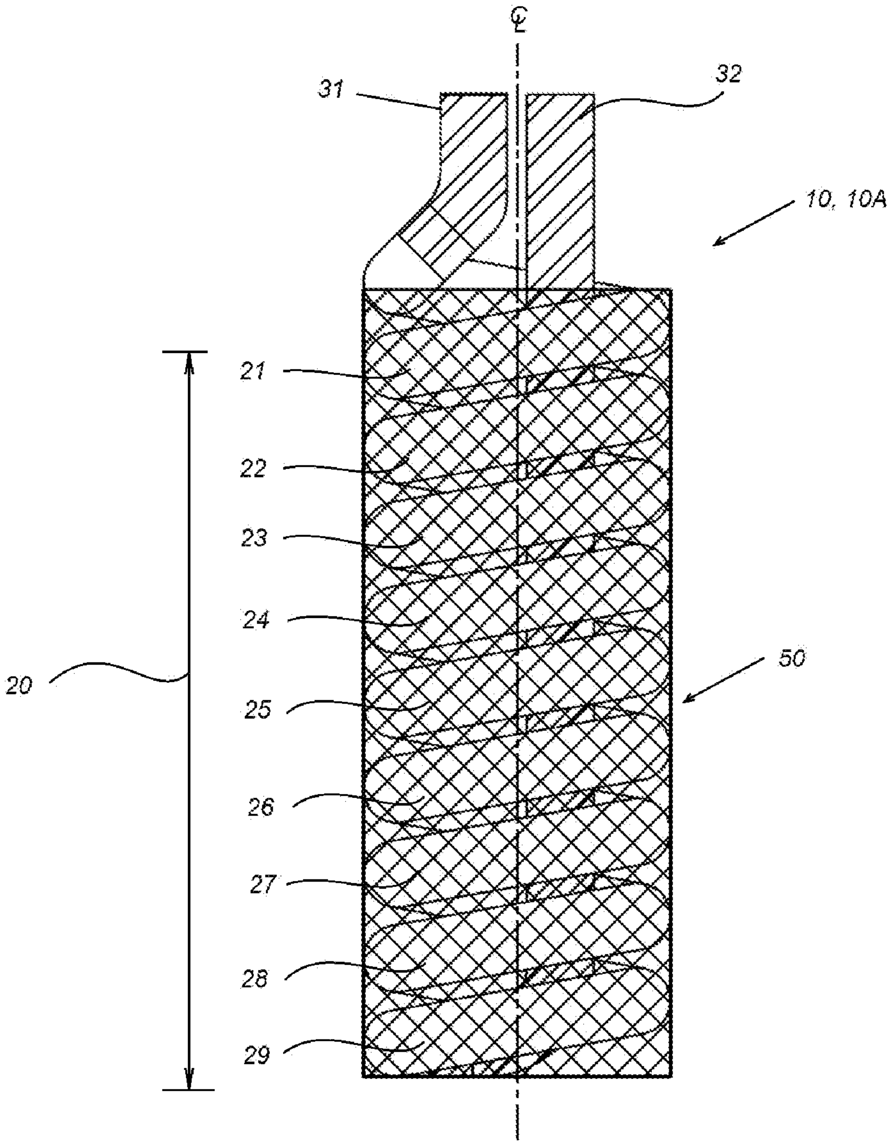

FIG. 6

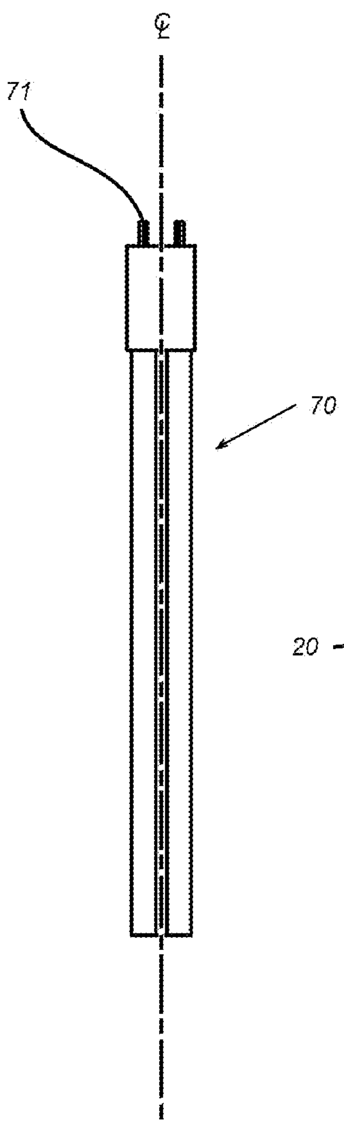

FIG. 7A

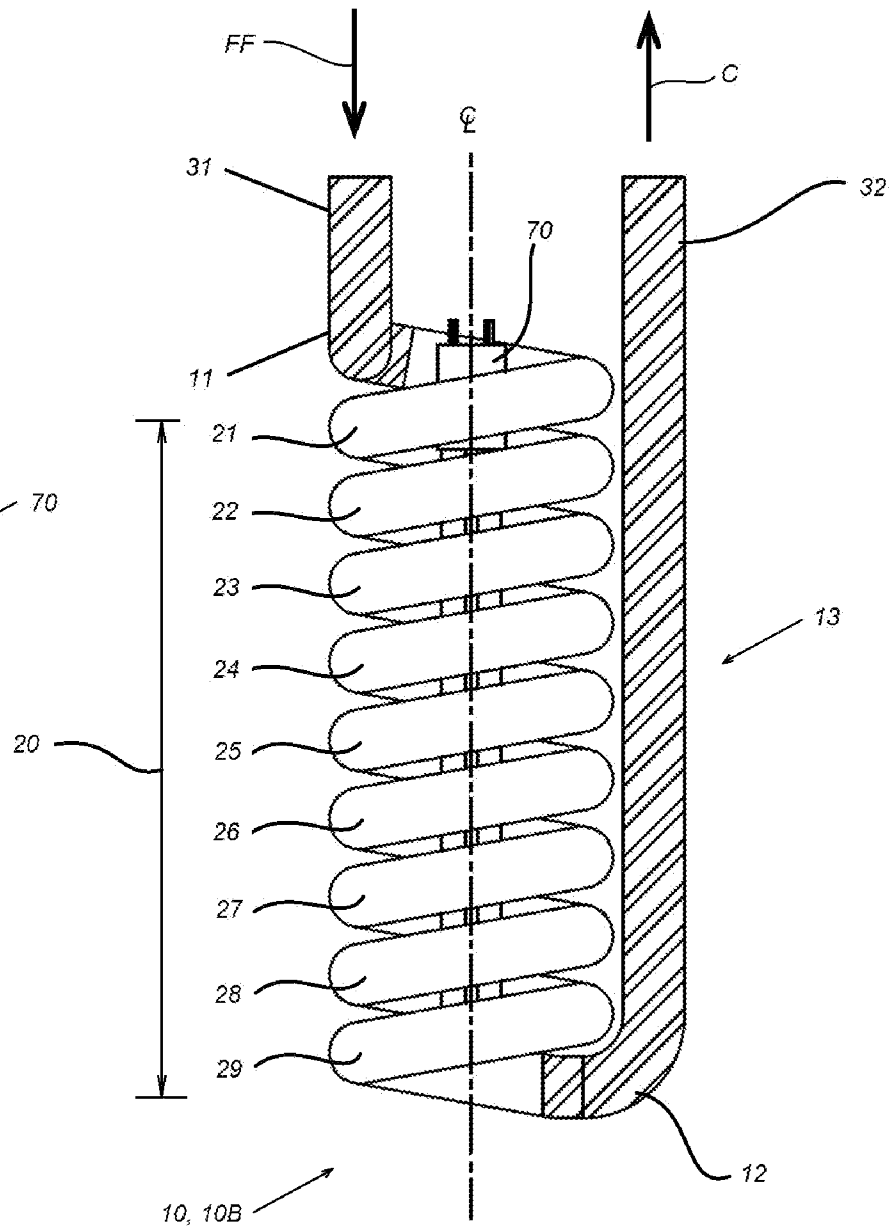

FIG. 7B

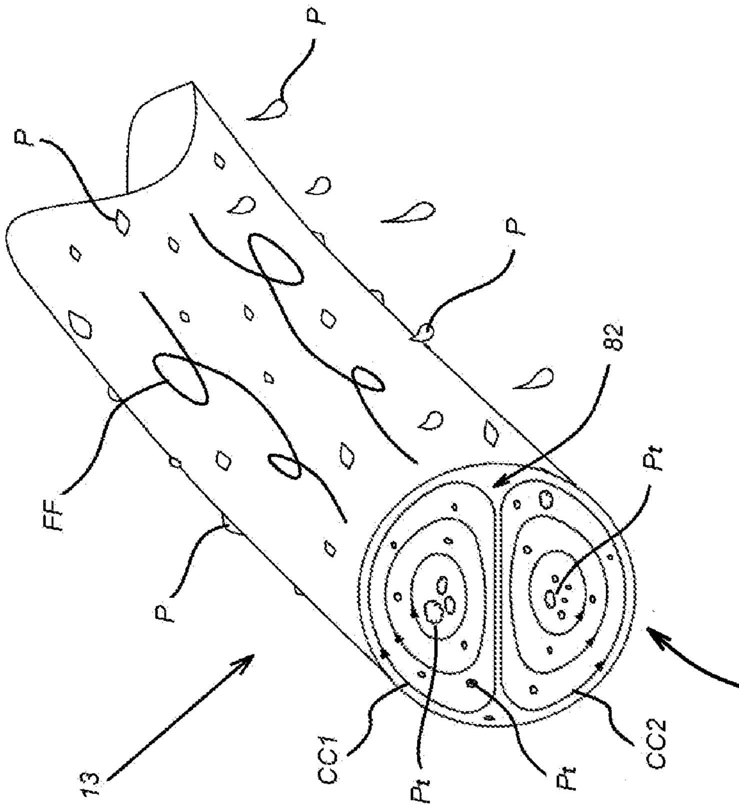

FIG. 8

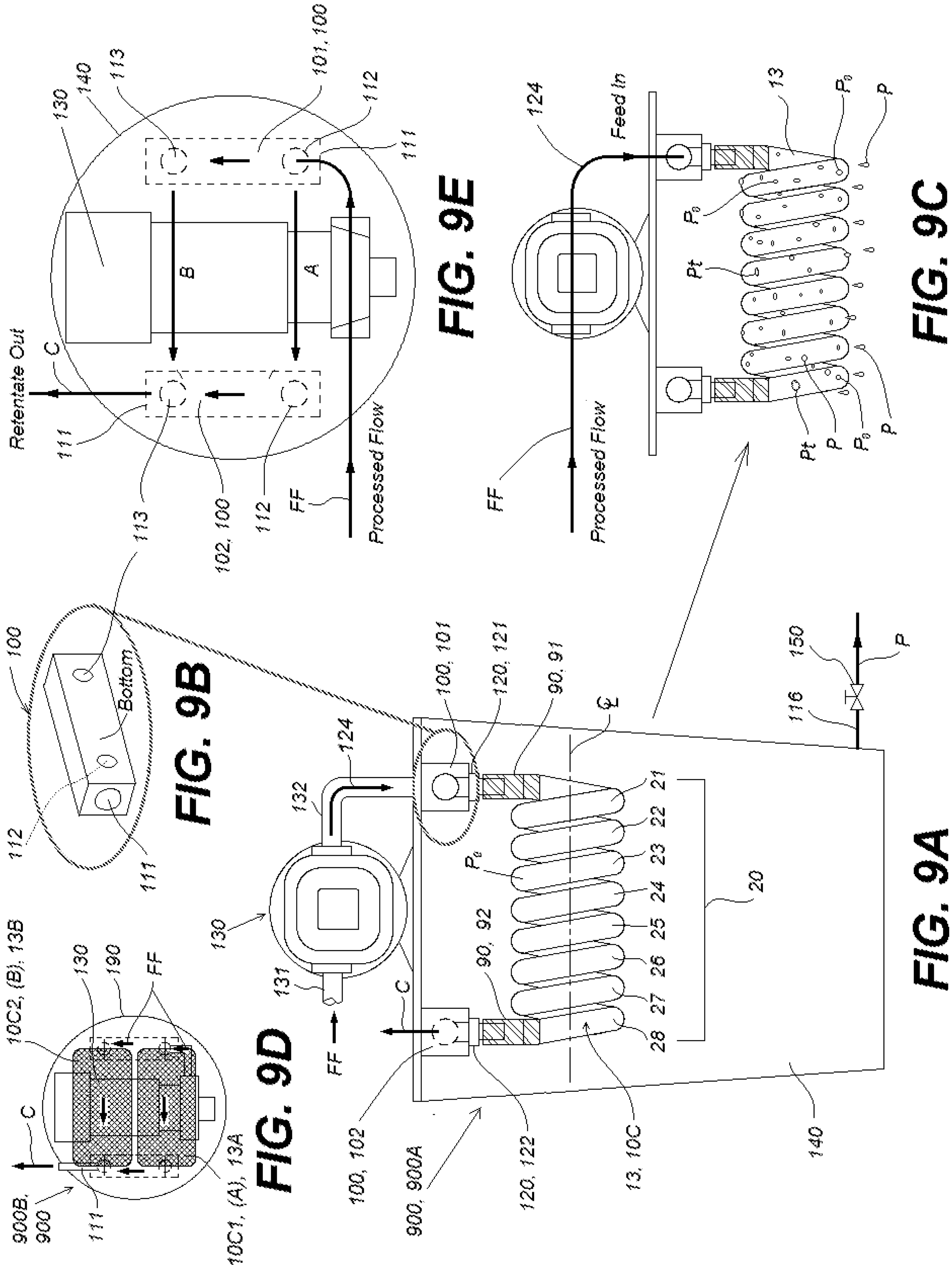

FIG. 9E

FIG. 9C

FIG. 9B

FIG. 9D

FIG. 9A

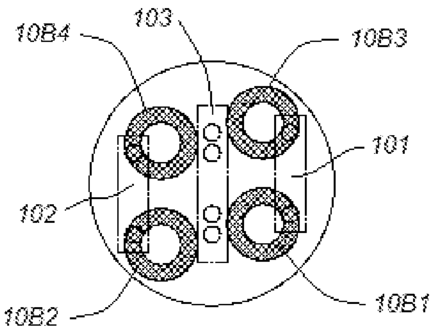

FIG. 10C1

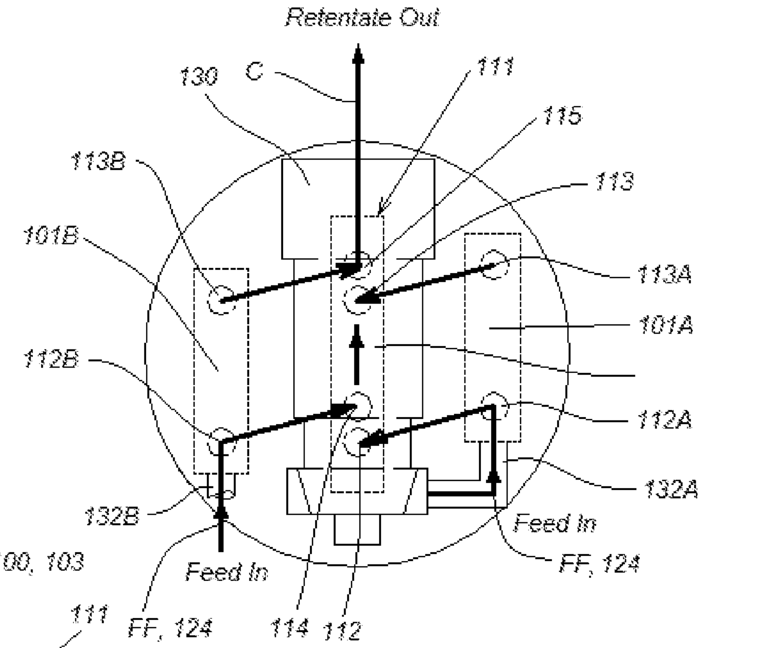

FIG. 10C2

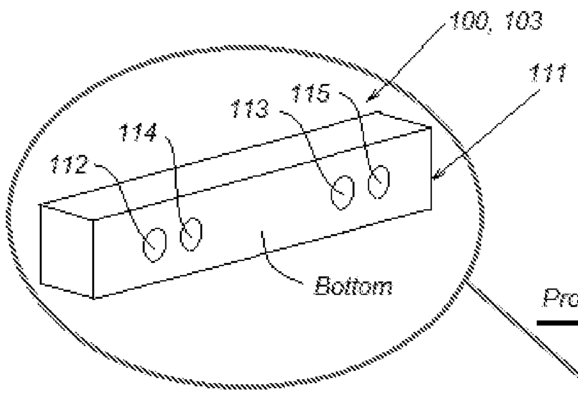

FIG. 10B

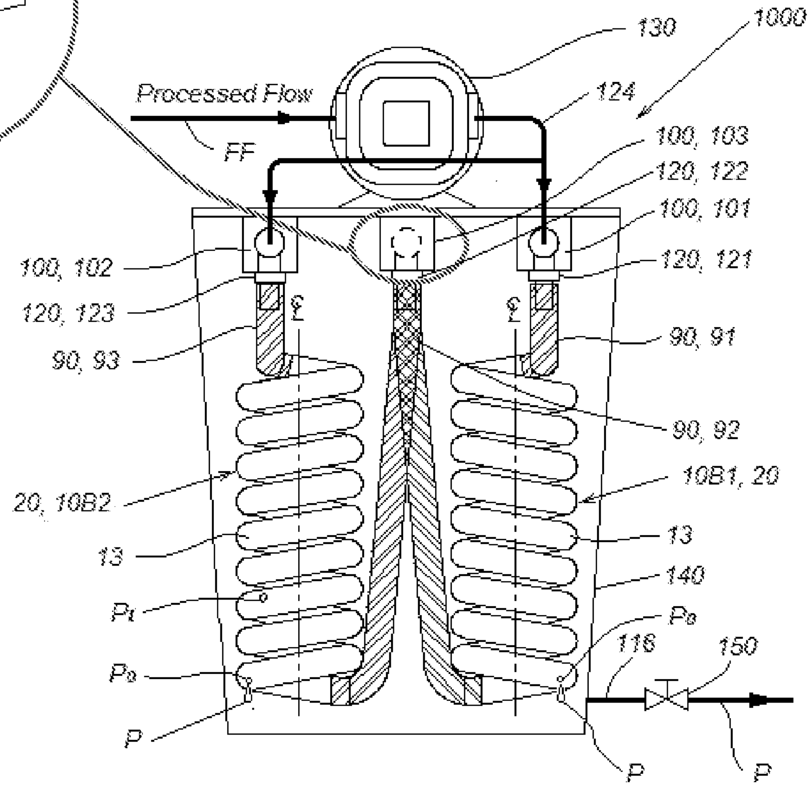

FIG. 10A

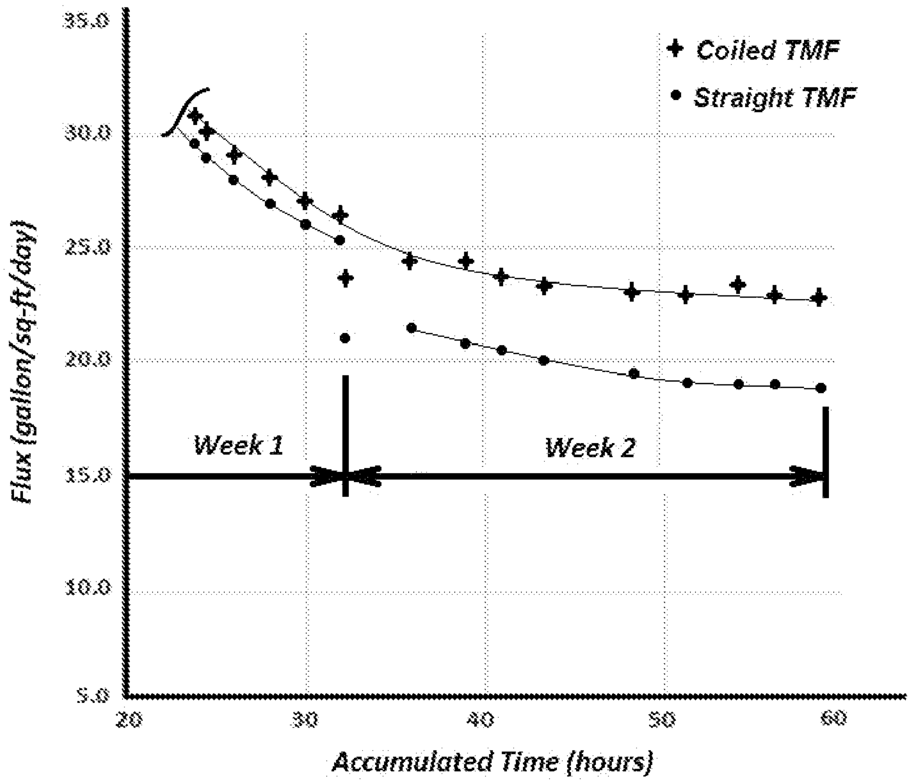
Coiled TMF
Straight TMF
Flux (gallon/sq-ft/day)
35.0
30.0
25.0
20.0
15.0
10.0
5.0
20
30
40
50
60
Accumulated Time (hours)
Week 1
Week 2

FIG. 11

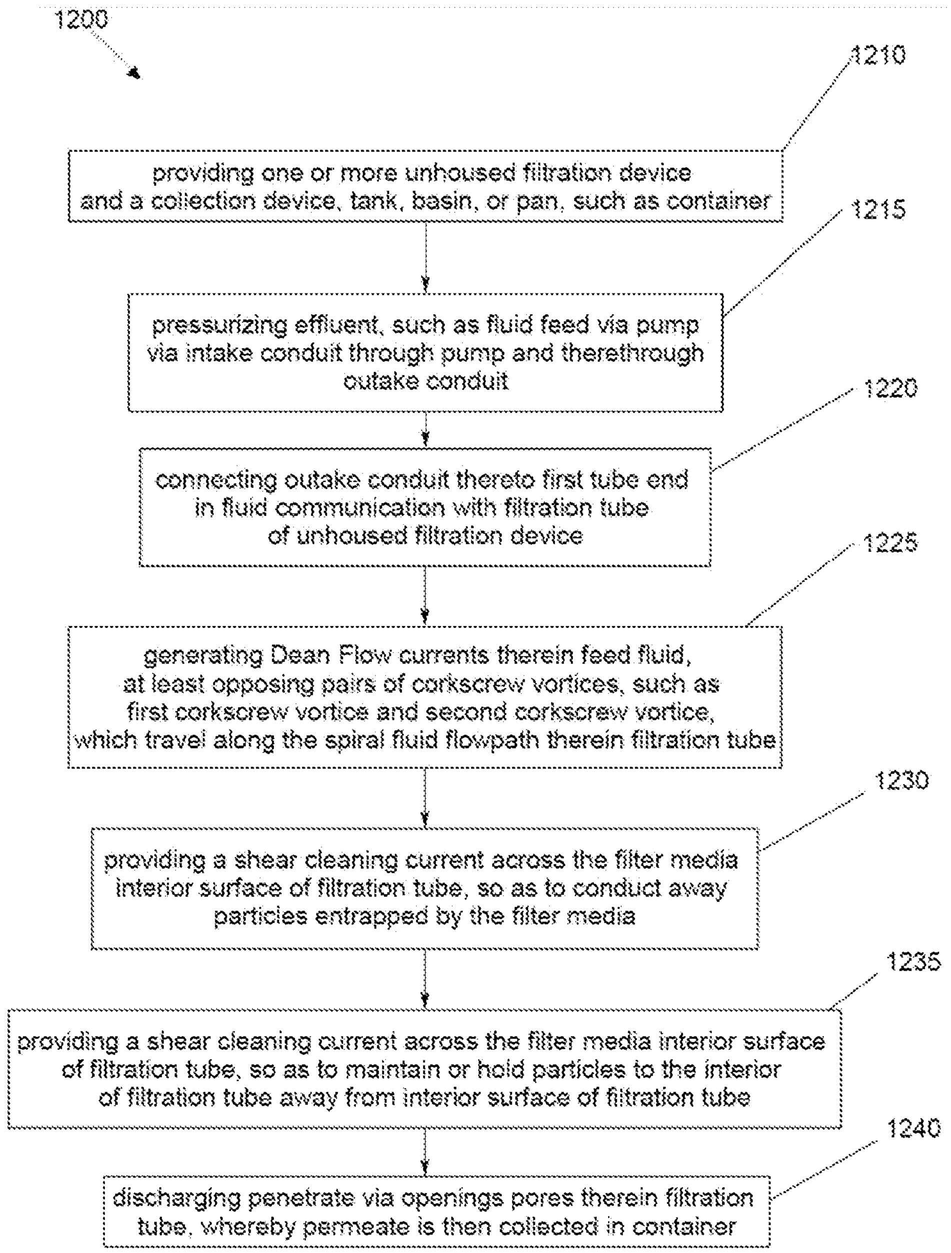
1200
1210
providing one or more unhoused filtration device and a collection device, tank, basin, or pan, such as container
1215
pressurizing effluent, such as fluid feed via pump via intake conduit through pump and therethrough outake conduit
1220
connecting outake conduit thereto first tube end in fluid communication with filtration tube of unhoused filtration device
1225
generating Dean Flow currents therein feed fluid, at least opposing pairs of corkscrew vortices, such as first corkscrew vortice and second corkscrew vortice, which travel along the spiral fluid flowpath therein filtration tube
1230
providing a shear cleaning current across the filter media interior surface of filtration tube, so as to conduct away particles entrapped by the filter media
1235
providing a shear cleaning current across the filter media interior surface of filtration tube, so as to maintain or hold particles to the interior of filtration tube away from interior surface of filtration tube
1240
discharging penetrate via openings pores therein filtration tube, whereby permeate is then collected in container

FIG. 12

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2017/016353

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - B01D 63/02; B01D 63/04; B01D 63/06; B01D 63/10; B01D 63/12 (2017.01)
CPC - B01D 63/02; B01D 63/04; B01D 63/06; B01D 63/10; B01D 63/12; B01D 2321/02; B01D 2321/2016 (2017.02)

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
USPC - 210/321.69; 210/321.83; 210/636; 210/650; 210/652 (keyword delimited)

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 — Y	US 6,203,707 B1 (HARTMANN) 20 March 2001 (20.03.2001) entire document	1-9, 11-23 — 10
X	US RE37,759 E (BELFORT) 25 June 2002 (25.06.2002) entire document	1-7, 24-26
Y	US 2014/0319045 A1 (SHEVITZ et al) 30 October 2014 (30.10.2014) entire document	10
A	US 5,985,151 A (AHMADI) 16 November 1999 (16.11.1999) entire document	1-26
A	US 6,461,513 B1 (JEN) 08 October 2002 (08.10.2002) entire document	1-26
A	US 5,202,023 A (TRIMMER et al) 13 April 1993 (13.04.1993) entire document	1-26

☐ 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
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"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	Date of mailing of the international search report
23 March 2017	14 APR 2017

Name and mailing address of the ISA/US	Authorized officer
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, VA 22313-1450 Facsimile No. 571-273-8300	Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774