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(54) Title: WATER PURIFICATION APPARATUSES USING FILTERS AND ULTRAVIOLET RADIATION

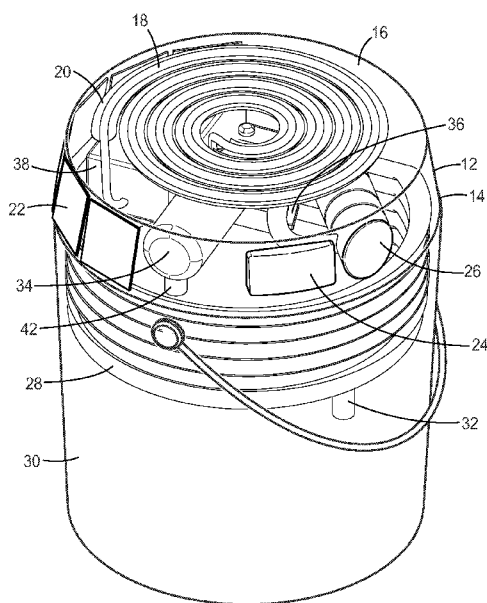


FIG. 1

(57) Abstract: A water purification apparatus may include at least one filter and a UV sterilization section. In some examples, the UV sterilization section may include at least one UV source positioned to irradiate an interior volume of the tube, and the purified water may flow to an expandable container configured to expand under pressure from water exiting the water outlet. Techniques for purifying water using the water purification apparatus are also described.



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WATER PURIFICATION APPARATUSES USING FILTERS AND ULTRAVIOLET RADIATION

TECHNICAL FIELD

5 The disclosure describes water purification apparatuses and systems including water purifications apparatuses.

BACKGROUND

10 Water purification systems have become more and more prevalent due to the scarcity of potable water. Many communities throughout the world have experienced increasing incidences of contaminated drinking water from aging water infrastructures or the lack of water infrastructures. Many water purification systems are expensive, difficult to use, difficult to maintain, and/or do not sufficiently purify water for drinking or other household use.

SUMMARY

15 The disclosure describes water purification apparatuses. The water purification apparatuses utilize filters to remove particulates (including bacteria, protozoa, microbial cysts, and the like) in the water, and utilize ultraviolet (UV) radiation to sterilize the filtered water. In some examples, the water purification apparatuses include at least one filter and a UV sterilization section fluidically connected to the at least one filter and downstream of the at least one filter. The at least one filter may be configured to filter particulates from the water. The filtering of the water may reduce its turbidity and remove at least some contaminants from the water.

20 After the water has been filtered, the water flows through the UV sterilization section, where the water is sterilized by exposure to UV radiation. Within the UV sterilization section, the water may flow through a tube. In some examples, the tube may be made of a UV-transparent material. In some examples, the UV radiation may be provided by sunlight, and the water purification apparatus may include at least one UV reflecting material, which may include a surface with a parabolic curve in at least one axis. The at least one parabolic UV reflecting material may be positioned relative to the UV-transparent tube such that the UV reflecting material reflects UV radiation to within the volume of the UV-transparent tube.

25 In other examples, the UV sterilization section may include at least one UV source, such as a light emitting diode (LED) configured to output UV radiation. The UV source may be disposed adjacent to the UV-transparent tube, e.g., next to an outer surface of the tube. In other examples, the UV source may be disposed within the volume of the tube, e.g., attached to an inner

surface of the tube, in which case, the tube may or may not be UV transparent. In some examples, the UV sterilization section may include both at least one UV reflecting material positioned relative to the UV-transparent tube such that the UV reflecting material reflects UV radiation from sunlight to within the volume of the UV-transparent tube and at least one UV source. The UV source may act as a supplemental UV source, e.g., when there is insufficient sunlight to provide the needed UV radiation.

Different water purification apparatuses may be constructed to provide different amounts of water during a given time period. For example, a water purification apparatus may be constructed that has a capacity to purify sufficient water daily for a small group of people, e.g., 5 people and about 5 gallons of water per day. The water purification apparatus may be portable, and may include an expandable container into which the purified water flows for storage. In some examples, the water purification apparatus may be sized and configured to fit on top of a bucket, such as a 5-gallon bucket.

As another example, a water purification apparatus may be constructed that has a capacity to purify sufficient water daily for a larger group of people, such as about 50 people and about 50 gallons of water per day. The water purification apparatus may include a pump, at least one filter downstream of the pump, and a UV sterilization section that includes at least one UV reflecting material positioned to reflect UV radiation (e.g., from sunlight) to within the volume of a UV transparent tube through which the water flows. In some examples, the water purification apparatus may be sized to be semi-portable, in which the water purification apparatus may be on wheels and/or may be movable using mechanical assistance, such as a semi-trailer.

In one example, the disclosure describes a water purification apparatus that includes a water inlet, at least one filter downstream of the water inlet and fluidically coupled to the water inlet, and a tube downstream of the filter and fluidically coupled to the filter. The water purification apparatus also may include at least one UV source positioned to irradiate an interior volume of the tube, a water outlet downstream of the tube and fluidically coupled to the tube, and an expandable container fluidically coupled to the water outlet, wherein the expandable container is configured to expand under pressure from water exiting the water outlet.

In another example, the disclosure describes a method including pumping water through an inlet using a pump, wherein the pump imparts sufficient energy to the water to cause the water to pass through at least one filter fluidically connected to the pump, a UV sterilization section fluidically connected to the at least one filter, and to an expandable container fluidically connected to the UV sterilization section. In this example, the method also includes filtering the water using the at least one filter, wherein the at least one filter is configured to remove at least some

particulates present in the water, and directing UV radiation into the water from at least one UV source of the UV sterilization section.

In another example, the disclosure describes a method including purifying water using any of the water purification apparatuses described herein.

5 The details of one or more examples are set forth in the accompanying drawings and the description below. Other features, objects, and advantages will be apparent from the description and drawings, and from the claims.

BRIEF DESCRIPTION OF DRAWINGS

10 FIG. 1 is a perspective diagram illustrating a partial cutaway view of an example water purification apparatus that includes at least one filter, a UV sterilization section, and an expandable container for storing purified water.

FIG. 2 is a cross-sectional diagram of an example multilayer optical film.

15 FIG. 3 is a conceptual block diagram of an example electronics module of the water purification apparatus of FIG. 1.

FIGS. 4A–4C are perspective diagrams illustrating the example water purification apparatus of FIG. 1 during different stages of a purification process.

20 FIG. 5 is a perspective diagram illustrating another example water purification apparatus that includes at least one filter and a UV sterilization section including at least one UV reflecting surface positioned to reflect UV radiation to within a UV transparent tube through which water to be sterilized flows.

FIG. 6 is a conceptual block diagram of an example electronics module of the water purification apparatus of FIG. 5.

25 FIG. 7 is a perspective diagram illustrating another view of the example water purification apparatus shown in FIG. 5.

FIG. 8 is a cross-sectional conceptual diagram illustrating another view of the example water purification apparatus shown in FIG. 5.

FIG. 9 is a partial cutaway perspective diagram illustrating another view of the example water purification apparatus shown in FIG. 5.

30 FIG. 10 is a perspective diagram illustrating a system including a plurality of water purification apparatuses.

FIG. 11 is a perspective diagram illustrating another example water purification apparatus that includes at least one filter and a UV sterilization section including at least one UV reflecting

surface positioned to reflect UV radiation to within a UV transparent tube through which water to be sterilized flows and at least one UV source.

DETAILED DESCRIPTION

5 As used herein, the term
“a”, “an”, “the”, and “at least one of” are used interchangeably and mean one or more;
“and/or” is used to indicate one or both stated cases may occur, for example A and/or B
includes, (A and B) and (A or B);

10 “interpolymerized” refers to monomers that are polymerized together to form a
macromolecular compound;

“copolymer” refers to a polymeric material comprising at least two different
interpolymerized monomers (i.e., the monomers do not have the same chemical structure) and
includes, for example, terpolymers (three different monomers) or tetrapolymers (four different
monomers);

15 “polymer” refers to a polymeric material comprising interpolymerized monomers of the
same monomer (a homopolymer) or of different monomers (a copolymer);

“light” refers to electromagnetic radiation having a wavelength or wavelengths in a range
from 200 nm to 2500 nm;

20 “melt-processible” refers to a polymeric material that flows upon melting, heating, and/or
application of pressure in normal process equipment such as extruders; and

“optical layer” refers to a layer of material having a thickness of about one quarter of a
wavelength or wavelengths of light to be reflected.

The disclosure describes water purification apparatuses. In some examples, the
purification apparatuses include at least one filter and a UV sterilization section fluidically
25 connected to the at least one filter and downstream of the at least one filter. The at least one filter
may be configured to filter particulates from the water. The filtering of the water may reduce its
turbidity and remove at least some contaminants from the water. After the water has been filtered,
the water flows through the UV sterilization section, where the water is sterilized by exposure to
UV radiation. In some examples, the UV radiation may be provided by sunlight. In other
30 examples, the UV sterilization section may include at least one UV source, such as a light emitting
diode (LED) configured to output UV radiation. In some examples, the UV sterilization section
may include both at least one UV reflecting material positioned relative to the UV-transparent tube
such that the UV reflecting material reflects UV radiation from sunlight to within the volume of
the UV-transparent tube and at least one UV source.

FIG. 1 is a perspective diagram illustrating a partial cutaway view of an example water purification apparatus 10 that includes at least one filter 26, a UV sterilization section, and an expandable container 28 for storing purified water. Other views of water purification apparatus 10 are shown in FIGS. 4A–4C. FIGS. 4A–4C are perspective diagrams illustrating an example water purification apparatus during different stages of a purification process. Similar structures of water purification apparatus 10 are labeled with similar reference numerals in FIGS. 1 and 4A–4C.

Water purification apparatus 10 includes a housing 12 that defines a perimeter surface 14 and a top surface 16. Although perimeter surface 14 is shown as defining a cylindrical shape, in other examples, perimeter surface 14 may define another shape, such as a rectangular shape or the like. Similarly, although top surface 16 is shown as defining a substantially planar surface (with a spiral depression approximately corresponding to the shape of tube 18), in other examples, top surface 16 may define another surface shape. Housing 12 also defines a bottom surface, which is not shown in FIGS. 1 and 4A–4C. Bottom surface is shaped to rest on a top edge of bucket 30. In some examples, bucket 30 may be a 5-gallon bucket. In some examples, water purification apparatus 10 may not include bucket 30, and may be provided separately from a bucket 30.

As shown in FIG. 1, water to be purified is disposed in bucket 30. Water purification apparatus 10 includes an inlet 32, which extends out of housing 12. In the example shown in FIG. 1 (also seen in FIGS. 4A–4C), inlet 32 is a tube that extends out of housing 12 and into the interior volume of bucket 30. Inlet 32 is fluidically connected to an inlet of pump 34. Pump 34 may be substantially fully (e.g., fully or nearly fully) disposed within housing 12, or a portion of pump 34 may be external to housing 12, as shown in FIG. 1. Pump 34 may be adapted to pump water through inlet 32 to other portions of water purification apparatus 10. In different examples, pump 34 may be manually powered (e.g., a hand-powered pump), battery powered, electrically powered, solar powered, and/or gasoline powered.

In some examples, as shown in FIG. 1, pump 34 may be electrically connected to a power source contained in electronic module 38 (e.g., power source 64 illustrated in FIG. 3) and/or electrically connected to photovoltaic cells 22. In some examples, the power source may be user-replaceable or non-user-replaceable. In some examples, the power source may be rechargeable. In other examples, the power source may be disposable (non-rechargeable). In some examples, the power source may be, for example, a lithium ion or lithium polymer battery.

Photovoltaic cells 22 may be disposed on an outer surface of housing 12, such as perimeter surface 14. In some examples, water purification apparatus 10 may include a plurality of photovoltaic cells 22, as shown in FIGS. 4A–4C. In some implementations, photovoltaic cells 22 may be electrically connected to the power source in electronic module 38, and may be used to

charge and recharge the power source. In other examples, photovoltaic cells 22 may be electrically connected to pump 34 and directly power pump 34.

In some examples, pump 34 may be primarily powered by photovoltaic cells 22, and may be powered by the power source in electronic module 38 when there is insufficient power provided by photovoltaic cells 22. Thus, pump 34 may be selectively powered by photovoltaic cells 22 and the power source in electronic module 38. In other examples, as mentioned above, photovoltaic cells 22 may be used to charge the power source, and the power source may be used to power pump 34.

An outlet of pump 34 may be fluidically connected to an inlet of at least one filter 26, e.g., via a tube. The at least one filter 26 thus may be downstream of pump 34 in some examples, although in other examples, the various components of water purification apparatus may be fluidically connected in different orders. The at least one filter 26 may be disposed at least partially within housing 12. In some examples, at least one filter 26 may be substantially fully (e.g., fully or nearly fully) disposed within housing 12. The at least one filter 26 may be adapted to and configured to remove at least some particles from the water to be purified. In some examples, the at least one filter 26 may include a size exclusion filter, which includes pores or other structured configured to allow molecules and particles less than a defined size pass while not allowing particles larger than the defined size pass through the filter. In other examples, the at least one filter 26 may include an activated carbon filter, which uses chemical adsorption to remove particles from the water.

In some examples, the at least one filter 26 may include a plurality of filters, which may be configured so water flows through the plurality of filters 26 in series configuration or in parallel configuration. In some examples, the at least one filter 26 may include a plurality of size exclusion filters disposed in series, in which the more upstream filters are adapted to and configured to remove particles having larger relative sizes and the more downstream filters are adapted to and configured to remove particles having smaller relative sizes. In some examples, the at least one filter 26 may be adapted to and configured to remove particles (e.g., including bacteria, protozoa, microbial cysts, and the like) having a characteristic dimension of greater than about 0.2 micrometers.

In some examples, as shown in FIG. 1, the at least one filter 26 may be provided in a user-accessible location and user-replaceable format. For example, the at least one filter 26 may be housed in a cartridge that is accessible from an exterior of housing 12, as shown in FIG. 1. This may allow a use of water purification apparatus 10 to replace the at least one filter 26 when the at least one filter 26 has no useful life remaining.

In some examples, the at least one filter 26 may include a sensor that detects the remaining useful life of the at least one filter 26. For example, the approximate useful life may be predetermined based on a volumetric capacity water that the at least one filter 26 is able to filter before exhausting its useful life. The at least one filter 26 may include (e.g., within a cartridge in which the at least one filter 26 is disposed) a flow sensor and an external indicator of when the at least one filter 26 should be replaced. As another example, water purification apparatus 10 may include sensors (e.g., pressure sensor 70 illustrated in FIG. 3) configured to determine a pressure drop across the at least one filter 26, and a controller in electronic module 38 may be configured to output the indication that the at least one filter 38 should be replaced for display at display device 24.

Additionally or alternatively, water purification apparatus 10 may include a sensor (e.g., turbidity sensor 68 illustrated in FIG. 3) disposed at the exit of the last of the at least one filter 26 that is configured to measure turbidity of water exiting the at least one filter 26. Turbidity is a measure of the cloudiness or haziness of the water caused by suspended particles in the water. Thus, turbidity provides an indication of the effectiveness of the at least one filter 26 in filtering particulates from the water flowing through the at least one filter 26. Turbidity may be measured by shining a light through the water and measuring the light attenuation caused by the water.

Upon exiting the at least one filter 26, water flows through tube 18. Tube 18 extends along a sterilization section of water purification apparatus 10. The sterilization section may include at least one UV source 36 and/or at least one UV reflective material 20. In the example shown in FIG. 1, the sterilization section includes both at least one UV source 36 and at least one UV reflective material 20. In other examples, the sterilization section may include at least one UV source 36 or at least one UV reflective material 20, but not both.

In some examples, tube 18 may be disposed adjacent to at least one UV source 36. In the example shown in FIG. 1, the at least one UV source 36 is disposed within the volume of housing 12 and is located downstream of the at least one filter 26. The at least one UV source 36 may include, for example, at least one light emitting diode (LED) configured to output UV radiation. As used here, UV radiation may refer to radiation having a wavelength less than about 400 nanometers (nm). Example wavelength ranges for UV light utilized herein include between about 200 nm and about 350 nm, or between about 200 nm and about 300 nm, or between about 250 nm and about 300 nm, or between about 250 nm and about 275 nm.

As shown in FIG. 1, in some examples, the at least one UV source 36 may be disposed adjacent to an external surface of tube 18. In such examples, tube 18 may be formed of a UV-transparent material, such as a UV-transparent polymer, glass, or plastic. Thus, the UV source 36 may emit UV radiation and direct the UV radiation to within the volume of tube 18 to expose

water flowing through tube 18 to UV radiation. In some examples, the at least one UV source 36 and/or tube 18 and/or housing 12 may include shielding that substantially prevents (e.g., prevents or nearly prevents) UV radiation from exiting housing 12, thus substantially confining (e.g., confining or nearly confining) UV radiation produced by UV source 36 to within the volume of housing 12.

In other examples, the at least one UV source 36 may be disposed within the volume of tube 18. In some of these examples, tube 18 may not be transparent (e.g., to at least UV radiation) at the portion of tube at which the at least one UV source 36 is disposed.

In some implementations, the at least one UV source 36 may be positioned at a different location within water purification apparatus 10. For example, the at least one UV source 36 may be disposed within tube 18 at locations where tube 18 is external to housing 12 (e.g., adjacent to top surface 16 of housing 12). Additionally or alternatively, the at least one UV source 36 may include a plurality of UV sources 36 disposed along a length of at least a portion of tube 18.

In the example shown in FIG. 1, tube 18 exits housing 12 after passing at least one UV source 36. Top surface 16 of housing 12 defines a spiral depression, in which a tube 18 is disposed. In some examples, tube 18 is formed of a transparent material, such as a transparent polymer, glass, or plastic. In other examples, tube 18 may be opaque to at least some wavelengths of light, such as visible wavelengths. Although in the example of FIGS. 1 and 4A–4C top surface 16 defines a spiral depression in which tube 18 is disposed, in other examples, top surface 16 may define a different shaped depression in which tube 18 is disposed. In other examples, top surface 16 may not define a depression, and tube 18 may be disposed on a flat surface of top surface 16 or at another location of housing 12.

In some examples, water purification apparatus 10 also may include at least one UV reflective material 20 disposed within the spiral depression. The at least one UV reflective material 20 may be positioned below tube 18, between an outer surface of tube 18 and top surface 16 of housing 12. For example, the at least one UV reflective material 20 may be attached (e.g., adhered) to top surface 16 within the spiral depression. In some examples, the at least one UV reflective material 20 may be positioned along at least a portion of the length of the spiral depression. In other examples, the at least one UV reflective material 20 may be positioned upon substantially the entire length (e.g., the entire length or nearly the entire length) of the spiral depression.

The at least one UV reflective material 20 may include a material that is adapted to reflect at least a portion of light (e.g., sunlight) having wavelengths within the UV spectrum. For example, the at least one UV reflective material 20 may be adapted to reflect at least a portion of light having a wavelength between about 200 nanometers (nm) and about 350 nm, or between

about 200 nm and about 300 nm, or between about 250 nm and about 300 nm, or between about 250 nm and about 275 nm. In some examples, the at least one UV reflective material 20 may be adapted to transmit and/or absorb at least some of the light having wavelengths outside of the UV spectrum (e.g., light having a wavelength greater than about 400 nm, or greater than about 350 nm, or greater than about 300 nm, or greater than about 275 nm).

Because, in some examples, the at least one UV reflective material 20 may reflect at least some incident light with a wavelength in the UV spectrum and transmit and/or absorb at least some incident light with a wavelength outside of the UV spectrum, the at least one UV reflective material 20 may reduce an amount of heat transferred to and absorbed by the water flowing through tube 18. This may reduce heating and/or vaporization of the water, which may simplify operation of water purification apparatus 10.

An example material that may be formed to reflect at least a portion of incident light having a certain wavelength or certain wavelengths and absorb and/or transmit at least a portion of incident light having different wavelength may be a multilayer optical film. FIG. 2 depicts an example of such a multilayer optical film. Multilayer optical film 50 includes an optical stack 52 and may include optional additional layers (not shown), such as, for example, optional protective boundary layers and/or optional skin layers. Optical stack 50 includes first optical layers 54a, 54b, . . . , 54n (collectively, "first optical layers 54") interleaved with and in intimate contact with second optical layers 56a, 56b, . . . , 56n (collectively, "second optical layers 56"). Second optical layers 56 are disposed in a repeating sequence with first optical layers 54, forming layer pairs that include a respective one of first optical layers 54 and a respective one of second optical layers 56. For example, first optical layers 54 and second optical layers 56 may be disposed in alternating layer pairs (e.g., ABABAB . . .) as shown in FIG. 2. In other examples, the layer pairs may be arranged with one or more intermediate layers between at least some of the adjacent layer pairs (e.g., ABCABC . . .) or in a non-alternating fashion (e.g., ABABABCAB . . . , ABABACABDAB . . . , ABABBAABAB . . . , etc.).

In some examples, first optical layers 54 may include a first fluoropolymeric material and second optical layers 56 may include a second fluoropolymeric material. The first fluoropolymeric material may be different than the second fluoropolymeric material. The fluoropolymeric materials may include melt-processible fluoropolymers derived from interpolymers of fully or partially fluorinated monomers and may be semi-crystalline or amorphous. In some examples, the fluoropolymeric materials may include at least one of the following monomers: tetrafluoroethylene (TFE), hexafluoropropylene (HFP), chlorotrifluoroethylene (CTFE), fluoroalkyl vinyl ethers, fluoroalkoxy vinyl ethers, fluorinated styrenes, fluorinated siloxanes, hexafluoropropylene oxide (HFPO), or combinations thereof.

Some example fluoropolymeric materials include: homopolymers of TFE (e.g., PTFEs); copolymers of ethylene and TFE (e.g., ETFEs); copolymers of TFE, HFP, and VDF (e.g., THVs); homopolymers of VDF (e.g., PVDFs); copolymers of VDF (e.g., coVDFs); homopolymers of VF (e.g., PVFs); copolymers of HFP and TFE (e.g., FEPs); copolymers of TFE and propylene (e.g., TFEPs); copolymers of TFE and perfluorovinyl ether (e.g., PFAs); copolymers of TFE, (perfluorovinyl) ether, and (perfluoromethyl vinyl) ether (e.g., MFAs); copolymers of HFP, TFE, and ethylene (e.g., HTEs); homopolymers of chlorotrifluoroethylene (e.g., PCTFE); copolymers of ethylene and CTFE (e.g., ECTFEs); homopolymers of HFPO (e.g., PHFPO); homopolymers of 4-fluoro-(2-trifluoromethyl)styrene; copolymers of TFE and norbornene; copolymers of HFP and VDF; or combinations thereof.

In some examples, the representative melt-processible copolymers including interpolymers of tetrafluoroethylene described above include additional monomers, which may be fluorinated or non-fluorinated. Examples include, ring opening compounds such as 3- or 4-membered rings that undergo ring opening under the conditions of polymerization such as, e.g., epoxides, olefinic monomers such as, e.g., propylene, ethylene, vinylidene fluoride, vinyl fluoride, and norbornene; and perfluoro(vinyl ethers)s of the formula $\text{CF}_2=\text{CF}=(\text{OCF}_2\text{CF}(\text{R}_f)_a\text{OR}'_f)_b$, where R_f is a perfluoroalkyl having 1 to 8 carbon atoms, such as 1 to 3 carbon atoms, and a is an integer from 0 to 3. Examples of the perfluoro(vinyl ether)s having this formula include: $\text{CF}_2=\text{CFOCF}_3$, $\text{CF}_2=\text{CFOCF}_2\text{CF}_2\text{CF}_2\text{OCF}_3$, $\text{CF}_2=\text{CFOCF}_2\text{CF}_2\text{CF}_3$, $\text{CF}_2=\text{CFOCF}_2\text{CF}(\text{CF})_3\text{OCF}_2\text{CF}_2\text{CF}_3$, and $\text{CF}_2=\text{CFOCF}_2\text{CF}(\text{CF})_3\text{OCF}_2\text{CF}(\text{CF}_3)\text{OCF}_2\text{CF}_2\text{CF}_3$. In some examples, melt-processible fluoropolymers may include at least three, or even at least four, different monomers.

Some examples of melt-processible copolymers of tetrafluoroethylene and other monomer(s) discussed above include those commercially available as: copolymers of tetrafluoroethylene, hexafluoropropylene, and vinylidene fluoride sold under the trade designation "DYNEON THV 220", "DYNEON THV 230", "DYNEON THV 500", "DYNEON THV 500G", "DYNEON THV 510D", "DYNEON THV 610", "DYNEON THV 815", "DYNEON THVP 2030G" by Dyneon LLC, Oakdale, MN; copolymers of tetrafluoroethylene, hexafluoropropylene, and ethylene sold under the trade designation "DYNEON HTE 1510" and "DYNEON HTE 1705" by Dyneon LLC, and "NEOFLON EFEP" by Daikin Industries, Ltd., Osaka, Japan; copolymers of tetrafluoroethylene, hexafluoropropylene, and ethylene sold under the trade designation "AFLAS" by Asahi Glass Co., Ltd., Tokyo, Japan; copolymers of tetrafluoroethylene and norbornene sold under the trade designation "TEFLON AF" by E.I. du Pont de Nemours and Co., Wilmington, DE; copolymers of ethylene and tetrafluoroethylene sold under the trade designation "DYNEON ET 6210A" and "DYNEON ET 6235" by Dyneon LLC, "TEFZEL ETFE" by E.I. du Pont de Nemours

and Co., and "FLUON ETFE" by Asahi Glass Co., Ltd.; copolymers of ethylene and chlorotrifluoroethylene sold under the trade designation "HALAR ECTFE" by Solvay Solexis Inc., West Deptford, NJ; homopolymers of vinylidene fluoride sold under the trade designation "DYNEON PVDF 1008" and "DYNEON PVDF 1010" by Dyneon LLC; copolymers of polyvinylidene fluoride sold under the trade designation "DYNEON PVDF 11008", "DYNEON PVDF 60512", "DYNEON FC-2145" (a copolymer of HFP and VDF) by Dyneon LLC, homopolymers of vinyl fluoride sold under the trade designation "DUPONT TEDLAR PVF" by E.I. du Pont de Nemours and Co.; MFAs sold under the trade designation "HYFLON MFA" by Solvay Solexis Inc.; or combinations thereof.

Some example layer pairs including fluoropolymeric materials in both the first optical layers 54 and second optical layers 56 that can be used in optical stack 52 include: homopolymers of vinylidene fluoride and (copolymers of tetrafluoroethylene, hexafluoropropylene, and vinylidene fluoride) layer pairs; (copolymers of ethylene and chlorotrifluoroethylene) and (copolymers of tetrafluoroethylene, hexafluoropropylene, and vinylidene fluoride) layer pairs; (copolymers of tetrafluoroethylene, hexafluoropropylene, and ethylene) and (copolymers of tetrafluoroethylene, hexafluoropropylene, and vinylidene fluoride) layer pairs; (copolymers of tetrafluoroethylene, hexafluoropropylene, and ethylene) and (copolymers of ethylene and tetrafluoroethylene) layer pairs; (copolymers of tetrafluoroethylene, hexafluoropropylene, and ethylene) and copolymers of tetrafluoroethylene and norbornene layer pairs; (copolymers of ethylene and tetrafluoroethylene) and (copolymers of tetrafluoroethylene, hexafluoropropylene, and vinylidene fluoride) layer pairs; or combinations thereof.

In other examples, first optical layers 54 may include a fluoropolymeric material and second optical layers 56 may include a non-fluorinated polymeric material selected from the group consisting of poly(methyl methacrylate); copolymers of poly(methyl methacrylate); polypropylene; copolymers of propylene; polystyrenes including, e.g., syndiotactic polystyrene, isotactic polystyrene, and atactic polystyrene, or combinations thereof; copolymers of styrene, such as, e.g., copolymers of acrylonitrile, styrene, and acrylate (e.g., ASA); polyvinylidene chloride; polycarbonates; thermoplastic polyurethanes; copolymers of ethylene, such as, e.g., copolymers of ethylene and vinyl acetate (e.g., EVAs); cyclic olefin copolymers; and combinations thereof.

Some example non-fluorinated polymeric materials include those such as: poly(methyl methacrylate) sold under the trade designations "CP71" and "CP80" by Ineos Acrylics, Inc., Wilmington, Del.; copolymers of poly(methyl methacrylate) sold under the trade designation "PERSPEX CP63" by Ineos Acrylics, Inc. made from 75 weight percent methyl methacrylate and 25 weight percent ethyl acrylate, and a copolymer made from methyl methacrylate and n-butyl

methacrylate; polypropylene including atactic polypropylene and isotactic polypropylene; copolymers of polypropylene sold under the trade designation "ADMER" by Mitsui Chemicals America Inc., Rye Brook, N.Y. made from polypropylene and maleic anhydride, and "REXFLEX W111" by Huntsman Chemical Corp., Salt Lake City, Utah, which is a copolymer of atactic polypropylene and isotactic polypropylene; polystyrene sold under the trade designation "STYRON" by Dow Chemical Co., Midland, Mich.; copolymers of polystyrene sold under the trade designation "TYRIL" by Dow Chemical Co., which is a copolymer of styrene and acetonitrile, "STAREX" by Samsung, La Mirada, Calif., which is a copolymer of acrylonitrile, styrene, and acrylate, and copolymers of styrene and acrylate available from Noveon, a subsidiary of Lubrizol Corp., Wickliffe, Ohio; PVDC sold under the trade designation "SARAN" by Dow Chemical Co.; polycarbonate sold under the trade designation "CALIBRE" by Dow Chemical Co.; thermoplastic polyurethane sold under the trade designation "STATRITE X5091" by Lubrizol Corp., "ELASTOLLAN" by BASF Corp., Freeport, Tex., and as available from Bayer MaterialScience, AG, Leverkusen, Gennany; coPEs sold under the trade designation "ENGAGE 8200" by Dow Chemical Co., which are copolymers of ethylene and octene, "DUPONT ELVAX" by E.I. duPont de Nemours and Co., which is a copolymer of ethylene and vinyl acetate, "DUPONT ELVALOY" by E.I. du Pont de Nemours and Co., which is a copolymer of ethylene and acrylate including butyl-, ethyl-, and methyl-acrylates (EBAs, EEAs, and EMAs), and "DUPONT BYNEL" by E.I. du Pont de Nemours and Co., which is an ethylene copolymer; cyclic olefin copolymers sold under the trade designation "TOPAS COC" by Topas Advanced Polymers, Florence, Ky., which is a copolymer of ethylene and norbornene; or combinations thereof. Further details regarding example UV-reflective materials formed from fluoropolymeric multilayer optical films can be found in U.S. Patent Publication No. 2011/0255155 A1, entitled, "FLUOROPOLYMERIC MULTILAYER OPTICAL FILM AND METHODS OF MAKING AND USING THE SAME," the entire content of which is incorporated herein by reference.

By appropriate selection of the first optical layers 54 and the second optical layers 56, optical stack 52 can be designed to reflect or transmit a desired bandwidth of light. It will be understood from the foregoing discussion that the choice of a second optical layer is dependent not only on the intended application of the multilayer optical film, but also on the choice made for the first optical layer, as well as the processing conditions.

As light passes through optical stack 52, the light or some portion of the light will be transmitted through an optical layer (e.g., one of first optical layers 54 and/or one of second optical layers 56), absorbed by an optical layer (e.g., one of first optical layers 54 and/or one of second optical layers 56), or reflected off the interface between the optical layers (e.g., an interface between one of first optical layers 54 and one of second optical layers 56).

The light transmitted through an optical layer is related to absorbance, thickness, and reflection. Transmission (T) is related to absorbance (A) in that $A = -\log T$, and $\%A + \%T + \% \text{reflection} = 100\%$. Reflection is generated at each interface between the optical layers. Referring again to FIG. 2, first optical layers 54 and second optical layers 56 have respective refractive indices that are different, n_1 and n_2 , respectively. Light may be reflected at the interface of adjacent optical layers, for example, at the interface between first optical layer 54a and second optical layer 56a; and/or at the interface between second optical layer 56a and first optical layer 54b. Light that is not reflected at the interface of adjacent optical layers typically passes through successive layers and is either absorbed in a subsequent optical layer, reflected at a subsequent interface, or is transmitted through the optical stack 52 altogether. In some examples, the optical layers of a given layer pair are selected such as to be substantially transparent to those light wavelengths at which reflectivity is desired. Light that is not reflected at a layer pair interface passes to the next layer pair interface where a portion of the light is reflected and unreflected light continues on, and so on. In this way, an optical layer stack with many optical layers (e.g., more than 50, more than 100, more than 1000, or even more than 2000 optical layers) is capable of generating a high degree of reflectivity.

The reflectivity of the interface of adjacent optical layers may be proportional to the square of the difference in index of refraction on the first optical layer and the second optical layer at the reflecting wavelength. The absolute difference in refractive index between the layer pair ($|n_1 - n_2|$) may be at least 0.1. Higher refractive index differences between the first optical layer and the second optical layer are desirable, because more optical power (e.g., reflectivity) can be created, thus enabling more reflective bandwidth. However, in the present disclosure, the absolute difference between the layer pair may be less than 0.20, less than 0.15, less than 0.10, less than 0.05, or even less than 0.03, depending on the layer pair selected. For example, poly(methyl methacrylate) and DYNEON HTE 1705 have an absolute refractive index difference of 0.12.

By selecting the appropriate layer pairs, the layer thickness, and/or the number of layer pairs, optical stack 52 can be designed to transmit or reflect the desired wavelengths. The thickness of each layer (e.g., of first optical layers 54 and second optical layers 56) may influence the performance of optical stack 52 by either changing the amount of reflectivity or shifting the reflectivity wavelength range. The optical layers 54 and 56 may have an average individual layer optical thickness of about one quarter of the wavelength of interest, and a layer pair optical thickness of about one half of the wavelength of interest. Optical thickness is defined as the product of the actual (physical) thickness of the layer times the layer's refractive index. The optical layers (e.g., first and second optical layers 54 and 56) can each be a quarter-wavelength thick or the optical layers (e.g., first and second optical layers 54 and 56) can have different optical

thicknesses, as long as the sum of the optical thicknesses for the layer pair is half of a wavelength (or a multiple thereof). For example, to reflect 400 nanometer (nm) light, the average individual layer optical thickness could be about 100 nm, and the average layer pair optical thickness would be about 200 nm. Similarly, to reflect 800 nm light, the average individual layer optical thickness could be about 200 nm, and the average layer pair optical thickness would be about 400 nm. As another example, to reflect UV light having a wavelength of about 260 nm, the average individual layer optical thickness could be about 65 nm, and the average layer pair optical thickness would be about 130 nm.

In some examples, all of first optical layers 54 may have the same physical and/or optical thicknesses and all of second optical layers 56 may have the same physical and/or optical thicknesses. The physical and/or optical thicknesses of the first optical layers 54 may be the same or different than the physical and/or optical thicknesses of the second optical layers 56. In other examples, optical stack 52 can include optical layers (e.g., first and second optical layers 54 and 56) with different optical thicknesses to increase the reflective wavelength range. An optical stack 52 having more than two layer pairs can include optical layers with different optical thicknesses to provide reflectivity over a range of wavelengths. For example, optical stack 54 can include layer pairs that are individually tuned to achieve optimal reflection of normally incident light having particular wavelengths or may include a gradient of layer pair thicknesses to reflect light over a larger bandwidth. The normal reflectivity for a particular layer pair is primarily dependent on the optical thickness of the individual layers. The intensity of light reflected from the optical layer stack is a function of its number of layer pairs and the differences in refractive indices of optical layers in each layer pair. The ratio $n_1 d_1 / (n_1 d_1 + n_2 d_2)$ (which may be referred to as the "f-ratio") correlates with reflectivity of a given layer pair at a specified wavelength. In the f-ratio, n_1 and n_2 are the respective refractive indexes at the specified wavelength of the first and second optical layers in a layer pair, and d_1 and d_2 are the respective optical thicknesses of the first and second optical layers in the layer pair. By proper selection of the refractive indexes, optical layer thicknesses, and f-ratio, one can exercise some degree of control over the intensity of first order reflection. For example, first order visible reflections of violet (400 nanometers wavelength) to red (700 nanometers wavelength) can be obtained with layer optical thicknesses between about 0.05 and 0.3 nanometers. In general, deviation from an f-ratio of 0.5 results in a lesser degree of reflectivity.

The equation $\lambda/2 = n_1 d_1 + n_2 d_2$ can be used to tune the optical layers to reflect light of wavelength λ at a normal angle of incidence. At other angles of incidence, the optical thickness of the layer pair depends on the distance traveled through the component optical layers (which is

larger than the thickness of the layers) and the indices of refraction for at least two of the three optical axes of the optical layer.

Increasing the number of optical layers (e.g., first and second optical layers 54 and 56) in optical stack 52 may also provide more optical power. For example, if the refractive index
5 between the layer pairs is small, optical stack 52 may not achieve the desired reflectivity, however by increasing the number of layer pairs, sufficient reflectivity may be achieved. In some examples, optical stack 52 comprises at least 2 first optical layers 54 and at least 2 second optical layers 56, at least 5 first optical layers 54 and at least 5 second optical layers 56, at least 50 first optical layers 54 and at least 50 second optical layers 56, at least 200 first optical layers 160 and at
10 least 200 second optical layers 162, at least 500 first optical layers 54 and at least 500 second optical layers 56, or even at least 1000 first optical layers 54 and at least 1000 second optical layers 56.

Birefringence (e.g., caused by stretching) of optical layers 54 and 56 is another effective method for increasing the difference in refractive index of the optical layers 54 and 56 in a layer
15 pair. Optical stacks 52 that include layer pairs that are oriented in two mutually perpendicular in-plane axes are capable of reflecting an extraordinarily high percentage of incident light depending on, e.g., the number of optical layers, f-ratio, and the indices of refraction, and are highly efficient reflectors.

As mentioned, optical stack 54 may be designed to reflect or transmit at least a specific
20 bandwidth (i.e., wavelength range) of interest. As UV light is used to sterilize the water flowing within UV-transparent tube 18, optical stack 52 may be designed to reflect UV light or a portion of the light in the UV spectrum (e.g., between about 250 nm and about 300 nm, such as between about 250 nm and about 275 nm). By "reflects" is meant that at least 30, 40, 50, 60, 70, 80, 85, 90, 92, or 95 percent of the wavelengths of interest are reflected at a 90 degree angle of incidence.

In some examples, optical stack 52 is designed to transmit at least a portion of the light
25 outside of the desired wavelength range for reflection (e.g., light with a wavelength above about 300 nm). By "at least a portion" is meant to comprise not only the entire range of wavelengths, but also a portion of the wavelengths, such as a bandwidth of at least 2 nm, 10 nm, 25 nm, 50 nm, or 100 nm. By "transmits" is meant that at least 30, 40, 50, 60, 70, 80, 85, 90, 92, or 95 percent of the
30 wavelengths of interest are transmitted at a 90 degree angle of incidence.

Optical stack 52 can be fabricated by techniques such as e.g., co-extruding, laminating, coating, vapor deposition, atomic layer deposition, or combinations thereof. In co-extrusion, the polymeric materials are co-extruded into a web. In co-extrusion, it is preferred that the two polymeric materials have similar rheological properties (e.g., melt viscosities) to prevent layer
35 instability or nonuniformity. In lamination, sheets of polymeric materials are layered together and

then laminated using either heat, pressure, and/or an adhesive. In coating, a solution of one polymeric material is applied to another polymeric material. In vapor deposition, one polymeric material is vapor deposited onto another polymeric material. Additionally, functional additives may be added to the first optical layer, the second optical layer, and/or the optional additional layers to improve processing. Examples of functional additives include processing additives, which may e.g., enhance flow and/or reduce melt fracture. Further details regarding example UV-reflective materials formed from fluoropolymeric multilayer optical films can be found in U.S. Patent Publication No. 2011/0249325 A1, entitled, "FLUOROPOLYMERIC MULTILAYER OPTICAL FILM AND METHODS OF MAKING AND USING THE SAME," the entire content of which is incorporated herein by reference.

In other examples, at least one UV reflective material 20 may include an aluminum vapor coated fluoropolymer film or glass. Aluminum may be an effective reflector of UV radiation.

Returning now to FIG. 1, in some examples, at least one UV reflective material 20 may define a parabolic curve in at least one plane, e.g., the plane orthogonal to a long axis of at least one UV reflective material 20. The parabolic curve may facilitate focusing of the reflected UV radiation within the volume of tube 18, e.g., the dimensions of the parabolic curve may be selected such that the focus of the parabola (in the plane orthogonal to the long axis of the at least one UV reflective material 20) lies within the volume of tube 18.

Upon reaching the internal end of the spiral depression, tube 18 extends back through housing 12 to outlet 42. Outlet 42 extends into an internal volume defined by expandable container 28. Expandable container 28 is a receptacle for purified water exiting the sterilization section. Because expandable container 28 is expandable, when container 28 is empty of water or only partially full of water, expandable container 28 occupies less space (volume). As expandable container 28 fills with purified water, expandable container 28 expands to hold the water and occupies more volume.

In some examples, operation of water purification apparatus 10 may be controlled by a control unit within electronics module 38. As shown in FIG. 1, electronics module 38 may be disposed within housing 12. FIG. 3 is a conceptual block diagram that illustrates various components of electronics module 38 and logical and/or electrical connections to other components of water purification apparatus 10. Electronics module 38 includes control unit 62, power source 64, and storage device 72. In the example shown in FIG. 3, control unit 62 is logically and/or electrically connected to a number of other devices in water purification apparatus 10, including display device 24, pump 34, UV source 36, UV sensor 66, turbidity sensor 68, and pressure sensor 70. Although FIG. 3 illustrates water purification apparatus 10 as including display device 24, pump 34, UV source 36, UV sensor 66, turbidity sensor 68, and pressure sensor

70, in some examples, water purification apparatus 10 may not include all of these devices/components, and may instead include a subset of these devices/components.

As described above, power source 64 may include a battery, which may be a rechargeable or non-rechargeable battery. In some examples, power source 64 may be user-accessible and/or user-replaceable. For example, the battery may include a lithium ion or lithium polymer battery.

Control unit 62 is configured to implement functionality and/or process instructions for execution. For example, control unit 62 may be capable of processing instructions stored by storage device 72. Examples of control unit 62 may include, any one or more of a microprocessor, a controller, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field-programmable gate array (FPGA), or equivalent discrete or integrated logic circuitry.

Storage device 72 may be configured to store information during operation. Storage device 72, in some examples, includes a computer-readable storage medium or computer-readable storage device. In some examples, storage device 72 includes a temporary memory, meaning that a primary purpose of storage device 72 is not long-term storage. Storage device 72, in some examples, includes a volatile memory, meaning that storage device 72 does not maintain stored contents when power is not provided to storage device 72. Examples of volatile memories include random access memories (RAM), dynamic random access memories (DRAM), static random access memories (SRAM), and other forms of volatile memories known in the art. In some examples, storage devices 72 are used to store program instructions for execution by control unit 62.

Control unit 62 is logically and/or electrically connected to display device 24, pump 34, UV source 36, UV sensor 66, turbidity sensor 68, and pressure sensor 70. Control unit 62 may be configured to control operation of display 24, pump 34, UV source 36, UV sensor 66, turbidity sensor 68, and pressure sensor 70 during operation of water purification apparatus 10. For example, control unit 62 may receive an indication of user input (e.g., from a power button) instructing water purification apparatus 10 to turn on and begin purifying water. Responsive to the indication, control unit 62 may initiate pump 34 to pump water and initiate UV source 36 to output UV radiation. Additionally, in some examples, control unit 62 may control turbidity sensor 68 to begin measuring turbidity of water downstream of at least one filter 26 (e.g., of water exiting at least one filter 26 through tube 18). In some examples, control unit 62 may be configured to control operation of pump 34 based at least in part on a signal received from turbidity sensor 68.

In some examples, control unit 62 also may be logically and/or electrically connected to at least one UV source 36 and a UV sensor 66. Control unit 62 may be configured to receive signals from UV sensor 66 indicative of a total UV dose provided to water flowing through tube 18.

Responsive the signals received from UV sensor 66, control unit 62 may control operation of water

purification sensor 10. For example, control unit 62 may control operation of pump 34, e.g., to reduce a flow rate of water (and thus increase a residence time of water adjacent to UV source 36) to increase a dose of UV radiation to the water. As another example, control unit 62 may control operation of at least one UV source 36 to increase and/or decrease output of UV radiation by the at least on UV source 36 based at least in part on the signals received from UV sensor 66.

In some examples, control unit 62 may be logically and/or electrically connected to pressure sensor 70. Pressure sensor 70 may be configured to determine a pressure drop across the at least one filter 26, which may be indicative of a status of the at least one filter 26. For example, a relatively low pressure drop across the at least one filter 26 may indicate that the at least one filter 26 is relatively new, and is not filled with particulates. Conversely, a higher pressure drop across the at least one filter 26 indicates a greater resistance to flow across the at least one filter 26 (e.g., due to particulates trapped in the at least one filter 26), which may imply that the at least one filter 26 is nearing the end of its useful life. In some examples, control unit 62 may be configured to output, for display at display device 24, an indication of status of the at least one filter 26, such as an indication that the at least one filter 26 should be replaced.

FIGS. 4A–4C are conceptual diagrams illustrating expandable container 28 at different levels of fill with water. As shown in FIG. 4A, expandable container 28 is disposed within the volume of bucket 30 and external to housing 12. When expandable container 28 is empty or nearly empty of water, expandable container 28 is collapsed and occupied little space. As shown in FIG. 4B, when expandable container 28 is partially filled with water, expandable container 28 is partially expanded (e.g., corresponding to the amount of water in container 28) and occupies a greater volume than when empty. Finally, as shown in FIG. 4C, when expandable container 28 is more filled with water, expandable container 28 is further expanded (e.g., corresponding to the amount of water in container 28) and occupies a greater volume than when empty and partially filled.

FIGS. 4A–4C also illustrate inlet 32 and outlet 42. Inlet 32 extends into bucket 30, which may be at least partially filled with water to be purified. Outlet 42 extends from housing 12 into expandable container 28. In some examples, when container 30 is substantially full (e.g., full or nearly full) of water, expandable container 28 may be substantially empty of water, as shown in FIG. 4A. As water purification apparatus 10 operates, water to be purified is taken in through inlet 32 under influence of pump 34 (FIG. 1). Water flows through water purification apparatus 10, including at least one filter 26 and the sterilization section (e.g., including UV source 36 and/or at least one UV reflective material 20) and emerges from outlet 42 into expandable container 28. Hence, water is transferred from container 30 to expandable container 28 during operation of water purification apparatus 10.

FIGS. 1–4C have illustrated an example water purification apparatus 10 that is configured to be portable and purify sufficient water for a small group of people (e.g., about 5 people). In other examples, a water purification apparatus according to this disclosure may be sized to purify sufficient water for a larger group of people (e.g., about 50 people). FIGS. 5 and 7–9 are conceptual diagrams illustrating various views of an example water purification apparatus 80 that may be configured to and adapted to purify water for a larger group of people (e.g., about 50 people). Although water purification apparatus 80 may be relatively less portable than water purification apparatus 10, water purification apparatus 80 may be movable, e.g., using mechanical assistance, such as a trailer and vehicle.

FIG. 5 is a perspective diagram illustrating another example water purification 80 apparatus that includes at least one filter and a UV sterilization section including at least one UV reflecting surface positioned to reflect UV radiation to within a UV transparent tube through which water to be sterilized flows. FIG. 7 is a perspective diagram illustrating another view of the example water purification apparatus shown in FIG. 5. FIG. 8 is a cross-sectional conceptual diagram illustrating another view of the example water purification apparatus shown in FIG. 5. FIG. 9 is a partial cutaway perspective diagram illustrating another view of the example water purification apparatus shown in FIG. 5.

Water purification apparatus 80 includes an inlet 82 adapted to receive water to be purified from a water source, such as a lake, river, well, reservoir, storage container, or the like. In the example illustrated in FIGS. 5 and 7–9, inlet 82 includes two pipes that extend from housing 84. In other examples, inlet 82 may include one or more rigid pipe, one or more flexible pipe, one or more flexible tubes, or the like.

Housing 84 may be attached to and supported by a frame 86. Frame 86 may extend substantially the length of water purification apparatus 80. Frame 86 supports the various components of water purification apparatus 80, and may be attached to wheels 88, which may facilitate moving water purification apparatus 80. Frame 86 also supports and is attached to at least one filter 90, tube 92, at least one UV reflective material 94, and at least one photovoltaic cell 96.

Housing 84 may at least partially enclose or contain various components of water purification apparatus 80, including, for example, a pump, a power source, a control unit, and at least one sensor. FIG. 6 is a conceptual block diagram that illustrates various electrical and electronic components that may be disposed within housing 84 and/or at other locations of water purification apparatus 80. An electronics module 100 includes control unit 102, power source 104, and storage device 106. In the example shown in FIG. 6, control unit 102 is logically and/or electrically connected to a number of other devices in water purification apparatus 80, including

turbidity sensor 108, UV sensor 110, UV source 112, pressure sensor 114, pump 116, and display device 118. Although turbidity sensor 108, UV sensor 110, UV source 112, pressure sensor 114, pump 116, and display device 118 are illustrated in FIG. 6, in some examples, water purification apparatus 80 may not include all of these devices/ components, and may instead include a subset of these devices/components.

In some examples, power source 104 may include a battery, which may be a rechargeable or non-rechargeable battery. In some examples, power source 104 may be user-accessible and/or user-replaceable. For example, the battery may include a lead acid battery, such as a lead acid car battery, a lithium ion battery, or a lithium polymer battery. In other examples, water purification apparatus 80 may not include a power source 104, and may instead include an electrical cord that extends from housing 84 and may be plugged into an electrical outlet.

Control unit 102 is configured to implement functionality and/or process instructions for execution. For example, control unit 102 may be capable of processing instructions stored by storage device 106. Examples of control unit 102 may include, any one or more of a microprocessor, a controller, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field-programmable gate array (FPGA), or equivalent discrete or integrated logic circuitry.

Storage device 106 may be configured to store information during operation. Storage device 106, in some examples, includes a computer-readable storage medium or computer-readable storage device. In some examples, storage device 106 includes a temporary memory, meaning that a primary purpose of storage device 106 is not long-term storage. Storage device 106, in some examples, includes a volatile memory, meaning that storage device 106 does not maintain stored contents when power is not provided to storage device 106. Examples of volatile memories include random access memories (RAM), dynamic random access memories (DRAM), static random access memories (SRAM), and other forms of volatile memories known in the art. In some examples, storage devices 106 are used to store program instructions for execution by control unit 102.

Control unit 102 is logically and/or electrically connected to turbidity sensor 108, UV sensor 110, UV source 112, pressure sensor 114, pump 116, and display device 118. Control unit 102 may be configured to control operation of turbidity sensor 108, UV sensor 110, UV source 112, pressure sensor 114, pump 116, and display device 118 during operation of water purification apparatus 80. For example, control unit 102 may receive an indication of user input (e.g., from a power button) instructing water purification apparatus 80 to turn on and begin purifying water. Responsive to the indication, control unit 102 may initiate pump 116 to pump water and initiate UV source 112 to output UV radiation. Additionally, in some examples, control unit 102 may

control turbidity sensor 108 to begin measuring turbidity of water downstream of at least one filter 90 (FIGS. 5 and 7–9; e.g., of water exiting at least one filter 90 through tube 92). In some examples, control unit 102 may be configured to control operation of pump 116 based at least in part on a signal received from turbidity sensor 108.

5 In some examples, control unit 102 also may be logically and/or electrically connected to a UV sensor 110. Control unit 102 may be configured to receive signals from UV sensor 110 indicative of a total UV dose provided to water flowing through tube 92. Responsive the signals received from UV sensor 110, control unit 102 may control operation of water purification apparatus 80. For example, control unit 102 may control operation of pump 116, e.g., to reduce a
10 flow rate of water (and thus increase a residence time of water adjacent to at least one UV reflective material 94; FIGS. 5 and 7–9) to increase a dose of UV radiation to the water. As another example, control unit 102 may control operation of an optional at one optional UV source 112 to increase and/or decrease output of UV radiation by the optional at least one UV source 112 based at least in part on the signals received from UV sensor 110.

15 In some examples, control unit 102 may be logically and/or electrically connected to pressure sensor 114. Pressure sensor 114 may be configured to determine a pressure drop across the at least one filter 90, which may be indicative of a status of the at least one filter 90. For example, a relatively low pressure drop across the at least one filter 90 may indicate that the at least one filter 90 is relatively new, and is not filled with particulates. Conversely, a higher
20 pressure drop across the at least one filter 90 indicates a greater resistance to flow across the at least one filter 90 (e.g., due to particulates trapped in the at least one filter 90), which may imply that the at least one filter 90 is nearing the end of its useful life. In some examples, control unit 102 may be configured to output, for display at display device 118, an indication of status of the at least one filter 90, such as an indication that the at least one filter 90 should be replaced.

25 Returning to FIGS. 5 and 7–9, pump 116 may be disposed within housing 84 and fluidically coupled to inlet 82. For example, an inlet of pump 116 may be fluidically connected to inlet 82 downstream of inlet 82. Pump 116 may be adapted to pump water through inlet 82 to other portions of water purification apparatus 80. In different examples, pump 116 may be manually powered (e.g., a hand-powered pump), battery powered, electrically powered, solar
30 powered, and/or gasoline powered. For example, pump 116 may be electrically connected to a power source 104 (FIG. 6) and/or electrically connected to at least one photovoltaic cell 96.

In some examples, at least one photovoltaic cell 96 may be disposed on a plate or support material and attached to frame 86. For example, as shown in FIGS 5 and 7, the at least one photovoltaic cell 96 may be attached to a support that is moveably attached to frame 86. By
35 moveably attaching the at least one photovoltaic cell 96 to frame 86, the at least one photovoltaic

cell 96 may be moveable independently of frame 86. For example, the support plate to which the at least one photovoltaic cell 96 is attached may be connected to a motor that operates under control of control unit 102 to rotate during the course of a day. In other examples, the support plate to which the at least one photovoltaic cell 96 is attached may be manually rotatable, e.g., by a user of water purification apparatus 80. Rotation of the at least one photovoltaic cell 96 throughout the day may result in sunlight being more directly incident (e.g., normal to a surface of the at least one photovoltaic cell 96) throughout the day, which may improve an amount of sunlight absorbed by the at least one photovoltaic cell 96. Rotation of the at least one photovoltaic cell 96 is illustrated in FIGS. 5 and 7.

In other examples, the at least one photovoltaic cell 96 may not be moveably attached to frame 86, and may be non-moveably attached to frame 86 and/or another structure of water purification apparatus 80, such as housing 84. In some examples, water purification apparatus 80 may include a plurality of photovoltaic cells 96, as shown in FIGS. 5, 7, and 8. In some implementations, the at least one photovoltaic cell 96 may be electrically connected to power source 104 (FIG. 6), and may be used to charge and recharge power source 104. In other examples, the at least one photovoltaic cell 96 may be electrically connected to pump 116 and directly power pump 116.

In some examples, pump 116 may be primarily powered by at least one photovoltaic cell 96, and may be powered by power source 104 when there is insufficient power provided by the at least one photovoltaic cell 96. Thus, pump 116 may be selectively powered by the at least one photovoltaic cell 96 and power source 104, and power source 104 may operate as a backup power source. In other examples, as mentioned above, the at least one photovoltaic cell 96 may be used to charge power source 104, and power source 104 may be used to power pump 116.

An outlet of pump 116 may be fluidically connected to an inlet of at least one filter 90, e.g., via a tube. The at least one filter 90 thus may be downstream of pump 116 in some examples, although in other examples, the various components of water purification apparatus 80 may be fluidically connected in different orders. The at least one filter 90 may be adapted to and configured to remove at least some particles from the water to be purified. In some examples, the at least one filter 90 may include a size exclusion filter, which includes pores or other structured configured to allow molecules and particles less than a defined size pass while not allowing particles larger than the defined size pass through the filter. In other examples, the at least one filter 90 may include an activated carbon filter, which uses chemical adsorption to remove particles from the water.

In some examples, as best seen in FIG. 9, the at least one filter 90 may include a plurality of filters, which may be configured so water flows through the plurality of filters 90 in series

configuration or in parallel configuration. In some examples, the at least one filter 90 may include a plurality of size exclusion filters disposed in series (shown in FIG. 9), in which the more upstream filters are adapted to and configured to remove particles having larger relative sizes and the more downstream filters are adapted to and configured to remove particles having smaller relative sizes. In some examples, the at least one filter 26 may be adapted to and configured to remove particles (e.g., including bacteria, protozoa, microbial cysts, and the like) having a characteristic dimension of greater than about 0.2 micrometers.

In some examples, as shown in FIG. 9, the at least one filter 90 may be provided in a user-accessible location. In some implementations, the at least one filter 90 may be user-serviceable, e.g., may be cleanable and/or replaceable by the user. This may allow a user of water purification apparatus 10 to replace the at least one filter 90 when the at least one filter 90 has no useful life remaining, e.g., as indicated by pressure sensor 114 (FIG. 6) or a flow sensor.

Upon exiting the at least one filter 90, water flows through tube 92. Tube 92 extends along a sterilization section of water purification apparatus 80. Tube 92 may be formed of a material that is at least partially transparent to UV radiation, such as a UV transparent polymer, glass, or plastic. The sterilization section may include at least one UV reflective material 94 and, optionally, at least one UV source 112 (FIG. 6). At least one UV reflective material 94 may be similar to or substantially the same (e.g., the same or nearly the same) as at least one UV reflective material 20 described with reference to FIGS. 1–4C. For example, the at least one UV reflective material 94 may include a material that is adapted to reflect at least a portion of light (e.g., sunlight) having wavelengths within the UV spectrum. For example, the at least one UV reflective material 20 may be adapted to reflect at least a portion of light having a wavelength between about 200 nm and about 350 nm, or between about 200 nm and about 300 nm, or between about 250 nm and about 300 nm, or between about 250 nm and about 275 nm. In some examples, the at least one UV reflective material 20 may be adapted to transmit and/or absorb at least some of the light having wavelengths outside of the UV spectrum (e.g., light having a wavelength greater than about 400 nm, or greater than about 350 nm, or greater than about 300 nm, or greater than about 275 nm). For example, the at least one UV reflective material 94 may include a multilayer optical film 50, shown in FIG. 2.

At least one UV reflective material 94 may define a parabolic curve in at least one plane, e.g., the plane orthogonal to a long axis of at least one UV reflective material 94. The parabolic curve may facilitate focusing of the reflected UV radiation within the volume of tube 92, e.g., the dimensions of the parabolic curve may be selected such that the focus of the parabola (in the plane orthogonal to the long axis of the at least one UV reflective material 94) lies within the volume of tube 92.

In some examples, the at least one UV reflective material 94 may be positioned along at least a portion of the length of tube 92. In other examples, the at least one UV reflective material 94 may be positioned along substantially the entire length (e.g., the entire length or nearly the entire length) of the tube 92. For example, as shown in FIGS. 5 and 7 – 9, the at least one UV reflective material 94 includes a plurality of UV reflective materials, and, together, the plurality of UV reflective materials extend along substantially the entire horizontal length of tube 92.

In some examples, the at least one UV reflective material 94 may be attached (e.g., adhered or laminated) to an underlying substrate, which may provide mechanical support for the at least one UV reflective material 94. For example, the substrate may comprise a glass or other substantially transparent and relatively rigid material.

In some examples, the at least one UV reflective material 94 may be movably attached to frame 86. For example, the at least one UV reflective material 94 may be rotatably attached to frame 86, such that the at least one UV reflective material 94 may be rotated about at least one axis. For example, the at least one UV reflective material 94 may be connected to a motor that operates under control of control unit 102 to rotate during the course of a day. In other examples, the at least one UV reflective material 94 may be manually rotatable, e.g., by a user of water purification apparatus 80. Rotation of the at least one UV reflective material 94 throughout the day may result in sunlight being more directly incident on the at least one UV reflective material 94 throughout the day, which may result in more UV radiation being reflected by the at least one UV reflective material 94 into the volume of tube 92. Rotation of the at least one UV reflective material 94 is illustrated in FIGS. 5 and 7. In other examples, the at least one UV reflective material 94 may not be moveably attached to frame 86 and may instead be non-moveably attached to frame 86.

In examples in which water purification apparatus 80 includes at least one UV source 112, the at least one UV source 112 may be disposed adjacent to an external surface of tube 92 or within a volume of tube 92, similar to at least one UV source 36 described with reference to FIGS. 1, 2, and 4A–4C. In examples in which the at least one UV source 112 is disposed adjacent to an external surface of tube 92, UV source 36 may emit UV radiation and direct the UV radiation to within the volume of tube 92 to expose water flowing through tube 92 to UV radiation. In some examples, the at least one UV source 112 and/or tube 92 may include shielding that substantially prevents (e.g., prevents or nearly prevents) a user of water purification apparatus 80 from being exposed to UV radiation.

In some examples, upon exiting the sterilization section, purified water may exit outlet 98, which extends through housing 84. In other examples, as best seen in FIG. 8, water purification apparatus 80 may include reservoir 122 for storing at least some purified water. Reservoir 122

may be fluidically connected to tube 92 downstream of the sterilization section. In some examples, as shown in FIG. 8, reservoir 122 may be enclosed within or defined by housing 84. In other examples, reservoir 122 may be positioned at a different location of water purification apparatus 80, such as attached to frame 86 at a different location of water purification apparatus 80. Outlet 98 is fluidically connected to reservoir 122, e.g., via a selectively openable valve. In other examples, water purification apparatus 80 may not include a reservoir.

FIGS. 5 and 7–9 illustrate an example of a single water purification apparatus 80, in some examples, a group of people (e.g., a village or other collective) may require more water than can be purified by a single water purification apparatus 80. In some examples, the water purification apparatus 80 may be used in parallel with other, similar water purification apparatuses. FIG. 10 is a perspective diagram illustrating a system 130 including a plurality of water purification apparatuses 132A–132F (collectively, “water purification apparatuses 132”).

In some examples, each of water purification apparatuses 132 may be the same as or substantially similar to (e.g., similar to or nearly similar to) water purification apparatus 80 illustrated in FIGS. 5–9. For example, each of water purification apparatuses 132 may include at least one filter for filtering water and at least one UV reflective material for sterilizing water.

In some examples, water purification apparatuses may be fluidically connected in a parallel flow configuration, such that a single inlet extends from the water source (e.g., lake, river, well, reservoir, storage container, or the like) to the respective inlet for each of water purification apparatuses 132 (e.g., inlet 82; FIGS. 5 and 7–9). Similarly, respective outlets (e.g., outlets 98; FIGS. 5 and 7–9) of water purification apparatuses 132 may be fluidically connected in parallel to a single, common outlet. In some implementations, the common outlet may be fluidically connected to a storage container for the purified water exiting water purification apparatuses 132. In other examples, each of water purification apparatuses 132 may operate substantially independently and may not be fluidically connected to others of water purification apparatuses 132. Additionally or alternatively, in some examples, operation of water purification apparatuses 132 may be controlled by a single control unit (e.g., a control unit 102 of one of water purification apparatuses 132).

In this way, the amount of water that can be purified in a given amount of time may be easily scaled (e.g., increased or decreased) by adding or removing water purification apparatuses 132 from system 130.

Although FIGS. 5–10 illustrate examples of water purification apparatuses 82 and 132 that utilize sunlight as a UV source, sufficient sunlight may not be available in locations to provide enough UV radiation to sterilize water. Hence, in some examples, instead of utilizing sunlight for UV radiation, a water purification apparatus sized to provide clean water for a larger group of

people may utilize at least one UV source to provide UV radiation. FIG. 11 is a perspective diagram illustrating an example water purification apparatus 140 that includes at least one filter 150 and a UV sterilization section including at least one UV reflecting material 154 positioned to reflect UV radiation to within a UV transparent tube 152 through which water to be sterilized flows and UV sources 158A–158D (collectively “UV sources 158”). In some examples, water purification apparatus 140 may be similar to or substantially the same as (e.g., the same or nearly the same) as water purification apparatus 80 illustrated in FIGS. 5–9, aside from the differences described herein.

For example, water purification apparatus 140 may include an inlet 142, a housing 144, a frame 146, at least one filter 150, and a pipe 152, all of which may be the similar to or substantially the same as (e.g., the same or nearly the same) inlet 82, housing 82, frame 86, at least one filter 90, and pipe 92 described with reference to FIGS. 5–9. Additionally, although not shown in FIG. 11, in some examples, water purification apparatus 140 may include some or all of an electronic module 100 (including a power source 104, a control unit 102, and a storage device 106), a turbidity sensor 108, a UV sensor 110, a pressure sensor 114, a pump 116, a display device 118, and a reservoir 122 as illustrated and described with respect to FIGS. 6 and 8.

In contrast to water purification apparatus 80, water purification apparatus 140 includes a plurality of UV sources 158. Water purification apparatus 140 also may include a plurality of top UV reflective materials 156A–156D (collectively, “top UV reflective materials 156”) disposed adjacent to the plurality of UV sources 158. In the example illustrated in FIG. 11, water purification apparatus 140 includes four UV sources 158 and four top UV reflective materials 156. In other examples, water purification apparatus 140 may include more or fewer than 4 UV sources 158 and more or fewer than four top UV reflective materials 156. Generally, water purification apparatus 140 may include at least one UV sources 158 and at least one top UV reflective materials 156. Further, in the example shown in FIG. 11, water purification apparatus 140 includes a respective one of top UV reflective materials 156 disposed adjacent to a respective one of UV sources 158, such that water purification apparatus 140 includes the same number of top UV reflective materials 156 and UV sources 158. In other examples, water purification apparatus 140 may include different numbers of top UV reflective materials 156 and UV sources 158.

Each of UV sources 158 may include, for example, at least one light emitting diode (LED) configured to output UV radiation. As used here, UV radiation may refer to radiation having a wavelength less than about 400 nanometers (nm). Example wavelength ranges for UV radiation (light) utilized herein include between about 200 nm and about 350 nm, or between about 200 nm and about 300 nm, or between about 250 nm and about 300 nm, or between about 250 nm and about 275 nm.

As shown in FIG. 11, UV sources 158 may extend in a direction generally parallel to a length of tube 152. In some examples, UV sources 158 may extend along substantially an entire horizontal length (e.g., the entire horizontal length or nearly the entire horizontal length) of tube 152. In some examples in which each of UV sources 158 includes a plurality of LEDs, the plurality of LEDs may be spaced within UV sources 158 along substantially the entire length of UV sources 158.

Each of top UV reflective materials 156 may extend generally parallel to the length of tube 152 (and, thus, the length of UV sources 158). In some examples, top UV reflective materials 156 may extend along substantially an entire horizontal length (e.g., the entire horizontal length or nearly the entire horizontal length) of tube 152. Top UV reflective materials 156 define a curve in a plane orthogonal to the long axis of top UV reflective materials 156. In some examples, the curve may be a parabolic curve. Top UV reflective materials 156 may reflect UV light emitted in an upward direction by UV sources 158 downward toward tube 152 and/or bottom UV reflector 154.

In some examples, top UV reflective materials 156 may include a material that is adapted to reflect at least a portion of light (e.g., sunlight) having wavelengths within the UV spectrum. For example, top UV reflective materials 156 may be adapted to reflect at least a portion of light having a wavelength between about 200 nanometers (nm) and about 350 nm, or between about 200 nm and about 300 nm, or between about 250 nm and about 300 nm, or between about 250 nm and about 275 nm. In some examples, top UV reflective materials 156 may be adapted to transmit and/or absorb at least some of the light having wavelengths outside of the UV spectrum (e.g., light having a wavelength greater than about 400 nm, or greater than about 350 nm, or greater than about 300 nm, or greater than about 275 nm). An example material that may be formed to reflect at least a portion of incident light having a certain wavelength or certain wavelengths and absorb and/or transmit at least a portion of incident light having different wavelength may be a multilayer optical film, such as multilayer optical film 50 illustrated in FIG. 2.

Similarly, bottom UV reflective material 154 may be formed of a material that is adapted to reflect at least a portion of light (e.g., sunlight) having wavelengths within the UV spectrum and is adapted to transmit and/or absorb at least some of the light having wavelengths outside of the UV spectrum, such as multilayer optical film 50. Bottom UV reflective material 154 may extend generally parallel to the length of tube 152 (and, thus, the length of UV sources 158). In some examples, bottom UV reflective material 154 may extend along substantially an entire horizontal length (e.g., the entire horizontal length or nearly the entire horizontal length) of tube 152.

Bottom UV reflective material 154 may define a curve in a plane orthogonal to the long axis of bottom UV reflective material 154. In some examples, the curve may be a parabolic curve.

Bottom UV reflective material 154 may reflect UV light emitted in a generally downward direction by UV sources 158 and light reflected by top UV reflective materials 156 upward toward tube 152. In some example, a focal line of bottom UV reflective material 154 may lie within the volume defined by tube 152.

5 In some examples, top UV reflective materials 156 and bottom UV reflective material 154 may be attached (e.g., adhered or laminated) to a respective underlying substrates, which may provide mechanical support for the top UV reflective materials 156 and bottom UV reflective material 154. For example, the respective substrates may comprise a glass or other substantially transparent and relatively rigid material.

10 Because, in some examples, top UV reflective materials 156 and bottom UV reflective material 154 may reflect at least some incident light with a wavelength in the UV spectrum and transmit and/or absorb at least some incident light with a wavelength outside of the UV spectrum, top UV reflective materials 156 and bottom UV reflective material 154 may reduce an amount of heat transferred to and absorbed by the water flowing through tube 152. This may reduce heating
15 and/or vaporization of the water, which may simplify operation of water purification apparatus 140.

Water purification apparatus 140 also includes a plurality of photovoltaic cells 160 disposed at and attached to components of water purification apparatus 140. In the example shown in FIG. 11, photovoltaic cells 160 are attached to frame 146 and top UV reflective materials 156.

20 In some implementations, photovoltaic cells 160 may be electrically connected to the power source in an electronic module (e.g., power source 104 of electronics module 100 shown in FIG. 6), and may be used to charge and recharge the power source. In other examples, photovoltaic cells 160 may be electrically connected to the pump of water purification apparatus 140 and UV sources 158 and directly power pump the pump and UV sources 158.

25 In some examples, the pump and UV power sources 158 may be primarily powered by photovoltaic cells 160, and may be powered by the power source in the electronic module when there is insufficient power provided by photovoltaic cells 160. Thus, the pump and UV power sources 158 may be selectively powered by photovoltaic cells 160 and the power source in the electronics module. In other examples, as mentioned above, photovoltaic cells 160 may be used to
30 charge the power source, and the power source may be used to power the pump and UV power sources 158. Hence, although water purification apparatus 140 does not directly utilize the sun as a UV source (as does water purification apparatus 80), water purification apparatus 140 utilizes the sun's energy to provide power for operation of water purification apparatus 140.

35 Similar to water purification apparatuses 132 shown in FIG. 10, in some examples, water purification apparatus 140 may be adapted to be able to be connected in parallel flow configuration

with at least one other water purification apparatus 140. This allows easy scaling of the amount of water purified in a given time period.

Various examples of water purification apparatuses and techniques for purifying water using water purification apparatuses have been described. These and other examples are within the scope of the following claims.

5

WHAT IS CLAIMED IS:

1. A water purification apparatus comprising:
a water inlet;
5 at least one filter downstream of the water inlet and fluidically coupled to the water inlet;
a tube downstream of the filter and fluidically coupled to the filter;
at least one UV source positioned to irradiate an interior volume of the tube;
a water outlet downstream of the tube and fluidically coupled to the tube; and
an expandable container fluidically coupled to the water outlet, wherein the expandable
10 container is configured to expand under pressure from water exiting the water outlet.
2. The water purification apparatus of claim 1, wherein the tube comprise a UV-transparent material.
- 15 3. The water purification apparatus of claim 2, further comprising at least UV-reflective material comprising a parabolic surface disposed to reflect UV radiation to within the volume of the UV-transparent tube.
4. The water purification apparatus of claim 3, wherein the at least one UV-reflective
20 material is configured to reflect radiation having a wavelength between about 200 nm about 300 nm.
5. The water purification apparatus of claim 3 or 4, wherein the at least one UV-reflective material is positioned to reflect UV radiation from the at least one UV source to within the volume
25 of the UV-transparent tube.
6. The water purification apparatus of any of claims 3 to 5, wherein the at least one UV-reflective material is positioned to reflect UV radiation from the sun to within the volume of the UV-transparent tube.
- 30 7. The water purification apparatus of any of claims 3 to 6, wherein the at least one UV-reflective material comprises a multilayer optical film, and wherein at least some of the layers of the multilayer optical film comprise a fluoropolymer.

8. The water purification apparatus of claim 7, wherein the multilayer optical film comprises a plurality of first optical layers and a plurality of second optical layers, wherein respective first optical layers are interleaved with respective second optical layers.

9. The water purification apparatus of claim 8, wherein each of the first optical layers comprise a first fluoropolymer, and wherein each of the second optical layers comprise a second fluoropolymer different than the first fluoropolymer.

10. The water purification apparatus of any of claims 1 to 9, wherein the filter comprises a filter configured to remove particles larger than about 0.2 microns.

11. The water purification apparatus of any of claims 1 to 10, wherein the filter comprises a plurality of filters arranged in series.

12. The water purification apparatus of claim 11, wherein the at least one filter comprises at least a first filter configured to filter particles above a first size limit, and at least a second filter configured to filter particles above a second size limit, wherein the second size limit is smaller than the first size limit, and wherein the second filter is fluidically coupled to the first filter and downstream of the first filter.

13. The water purification apparatus of any of claims 1 to 10, wherein the filter comprises a plurality of filters arranged in parallel.

14. The water purification apparatus of any of claims 1 to 13, wherein the expandable container is substantially impermeable to water.

15. The water purification apparatus of any of claims 1 to 14, wherein the expandable container comprise bellows-type container.

16. The water purification apparatus of any of claims 1 to 15, wherein the at least one UV source comprises at least one light emitting diode configured to emit UV radiation.

17. The water purification apparatus of claim 16, wherein the UV radiation comprises a wavelength between about 200 nm and about 300 nm.

18. The water purification apparatus of claim 16 or 17, wherein the at least one light emitting diode is disposed within the volume defined by the tube.

19. The water purification apparatus of any of claims 1 to 18, further comprising a pump
5 located downstream of the water inlet and upstream of the at least one filter.

20. The water purification apparatus of claim 19, further comprising at least one power source electrically connected to the pump for powering the pump.

10 21. The water purification apparatus of claim 20, wherein the at least one power source comprises a battery.

22. The water purification apparatus of claim 20 or 21, wherein the at least one power source comprises at least one photovoltaic module.

15 23. The water purification apparatus of claim 22, further comprising a housing, wherein the at least one photovoltaic module is disposed on an external surface of the housing.

24. The water purification apparatus of any of claims 19 to 23, further comprising a control
20 unit configured to control operation of the pump.

25. The water purification apparatus of claim 24, further comprising at least one sensor.

26. The water purification apparatus of claim 25, wherein the at least one sensor comprises
25 turbidity sensor, positioned to measure turbidity of water exiting the at least one filter, and wherein the control unit is configured to control operation of the pump based at least in part on a signal received from the turbidity sensor.

27. The water purification apparatus of claim 25, wherein the at least one sensor comprises at
30 least one pressure sensor configured to sense a pressure drop across the at least one filter.

28. The water purification apparatus of claim 25, wherein the at least one sensor comprises a UV sensor configured to sense a UV dose delivered to a volume of water.

29. The water purification apparatus of any of claims 1 to 28, further comprising a housing, wherein the housing comprises an external surface defining a spiral depression, and wherein the tube is disposed at least partially within the spiral depression.

30. The water purification apparatus of claim 29 in combination with claim 3, wherein the at least UV-reflective material is disposed within the spiral depression between the external surface of the housing and the UV-transparent tube.

31. A method comprising:
purifying water using the water purification apparatus of any of claims 1 to 30.

32. A method comprising:
pumping water through an inlet using a pump, wherein the pump imparts sufficient energy to the water to cause the water to pass through at least one filter fluidically connected to the pump, a UV sterilization section fluidically connected to the at least one filter, and to an expandable container fluidically connected to the UV sterilization section;

filtering the water using the at least one filter, wherein the at least one filter is configured to remove at least some particulates present in the water; and

directing UV radiation into the water from at least one UV source of the UV sterilization section.

33. The method of claim 32, wherein the UV sterilization section further comprises a tube, wherein the tube comprise a UV-transparent material, and wherein directing UV radiation into the water comprises directing UV radiation within the volume of the UV-transparent tube as the water flows through the UV-transparent tube.

34. The method of claim 33, wherein the UV sterilization section further comprises at least UV-reflective material comprising a parabolic surface disposed to reflect UV radiation to within the volume of the UV-transparent tube, and wherein directing UV radiation into the water from at least one UV source of the UV sterilization section comprises reflecting UV radiation into the water from the at least one UV source using the at least one UV-reflective material.

35. The method of claim 34, wherein the at least one UV-reflective material is configured to reflect radiation having a wavelength between about 200 nm about 300 nm.

36. The method of claim 34 or 35, wherein the at least one UV-reflective material is positioned to reflect UV radiation from the at least one UV source to within the volume of the UV-transparent tube.

37. The method of any of claims 34 to 36, wherein the at least one UV-reflective material is positioned to reflect UV radiation from the sun to within the volume of the UV-transparent tube.

38. The method of any of claims 34 to 37, wherein the at least one UV-reflective material comprises a multilayer optical film, and wherein at least some of the layers of the multilayer optical film comprise a fluoropolymer.

39. The method of any of claims 32 to 38, wherein the filter comprises a filter configured to remove particles larger than about 0.2 microns.

40. The method of any of claims 32 to 39, wherein the filter comprises a plurality of filters arranged in series.

41. The method of claim 40, wherein the at least one filter comprises at least a first filter configured to filter particles above a first size limit, and at least a second filter configured to filter particles above a second size limit, wherein the second size limit is smaller than the first size limit, and wherein the second filter is fluidically coupled to the first filter and downstream of the first filter.

42. The method of any of claims 32 to 39, wherein the filter comprises a plurality of filters arranged in parallel.

43. The method of any of claims 32 to 42, wherein the expandable container is substantially impermeable to water.

44. The method of any of claims 32 to 43, wherein the expandable container comprise bellows-type container.

45. The method of any of claims 32 to 44, wherein the at least one UV source comprises at least one light emitting diode configured to emit UV radiation comprising a wavelength between about 200 nm and about 300 nm.

46. The method of claim 45, wherein the at least one light emitting diode is disposed within the volume defined by the tube.

5 47. The method of any of claims 32 to 46, further comprising controlling operation of the pump based at least in part on an indication received from at least one sensor.

48. The method of claim 47, wherein the at least one sensor comprises turbidity sensor, positioned to measure turbidity of water exiting the at least one filter, and wherein the control unit
10 is configured to control operation of the pump based at least in part on a signal received from the turbidity sensor.

49. The method of claim 47, wherein the at least one sensor comprises at least one pressure sensor configured to sense a pressure drop across the at least one filter.
15

50. The method of claim 47, wherein the at least one sensor comprises a UV sensor configured to sense a UV dose delivered to a volume of water.

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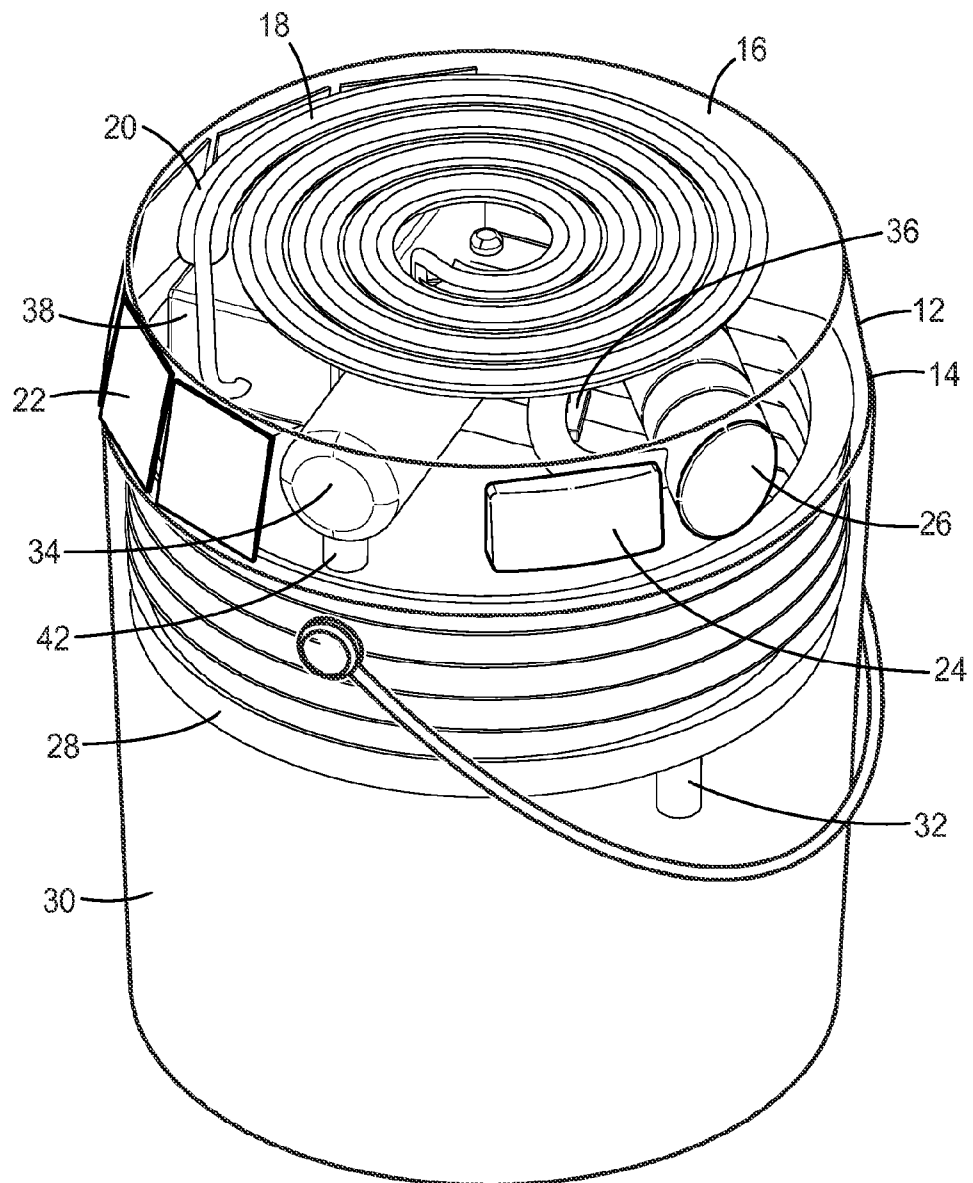


FIG. 1

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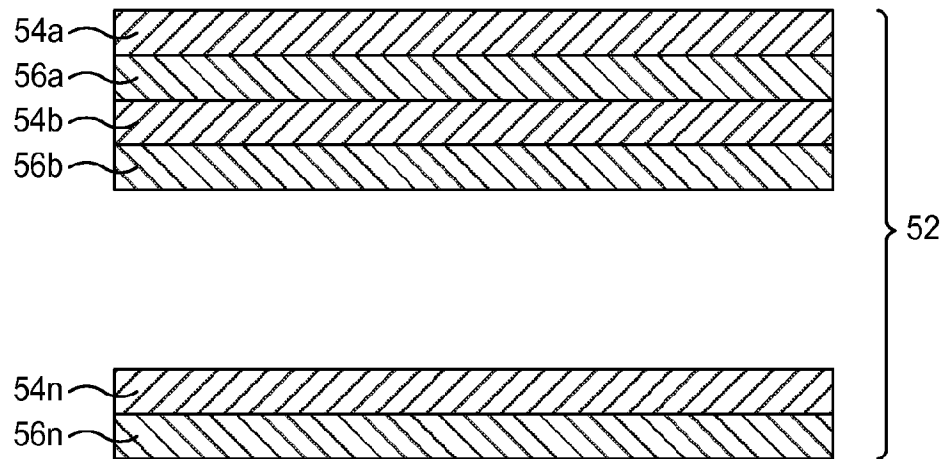


FIG. 2

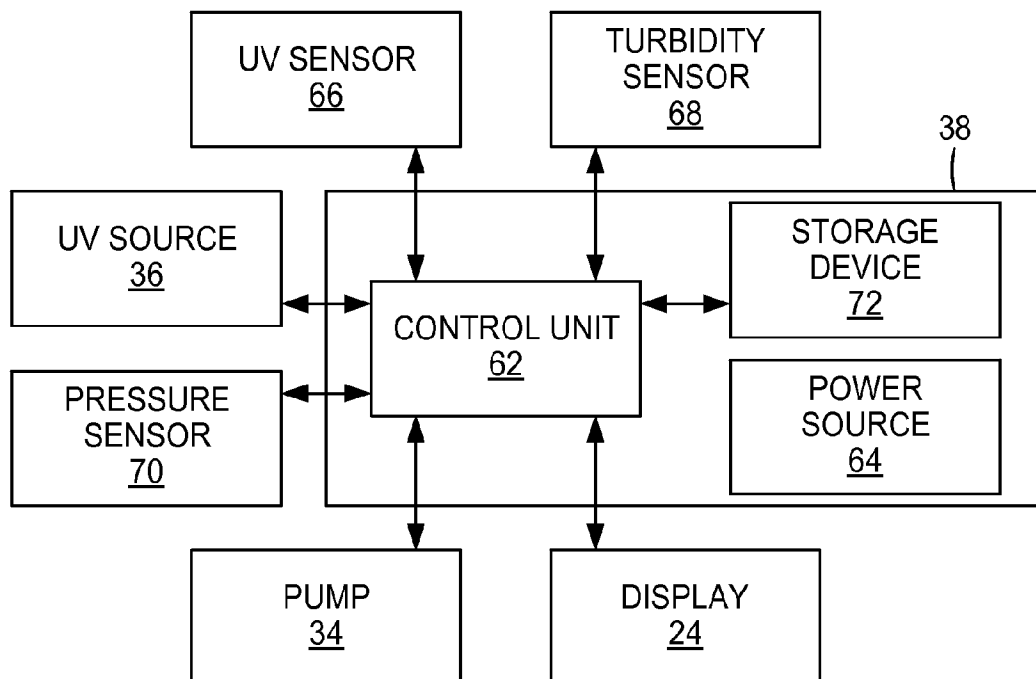


FIG. 3

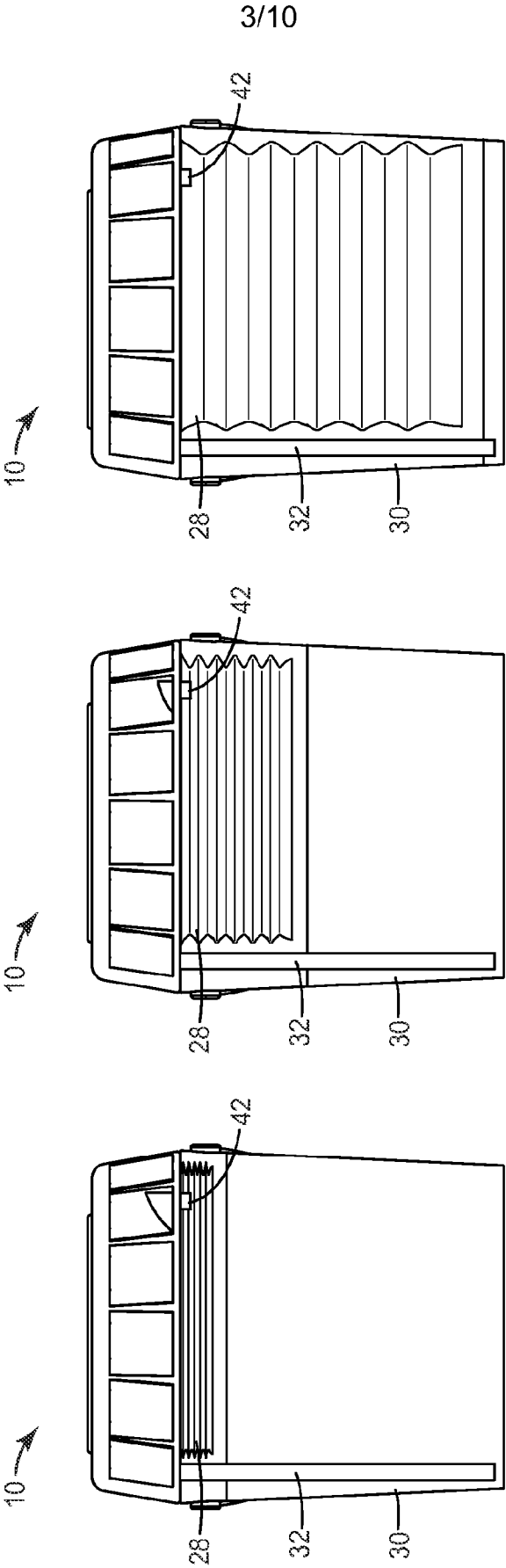
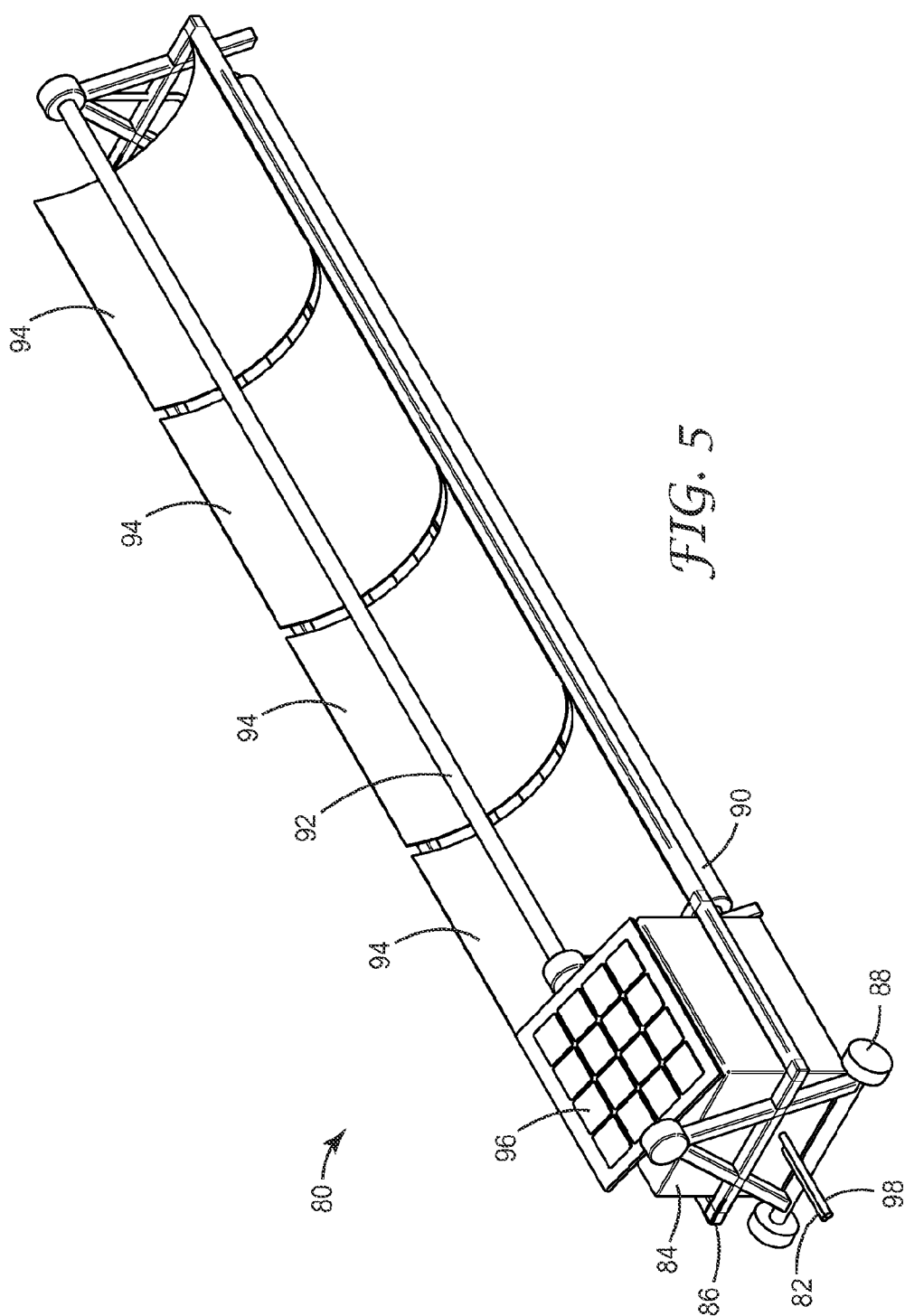


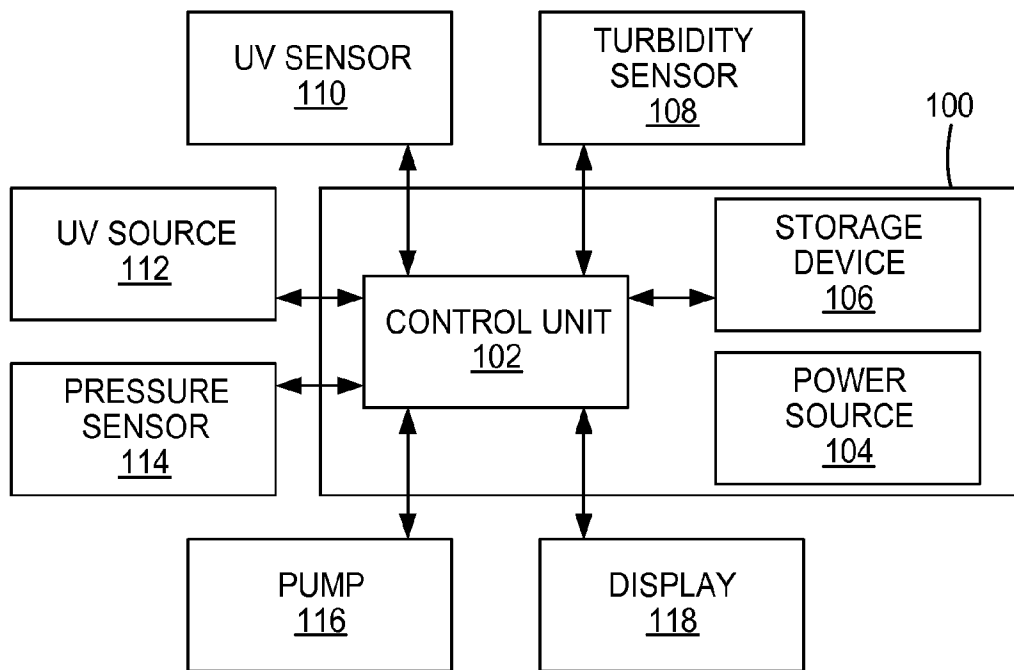
FIG. 4C

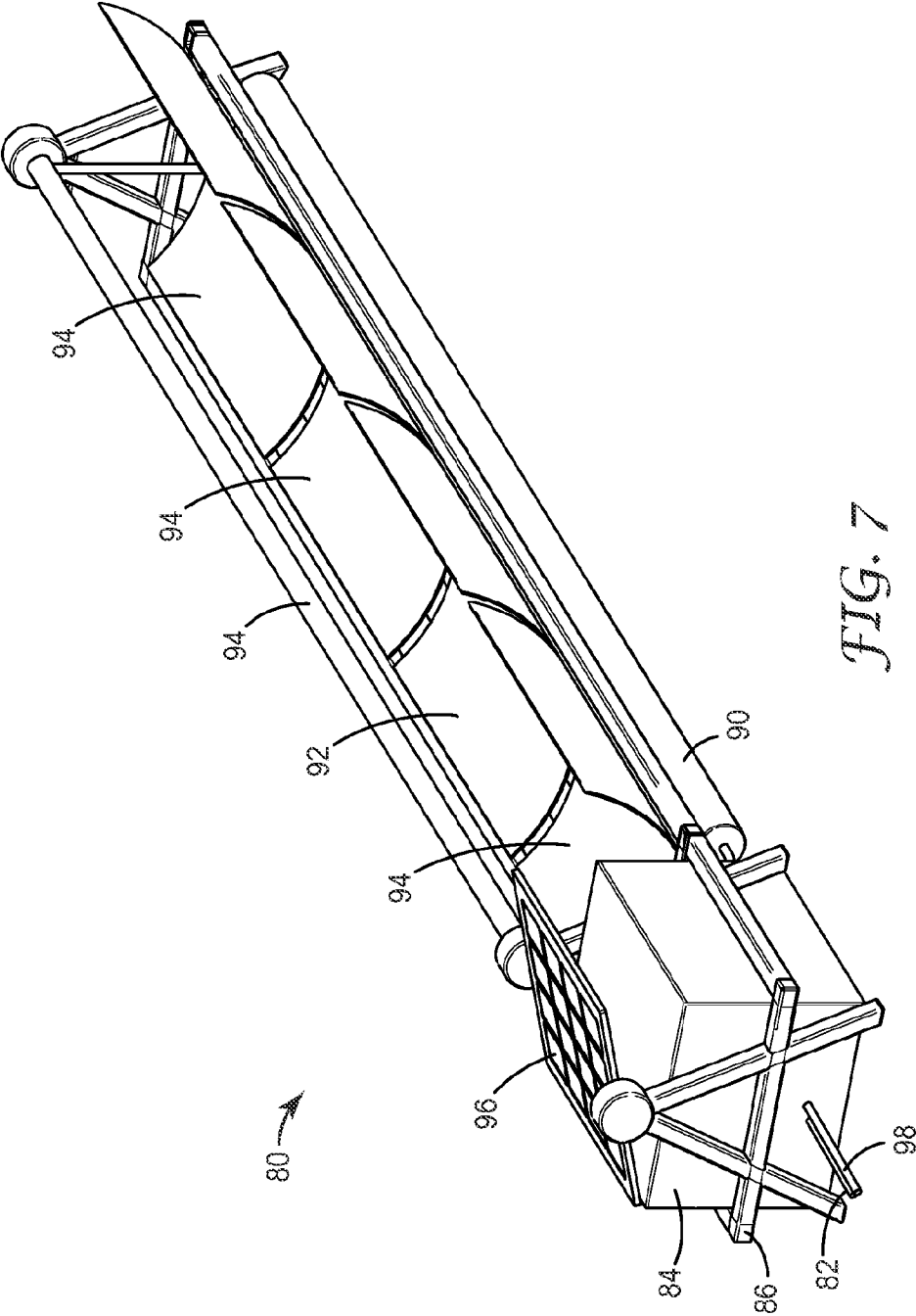
FIG. 4B

FIG. 4A



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*FIG. 6*



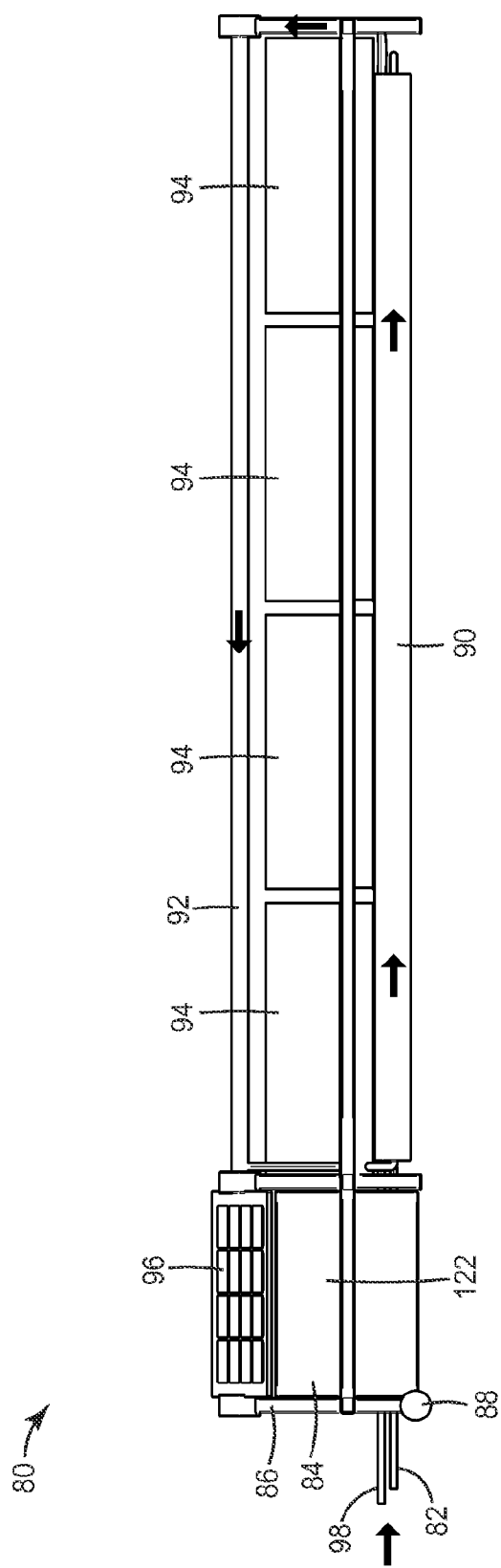
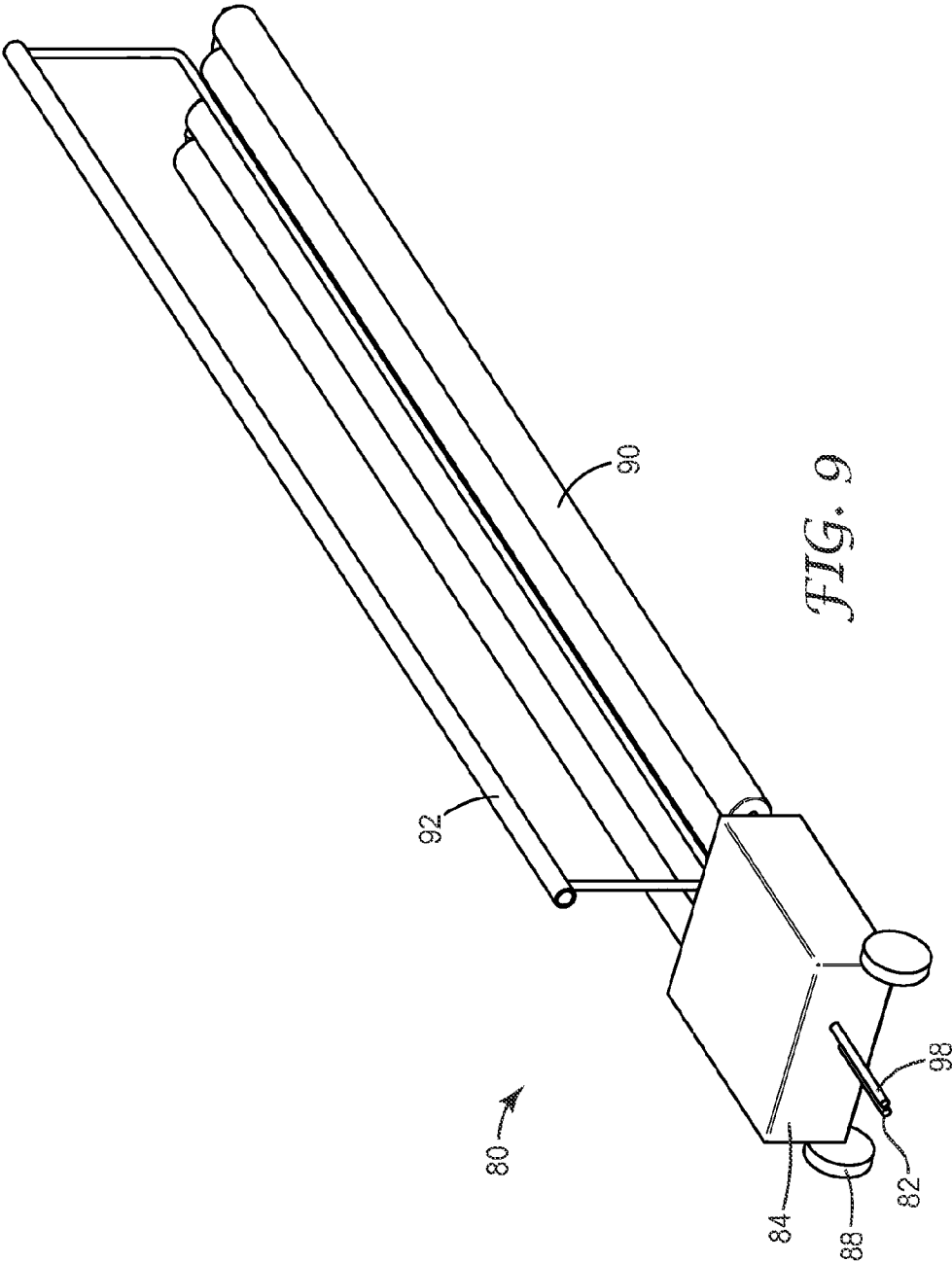


FIG. 8



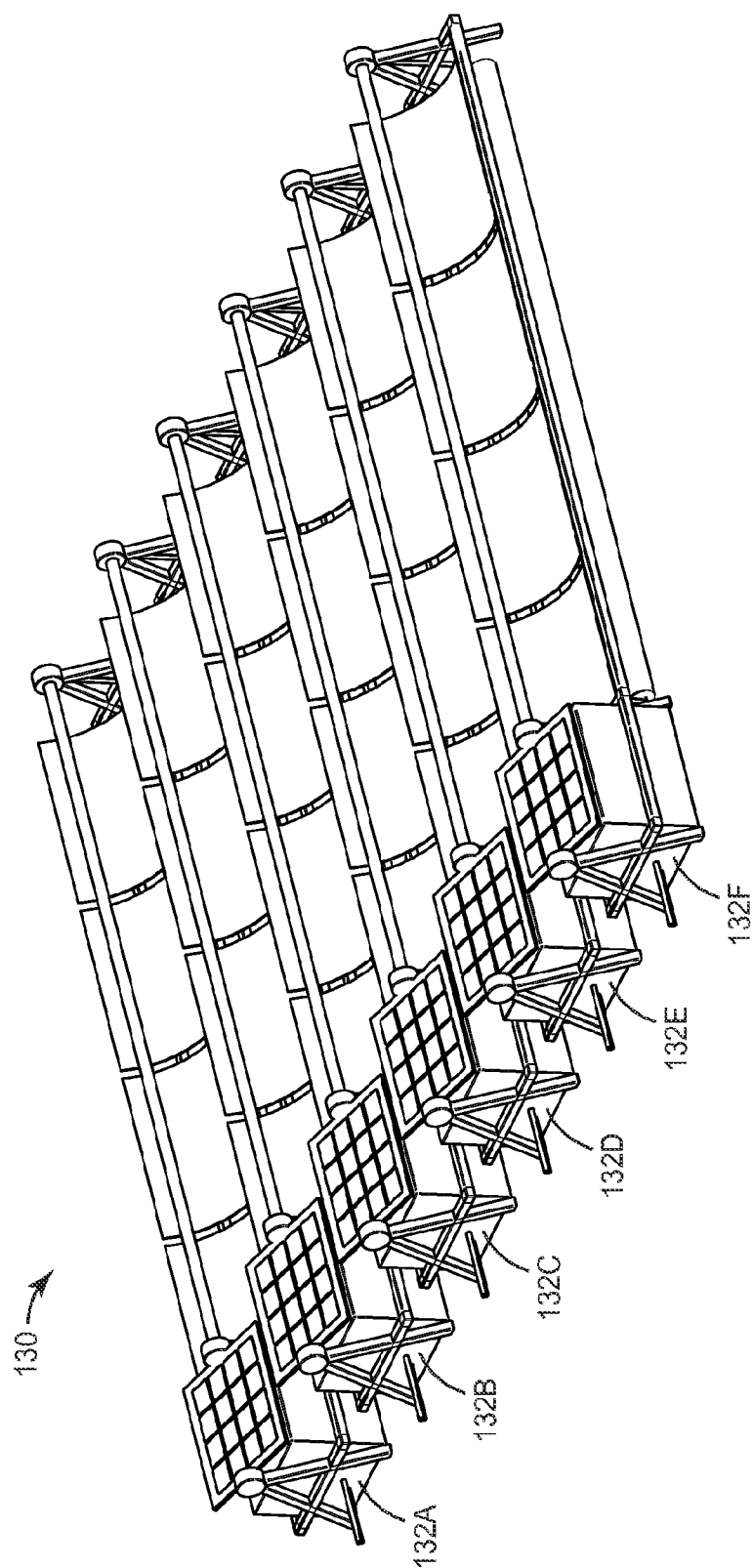
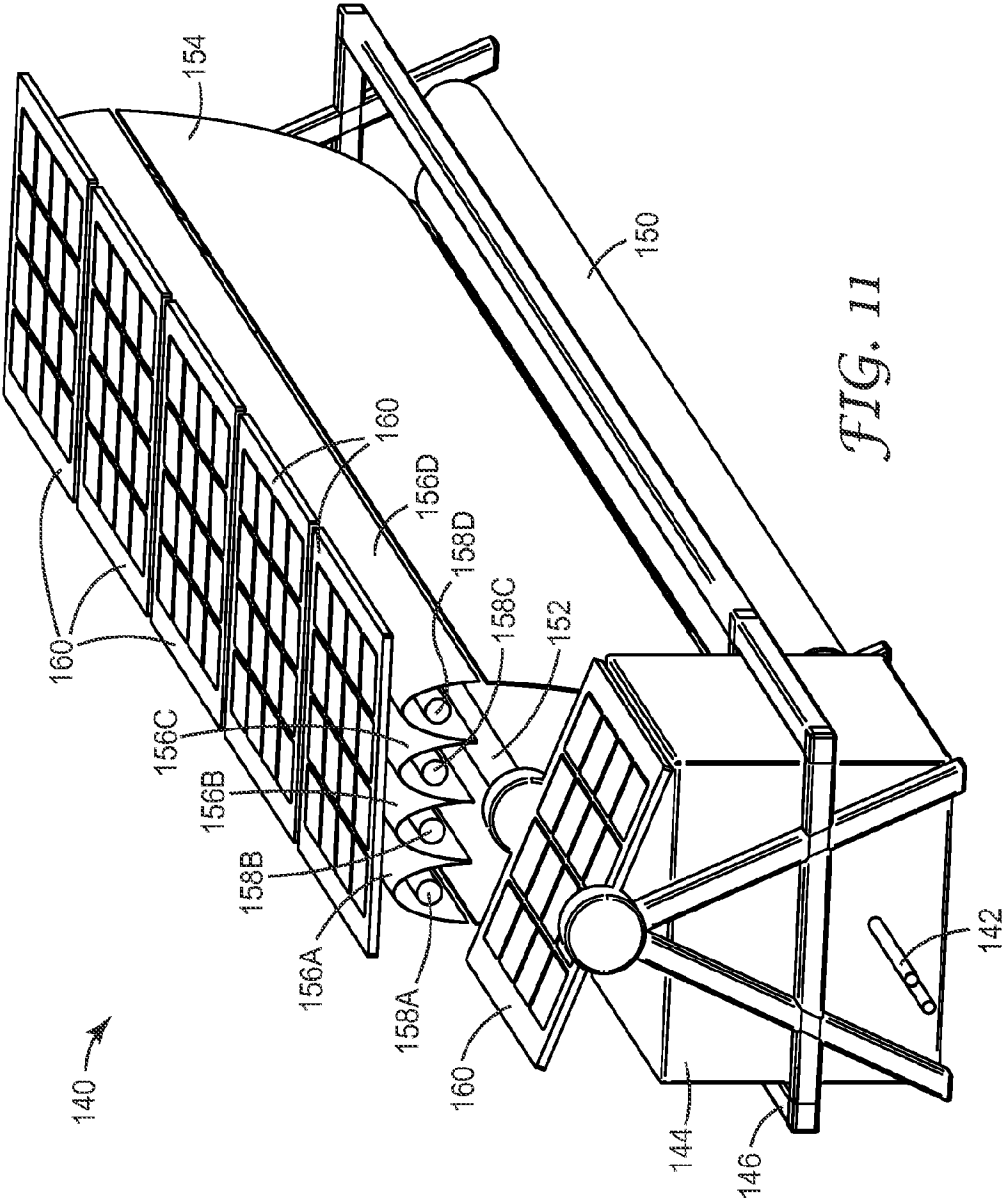


FIG. 10



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/052944**A. CLASSIFICATION OF SUBJECT MATTER****C02F 1/32(2006.01)i, C02F 1/28(2006.01)i**

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

B. FIELDS SEARCHEDMinimum documentation searched (classification system followed by classification symbols)
C02F 1/32; C02F 1/48; C02F 1/02; A23L 3/28; B01D 17/12; C02F 1/28Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility modelsElectronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: water, purification, sterilization, UV, ultraviolet, filter, tube, expandable, container**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 95-13853 A1 (WHITEHALL WATER FILTRATION SYSTEMS) 26 May 1995 See abstract; page 4, line 24 - page 6 line 9; claim 1; and figure 2.	1-5, 32-36
Y	WO 01-12559 A1 (THE COCA-COLA COMPANY) 22 February 2001 See abstract; claim 3; and figure 1.	1-5, 32-36
Y	US 2004-0182761 A1 (KUENNEN, R. W. et al.) 23 September 2004 See abstract; paragraph [0072]; and figure 5.	3-5, 34-36
A	US 2009-0145855 A1 (DAY, E. D. et al.) 11 June 2009 See abstract; paragraphs [0067], [0068]; claim 1; and figure 1.	1-5, 32-36
A	US 2012-0241644 A1 (BEN-DAVID, J. et al.) 27 September 2012 See abstract; paragraphs [0056], [0057]; claims 1-2; and figures 1-2.	1-5, 32-36

☐ 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

"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

26 December 2014 (26.12.2014)

Date of mailing of the international search report

29 December 2014 (29.12.2014)

Name and mailing address of the ISA/KR

International Application Division
Korean Intellectual Property Office
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INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2014/052944**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.: 8-9, 12, 17, 20-21, 23, 25-28, 41, 46, 48-50
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:
Claims 8-9, 12, 17, 20-23, 25-28, 41, 46 and 48-50 are unclear because they refer to multiple dependent claims which do not comply with PCT Rule 6.4(a).
3. ☒ Claims Nos.: 6-7, 10-11, 13-16, 18-19, 22, 24, 29-31, 37-40, 42-45, 47
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:

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 an additional fees, this Authority did not invite payment of any 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.:

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.

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