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(71) Applicant: **ECODYST, INC.** [US/US]; 204 Lime Creek Court, Cary, NC 27519 (US).

(72) Inventors: **ADJABENG, George**; 204 Lime Creek Court, Cary, NC 27519 (US). **WILLIAMS, Kwabena**; 1725 TW Alexander Drive, Unit 803, Durham, NC 27703 (US).

(74) Agent: **LEGLEITER, Leon, R.**; Jenkins, Wilson, Taylor & Hunt, P.A., Suit 1200, University Tower, 3100 Tower Boulevard, Durham, NC 27707 (US).

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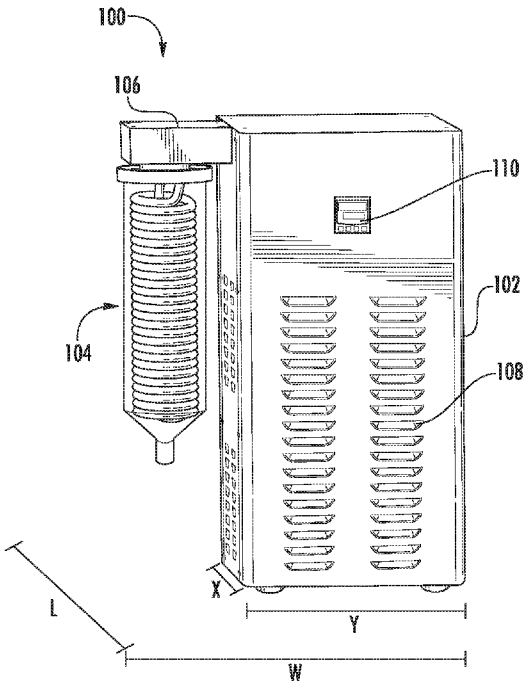


FIG. 1

(57) Abstract: Provided herein are compact chiller and cooler apparatuses, devices and systems. Chiller apparatuses disclosed herein can comprise a refrigeration system contained in a central housing with an external heat exchanger or "cold finger" configured to be universally applicable to cooling various sizes and configurations of water baths and laboratory applications needing a cooling capacity. Chiller apparatuses disclosed herein are configured to be universally used with rotary evaporators, vacuum ovens, centrifugal concentrators and freeze dryers.

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DESCRIPTION

COMPACT CHILLER AND COOLER APPARATUSES, DEVICES AND SYSTEMS

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of and priority to U.S. Provisional Patent Application Serial No. 62/174,092, filed June 11, 2015, the disclosure of which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

The presently disclosed subject matter relates to compact chiller and cooler apparatuses, devices and systems. The presently disclosed subject matter also relates to the use of such compact chiller and cooler apparatuses, devices and systems.

BACKGROUND

Chilling or cooling devices are used in laboratories and industries throughout the world, such as for cooling semiconductor equipment, medical equipment, medical and industrial lasers, electron microscopes, analytical instrumentation, and printing equipment. Other applications include plastics processing and testing, cryogenic testing, biological applications, pharmaceutical synthesis, and chemical synthesis. Additionally, chillers are used to provide cooling for rotary evaporators, a device used in chemical laboratories to remove solvents from samples by evaporation and in molecular cooking for the preparation of distillates and extracts.

Conventional chillers are often described as all in one packages with respect to system integration and control. That is, all the components are packaged in one housing. Unfortunately, all in one package chillers can be bulky, heavy and complex, which limits their widespread use. Integrating a cooling system, reservoir, and temperature controller has resulted in many versions of chillers that essentially deliver the same cooling functionality.

Some components of a chiller can remain relatively the same, but the reservoir (or tank) volume and/or size often vary. Thus, conventional chillers

with the same cooling functionality can have widely varying reservoir capacities, which affects the overall size, weight and price of varying chiller models. For example, two chillers having the same cooling capacity can vary significantly in size and weight, e.g. 550 pounds for a large capacity chiller compared to 150 pounds for a smaller tank chiller. Based on current designs, the reservoir capacity for each chiller is fixed. Thus, a user that purchases a 4.5 L model but later has a need for a larger capacity reservoir will have no other option than to purchase a more expensive, bulkier, and heavier chiller with a larger reservoir. This is not economical particularly when the cooling functionality remains essentially the same.

Chillers have proven valuable for use in laboratories and industries. They are generally considered environmentally friendly and water saving laboratory devices to cool, for example, a rotary evaporator. However, what is needed is chiller designs and systems that provide sufficient cooling capabilities that are cost effective and easy to use. It would be advantageous to reduce size, weight and complexity, improve cooling temperature ranges and cooling functions of chillers. Additionally, chiller designs that are multifunctional, flexible and easier to use are needed, particularly where improved functionalities can be realized. Laboratory space is a premium and chiller designs that are compact and have a small footprint are needed. Compact and lighter-weight chiller designs solve the persistent issue of limited bench space, and the frequent movement of chillers within a laboratory, or from laboratory to laboratory. Such advantages, and others disclosed herein, are provided by the instant disclosure.

SUMMARY

The presently disclosed subject matter provides compact chiller and cooler apparatuses, devices and systems configured to operate efficiently while taking up less space.

Provided in some embodiments is a chiller apparatus configured to cool a liquid, vapor or other medium, comprising a condenser, a compressor, a temperature controller, and a heat exchanger, wherein the condenser,

compressor and temperature controller are contained inside a housing, wherein the heat exchanger is external to the housing, wherein the heat exchanger is configured to be exposed to a liquid, vapor or other medium in a vessel, and from which heat is to be removed by the heat exchanger, wherein the condenser, compressor, temperature controller and heat exchanger are integrated into a single stand alone chiller apparatus, and wherein the chiller is configured to be universally used with any vessel containing liquids, vapors or other medium to be cooled. In some embodiments, the heat exchanger is positioned outside of the housing but affixed to the housing and configured to be submerged or placed in the vessel. In some embodiments, the chiller can further comprise a pump configured to be attachable to a vessel containing the liquids, vapors or other medium to be cooled, wherein the pump is configured to circulate the liquids, vapors or other medium in the vessel. In some embodiments, the chiller can further comprise a vacuum pump and controller.

In some embodiments, the heat exchanger, condenser and compressor further comprise a refrigerant, and wherein the heat exchanger, condenser and compressor are in fluid communication with one another and configured to circulate the refrigerant. In some embodiments, the heat exchanger is configured as a condenser for use with a rotary evaporator. In some embodiments, the heat exchanger is configured to be placed in a vessel comprising a circulating water bath or reaction bath.

In some embodiments, the chillers provided herein can further comprise a pump outside the chiller housing, wherein the pump is equipped with a detachable reservoir, wherein the pump is configured as a support structure for the reservoir, and wherein the heat exchanger is configured to be placed in the reservoir.

In some embodiments, the chillers provided herein can further comprise a double-walled vessel surrounding the heat exchanger. In some embodiments, the heat exchanger comprises an evaporator coil. In some embodiments, the evaporator coil comprises a titanium alloy. In some embodiments, the evaporator coil comprises stainless steel. In some embodiments, the evaporator coil comprises a copper pipe.

In some embodiments, a plurality of heat exchangers external to the housing and affixed to the housing can be provided.

In some embodiments, the chiller is tankless and is configured with a heat exchanger configured for contact and cool a liquid, vapor or other medium in a vessel detached from the chiller. In some embodiments, the vessel comprises an enclosed tank, open container, sealed vessel, double-walled vessel, conduit, and/or water bath. In some embodiments, the vessel comprises any size, volume and/or configuration so long as the liquid, vapor or other medium to be cooled comes into contact with the heat exchanger.

In some embodiments, a chiller as provided herein can further comprise a rotary evaporator, wherein the chiller is configured to condense an evaporate from the rotary evaporator. In some embodiments, a chiller as provided herein can further comprise a vacuum oven, wherein the chiller is configured to attach to and cool the vacuum oven. In some embodiments, a chiller as provided herein can further comprise a centrifugal concentrator, wherein the chiller is configured to attach to and cool the centrifugal concentrator. In some embodiments, a chiller as provided herein can further comprise a freeze dryer, wherein the chiller is configured to attach to and cool the freeze dryer.

In some embodiments, the heat exchanger can comprise a coolant coil and a chemical-resistant sleeve surrounding the coolant coil, wherein the coolant coil is configured to circulate a coolant from a refrigeration system to thereby cool a surface of the chemical-resistant sleeve. In some embodiments, a chemical-resistant sleeve can comprise a substantially cylindrical sleeve having an opening at a first end to receive the coolant coil.

In some embodiments, the chemical-resistant sleeve can comprise an inner cavity extending from a second end, wherein the inner cavity is configured to extend inside the coolant coil when the coolant coil resides in the substantially cylindrical sleeve. In some embodiments, the chemical-resistant sleeve comprises one or more structures extending from a surface of the chemical-resistant sleeve to increase a cooling surface area of the heat exchanger.

In some embodiments provided herein are chiller systems comprising a chiller apparatus configured to cool a liquid and a separate reservoir, the chiller apparatus comprising a condenser, a compressor, a temperature controller, and a heat exchanger, wherein the condenser, compressor and temperature controller are contained inside a housing, wherein the heat exchanger is external to the housing, wherein the heat exchanger is configured to be exposed to a liquid from which heat is to be removed by the heat exchanger, and the separate reservoir comprising a vessel configured to contain a liquid, wherein the reservoir is configured to place the liquid in contact with the heat exchanger, wherein the reservoir is separate from the chiller apparatus, and wherein the chiller apparatus is configured to be universally used with a separate reservoir of any size, volume or configuration provided that the separate reservoir positions the liquid to be in contact with the heat exchanger. In some embodiments, the chiller system can further comprise a plurality of separate reservoirs, wherein the plurality of separate reservoirs vary in size and/or liquid capacity but are configured to position the liquid in contact with the heat exchanger. In some embodiments, the reservoir further comprises a pump configured to circulate the liquid.

An object of the presently disclosed subject matter having been stated hereinabove, and which is achieved in whole or in part by the presently disclosed subject matter, other objects will become evident as the description proceeds when taken in connection with the accompanying Examples as best described hereinbelow.

BRIEF DESCRIPTION OF THE DRAWINGS

The presently disclosed subject matter can be better understood by referring to the following figures. The components in the figures are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the presently disclosed subject matter (often schematically). In the figures, like reference numerals designate corresponding parts throughout the different views. A further understanding of the presently disclosed subject matter can be obtained by reference to an embodiment set

forth in the illustrations of the accompanying drawings. Although the illustrated embodiment is merely exemplary of systems for carrying out the presently disclosed subject matter, both the organization and method of operation of the presently disclosed subject matter, in general, together with further objectives and advantages thereof, may be more easily understood by reference to the drawings and the following description. The drawings are not intended to limit the scope of this presently disclosed subject matter, which is set forth with particularity in the claims as appended or as subsequently amended, but merely to clarify and exemplify the presently disclosed subject matter.

For a more complete understanding of the presently disclosed subject matter, reference is now made to the following drawings in which:

Figure 1 is a perspective view of one embodiment of a chiller as disclosed herein;

Figures 2A and 2B are cross-sectional schematic views of two embodiments of chiller apparatuses as disclosed herein;

Figures 3A and 3B are cross-sectional schematic views of two embodiments of water bath devices as disclosed herein;

Figures 4A and 4B are cross-sectional schematic views of two embodiments of chiller apparatuses and water bath devices as disclosed herein;

Figures 5A, 5B and 5C are cross-sectional schematic views of embodiments of water bath devices as disclosed herein;

Figures 6A through 6D are perspective views of multiple embodiments of chiller apparatuses as disclosed herein;

Figures 7A through 7D are perspective and partial cut-away views of components of heat exchanger apparatuses as disclosed herein;

Figures 8A through 8D are perspective and partial cut-away views of components of heat exchanger apparatuses as disclosed herein;

Figure 9 is a perspective view of an embodiment of a heat exchanger apparatus as disclosed herein;

Figure 10 is a schematic illustration of an embodiment of a heat exchanger apparatus as disclosed herein;

Figure 11 is a perspective view of an embodiment of a heat exchanger apparatus as disclosed herein;

Figure 12 is a perspective view of an embodiment of a heat exchanger apparatus and freeze dryer as disclosed herein;

Figure 13 is a perspective view of an embodiment of a chiller apparatus and rotary evaporator system as disclosed herein;

Figure 14 is a perspective view of an embodiment of a chiller apparatus and vacuum oven system as disclosed herein; and

Figure 15 is a perspective view of an embodiment of a chiller apparatus and centrifugal concentrator system as disclosed herein.

DETAILED DESCRIPTION

Chillers are refrigerated cooling systems that generally include a compressor, condenser, evaporator, pump, reservoir, and temperature controller. Chillers cool down samples or processes by removing heat from one element and transferring it to another. Chillers are often referred to as recirculating chillers or coolers, which describe cooling liquid or medium (coolant) that is pumped through the system to be cooled and returned to the chiller.

Provided herein are chillers, also referred to as recirculating chillers, circulating coolers, circulators, and the like. In some embodiments, provided herein are chillers that comprise a compressor, condenser, heat exchanger (or evaporator), and/or temperature controller. In some embodiments such chillers are configured in a compact design. That is, in some aspects a chiller as provided herein can comprise a fully integrated “tankless” chiller apparatus with all components required for operation in a compact design, except the tank or reservoir for recirculated fluid/medium (coolant). The reservoir is not included in the chiller housing in some aspects but is instead a separate component such that the chiller itself is a separate and universal standalone piece of equipment that is not limited by the size/capacity/configuration of the reservoir, and can be configured to be used with a plurality of reservoir sizes, configurations and capacities in a multitude of applications.

In some embodiments chiller designs having the heat exchanger outside the main housing provides advantages over traditional recirculating chillers. For example, where the heat exchanger is inside the housing the chiller has limited uses and a fixed reservoir capacity. Cooled liquid must be circulated and the heat exchanger cannot be used for other activities like cooling reactions. Nor can such a configuration be used as a circulator bath. When the heat exchanger is inside the housing this means that separate instruments are needed for circulating chillers, circulating baths, immersion coolers, etc. This approach can be expensive, and can take up too much precious lab space and waste limited resources.

Conversely, chillers configured with the heat exchanger on the outside of the housing, as disclosed herein, can be used directly as a condenser in rotary evaporators, and/or to cool centrifugal concentrators, vacuum ovens, freeze dryers, gel dryers, DNA sample concentration applications, acid sample concentrations, and the like. In the case of rotary evaporators, for example, no coolant or circulating water is required. Vapors can be condensed directly on the heat exchanger. In some embodiments refrigerant inside the heat exchanger pipes or cooling lines can be configured to cool the pipes or cooling lines which in turn removes heat from the environment surrounding the heat exchanger, e.g. the evaporate.

Moreover, a tankless chiller, or one with a heat exchanger on the exterior of the housing, can provide for numerous and flexible uses. Any size reservoir, reaction vessels (to cool down or warm experiments), or circulator baths (to cool down or warm samples placed in the bath) can be used as well. Moreover, it is cheaper for researchers, clinicians or technicians to purchase various size reservoirs, circulating baths, etc., to use with one chiller than purchasing multiple chillers, separate circulator baths and an immersion cooler (used to cool down reactions). By housing the heat exchanger/evaporator outside the housing the disclosed chillers can in some embodiments be used in place of at least four pieces of equipment (circulating chillers, circulating baths, rotary evaporator condensers, and immersion coolers). Such a configuration provides significant advantages in cost savings and conservation of lab space.

In some embodiments, the disclosed chillers can improve cooling performance over existing cooling devices. For example, the cooling capability can be improved such as in applications that no longer require a coolant/circulating fluid, e.g. in rotary evaporators. In traditional chillers the coolant/circulating fluid is pumped through hoses from the chiller to the rotary evaporator condenser. Such coolant that is transported through these hoses can get warm, or at least warmer, by the time it reaches the condenser as it absorbs heat from the ambient surroundings. Such is not the case in the disclosed chiller designs.

Chiller apparatuses provided herein can in some embodiments comprise integrated cooling systems, such as for example a cooling system and a pump. Such chiller apparatus can further comprise a heat exchanger/evaporator positioned outside the housing of the compressor so that the heat exchanger/evaporator can be submerged or soaked in a reservoir or bath to remove heat from a liquid or medium within the reservoir or bath, or otherwise exposed to a coolant fluid, liquid, vapor or other cooling medium.

In some embodiments, the disclosed chillers can comprise a refrigeration system, including refrigeration lines, such as copper lines, through which refrigerant, e.g. chlorofluorocarbons, can pass, and a receiving tank, compressor, refrigeration condenser and dryer. The refrigeration lines can be connected to a heat exchanger in the condenser unit that provides a cooling surface for use in a water bath, reservoir, rotary evaporator or any other suitable environment desired to be cooled and capable of coming into contact with the heat exchanger. In some embodiments a cooling coil, which can be exposed, or in some embodiments concealed in a chemically-resistant vapor trap or sleeve made of titanium (including commercial pure grade titanium), stainless steel, metal alloys, plastic, glass, rubber, such as neoprene rubber, and/or combinations thereof, can be fluidly connected to the refrigeration lines. In some embodiments titanium is used in the sleeve due to its robust chemical resistance. The condenser unit in some embodiments can comprise a cooling coil chamber that is cooled by direct expansion of refrigerant in the

refrigeration lines. In some embodiments, the heat exchanger can comprise a copper coil through which cooled refrigerant passes, and which is encased in a titanium sleeve. In some embodiments, the heat exchanger can comprise a coil that is double looped and not encased in a sleeve such that vapors or cooling media are exposed to an increased surface area on the cooled coils. In such embodiments the double coils can comprise stainless steel, titanium, and/or a combination thereof. In some embodiments, the chiller, including mechanical refrigeration system, can be mechanically linked to and fixed with the heat exchanger/condenser such that the two are provided in a single unitary device.

In some embodiments the heat exchanger can comprise a cooling coil in fluid communication with the refrigeration system. The heat exchanger can comprise a titanium sleeve surrounding the cooling coil, whereby the titanium sleeve is cooled by the cooling coil, wherein the environment, e.g. a cooling fluid in a water bath or evaporate from a rotary evaporator, around the titanium sleeve is cooled. The condenser can comprise metal alloy sleeve surrounding the cooling coil, whereby the metal alloy sleeve is cooled by the cooling coil.

In some aspects, a detachable reservoir, in some embodiments integrated with a pump or other means for providing a pressure/circulating capacity, can be provided. Such a reservoir can in some embodiments be attached to a pump hose or conduit at one end of the hose or conduit, and the other end of the hose or conduit to the reservoir at a point that liquid or cooling media in the reservoir can be pumped to systems be cooled.

In some aspects, each of the components above, including a compressor for the refrigeration system and a pump, can be integrated into one stand alone or all-in-one system with one or more heat exchangers/evaporators. Without a built-in reservoir or water bath such stand alone or all-in-one system chillers can be more compact than existing chiller systems. Such a compact configuration can make the disclosed chillers more portable and space saving.

A stand alone chiller apparatus as disclosed herein can in some embodiments comprise one or more compressors, a condenser, a

temperature controller, a receiver tank, an evaporator that can be positioned in a reservoir liquid or other vessels and configured to remove heat from a liquid or medium, an external reservoir or a vessel into which the evaporator can be positioned or submerged; and/or a pump or other mechanical apparatus to pump a cooled liquid or other medium in the reservoir to the systems to be cooled or for vacuum distillation.

In some embodiments, the heat exchanger/evaporator can be fitted with a condenser of a distillation apparatus like a rotary evaporator, such as for example that disclosed in US Patent No. US 9,005,403, which is incorporated herein by reference in its entirety. In yet other embodiments, the chiller apparatus can comprise an integrated vacuum pump and controller. In some aspects more than one rotary evaporator can be connected to one chiller.

In some embodiments, a cooling temperature range for the disclosed chillers can range from about +40°C to about -45°C, about +40°C to about -100°C, or about +40°C to about -150°C. Desired temperatures can be achieved through refrigeration engineering and/or refrigerant selection.

Turning now to the figures, Figure 1 is a perspective view of a compact multifunctional chiller **100** as disclosed herein. As depicted in Figure 1, chiller **100** can comprise a housing **102** with a heat exchanger **104** connected to but extending from housing **102**. Chiller **100**, and internal components discussed below, can be configured in such as way as to be integrated into a single device or apparatus that is configured to compactly arrange the elements in such a way that provides for an effective and efficient cooling/chilling system while minimizing the operational area and/or footprint. For example, the footprint or operational area of chiller **100** can be defined by the length **L**, width **W**, and/or combination thereof (area in square inches for example) of the outer dimensions of the apparatus. Alternatively, or in addition, the footprint or operational area of chiller **100** can be defined by the length **X**, width **Y**, and/or combination thereof (area in square inches for example) of the dimensions of housing **102**. By way of example and not limitation, the footprint of traditional or existing chillers is about 300 to about 500 square inches, with some designs having an about 368 square inch

footprint. For example, some existing chillers can have dimensions (W x H x D) of about 15.8 x 22.8 x 19.7 inches, about 15.8 x 26.0 x 19.7 inches, about 19.7 x 29.9 x 25.2 inches, or about 30.7 x 33.5 x 58.3 inches. In contrast, the presently disclosed chiller apparatuses, can in some embodiments comprise a total footprint or operational area of about 18.7 x 10 inches (**L** x **W** in Figure 1), or about 150 square inches to about 350 square inches. In some embodiments the disclosed chillers can comprise a housing **102** footprint of about 12 x 10 inches (length **X** by width **Y**, in Figure 1, or about 150 square inches to about 350 square inches In some embodiments a chiller as disclosed herein can be about 12 x 10 x 26 (L x W x H) inches in size.

Housing **102** can comprise a substantially rectangular or square or other suitable shape, box-like structure with four sides, a top and bottom. Housing **102** can be configured to fully, or substantially fully, enclose the mechanical or working components of chiller **100**, except for heat exchanger **104**. In some embodiments chiller **100** can comprise a heat exchanger arm **106** extending substantially horizontally from housing **102** and configured to support and mechanically connect heat exchanger **104** to chiller **100**. Heat exchanger **104** can be attached to heat exchanger arm **106** by a clamp or other attachment mechanism, e.g. threads, screws, bolts, pressure fitting, etc. In some embodiments housing **102** can comprise a sheet metal or other suitable material, e.g. plastic, fiberglass, aluminum, etc., sufficiently rigid to maintain its structure and encase chiller **100**, and also withstand extended use in a laboratory or field setting.

In some embodiments housing **102** can optionally comprise ventilation grates **108**, louvers or other suitable ventilation structures configured to permit air circulation within the interior of housing **102 a**nd around the refrigeration system housed therein. In some aspects chiller **100** can also comprise a control panel **110** conveniently located, such as on an outer surface of housing **102**, such that a user can manipulate control panel **110** to facilitate operation of chiller **100**. Control panel **110** can in some embodiments comprise a touch-screen or other electronic controller. Control panel **110** can in some embodiments comprise a temperature controller

configured to control and/or regulate a temperature of a medium and/or the heat exchanger.

Figures 2A and 2B are schematics illustrations of the internal working components of chiller **100**. Chiller **100** can comprise an integrated refrigeration system housed within housing **102** and continuing through heat exchanger arm **106** to provide a cooled refrigerant to heat exchanger coil **104**. As shown in these cut-away views chiller **100** can comprise a compressor **120**, refrigeration condenser **122** and fan **126**. In some embodiments a refrigeration dryer may also be included. In some embodiments compressor **120**, refrigeration condenser **122** and heat exchanger coil **104** (and optionally dryer) can be connected by refrigeration lines **132** (copper tubing) by feeding through heat exchanger arm **106**. Heat exchanger **104** can comprise single or double coiled lines **130** connected to refrigeration lines **132** fed through heat exchanger arm **106**. Thus, refrigeration coolant can pass through the refrigeration system (e.g. compressor **120**, refrigeration condenser **122**) and into coiled lines **130** of heat exchanger **104** in a closed or continuous circuit such that heat absorbed by heat exchanger **104** from a surrounding media, e.g. cooling liquid or vapors, can be removed by the refrigeration system to thereby cool the surrounding media.

Figures 2A and 2B depict similar chillers **100'** and **100''**, respectively, both of which are optional configurations of chiller **100** of Figure 1. Chiller **100'** in Figure 2A includes a pump **126** whereas chiller **100''** does not. In some embodiments, such as in chiller **100'**, pump **126** can be configured to provided a pumping or pressurization capacity for a reservoir, water bath or reaction vessel to be used with the chiller. Having a pump built in to the chiller provides an additional functional feature that can be used to circulate a cooling media in a reservoir, water bath (Figure 3A) or reaction vessel as needed. However, in some embodiments, such as in chiller **100''** no pump **126** is provided since in some embodiments no pump is needed, such as for example when used with a rotary distillation apparatus, or a water bath with built-in circulating capabilities (Figure 3B).

Figures 3A and 3B depict example water baths, reservoirs or reaction vessels configured to be used with the disclosed chillers. Water baths **200** (Figure 3A) and **202** (Figure 3B) can in some embodiments be configured to contain a liquid or other cooling medium **206** in a closed compartment, e.g. rectangular, square or other suitable shape, with exterior walls **204**, e.g. a bottom, side walls and optionally a top, to create the container. In some embodiments water baths **200** and **202** can comprise an opening **208** configured to receive or otherwise allow heat exchanger **104** to be placed inside water baths **200** and **202** (see Figures 4A and 4B). In some embodiments water baths **200** and **202** can comprise an inlet **210** and outlet **212** configured to allow cooling medium **206** to flow into and out of water baths **200** and **202**. In some embodiments water baths **200** and **202** can comprise a handle **214** or other apparatus to facilitate handling and movement of the water bath by a user, even when full of cooling medium **206**.

Water bath **200** as depicted in Figure 3A does not have a built in pump while the version depicted in Figure 3B does have an integrated pump **126**. Pump **126** can be positioned adjacent to and/or underneath water bath **202** and connected to the interior via conduit **214** to facilitate pumping of cooling medium **206** from water bath **202** to outlet **212**.

Figures 4A and 4B illustrate the use of chillers **100'** (Figure 2A) and **100''** (Figure 2B) with water bath **200** (Figure 3A) and water bath **202** (Figure 3B), respectively. In Figure 4A illustrates the use of water bath **200** (Figure 3A) with chiller **100'** (Figure 2A). Heat exchanger **104** (including coiled lines **130**) is inserted in water bath **200** via opening **208** such that cooling medium **206** is in contact with heat exchanger **104**. In some embodiments outlet **212** is connected to pump **126** built into chiller **100'** such that cooling medium **206** can be circulated back into water bath **200** via inlet **210** (via a conduit as needed) or pumped to another desired location (via a conduit as needed).

Similarly, in Figure 4B heat exchanger **104** (including coiled lines **130**) is inserted in water bath **202** via opening **208** such that cooling medium **206** is in contact with heat exchanger **104**. Since pump **126** is built into water bath **202** circulating cooling medium **206**, as needed, can be achieved

without the need for such a pump in chiller **100''**. Cooling medium **206** can be circulated back into water bath **202** via inlet **210** (via a conduit as needed) or pumped to another desired location (via a conduit as needed).

The orientation of chillers **100'** and **100''** with water baths **200** and **202** in Figures 4A and 4B are for illustration purposes only and not intended to be limiting. From a functional standpoint the ability to use heat exchanger **104** in any size, shape or style of water bath, vessel or container is an aspect of the presently disclosed subject matter. Thus, the positioning, orientation or configuration of the water bath or vessel to be cooled can be varied as needed without departing from the scope of the instant disclosure so long as such water bath or vessel can receive heat exchanger **104**.

As depicted in Figures 5A, 5B and 5C, water baths **200A**, **200B**, and **200C** can be configured in various sizes, all of which can be utilized with chiller **100**. In contrast to currently available cooling systems that have integrated water baths of a fixed size, the presently disclosed chillers are configured to be utilized with water baths of various sizes and configurations. This allows the same chiller to be used for multiple applications without requiring the purchase of multiple chillers. Significant cost savings can be realized since it is significantly cheaper to buy one universal chiller and multiple water baths than to buy multiple chillers having varying sizes of water baths. Additionally, as disclosed herein, the disclosed chillers can be used with a plurality of other applications besides cooling water baths. Water baths **200A**, **200B**, and **200C** shown in Figures 5A, 5B and 5C are exemplary only and are provided to show their size can vary while still being usable with the disclosed chillers. Additionally, although not depicted in Figures 5A, 5B and 5C, such water baths can comprise an integrated pump as shown in Figure 3B, or any other suitable configuration.

Chiller **100** is configured to be utilized with a plurality of heat exchanger designs as depicted in Figures 6A-6D. By way of example and not limitation, heat exchanger **250**, as depicted in Figure 6A, can comprise a single walled vessel design comprising heat exchanger coils **130**, a single-walled enclosure **260** surrounding and enclosing coils **130**. Single-walled enclosure **260** can in some embodiments comprise a glass canister

configured to slide over heat exchanger coils **130** and securely attach to heat exchange arm **106** to create a sealed enclosure by way of a securing element, including for example collar **258**. Single-walled enclosure **260** can be attached to heat exchange arm **106** by a clamp or other attachment mechanism, e.g. threads, screws, bolts, pressure fitting, etc. One or more ports **262**, **264**, and/or **266** can be provided to allow attachment of one or more conduits or additional instruments/vessels to act as inlets/outlets for compounds/fluids to be cooled and/or condensed. Compounds, vapors or fluids entering single-walled enclosure **260** can come into contact with heat exchange coils **130**, or a cooling sleeve surrounding the coils, to thereby cool the compounds, vapors or fluids.

By way of example and not limitation, heat exchanger **252**, as depicted in Figure 6B, can comprise a double-walled vessel design comprising heat exchanger coils **130** enclosed in a double-walled enclosure **270**. Double-walled enclosure **270** can in some embodiments comprise a glass canister configured with an inner sleeve **272** configured to slide over heat exchanger coils **130** and securely attach to heat exchange arm **106** to create a sealed enclosure by way of a securing element, including for example collar **258**, and/or other attachment mechanism, e.g. threads, screws, bolts, pressure fitting, etc. One or more ports **262**, **264**, and/or **266** can be provided to allow attachment of one or more conduits or additional instruments/vessels to act as inlets/outlets for compounds/fluids to be cooled. Compounds, vapors or fluids entering double-walled enclosure **270** can come into contact with inner sleeve **272** in the space between double-walled enclosure **270** and inner sleeve **272**. Inner sleeve **272** in contact with or close proximity to heat exchange coils **130** can be cooled and thereby cool the compounds, vapors or fluids introduced into double-walled enclosure **270**. In this configuration compounds, vapors or fluids to be cooled do not come into direct contact with heat exchange coils **130**.

In some embodiments chiller **100** can comprise one or more heat exchangers to increase the cooling capacity and ability to use the same chiller for multiple applications simultaneously. In some embodiments the one or more heat exchangers, such as **254** and **254'** in Figure 6C, can be

adapted to run off of the same refrigeration system as shown in Figures 2A and 2B. The orientation of heat exchangers **254** and **254'** extending from housing **102** can be arranged as desired without departing from the scope of the instant disclosure, including for example from opposing sides of housing **102** as depicted in Figure 6C. Alternatively, as shown in Figure 6D, one heat exchanger **256** can extend from a side of housing **102** via heat exchanger arm **106**, while a second heat exchanger **256'** can extend from a front side of housing **102** via a second exchanger arm **106**. Any other orientation, with two or more heat exchangers, is within the scope of the instant disclosure. Moreover, the types of heat exchanger units can be varied from one heat exchanger arm **106** to another, as depicted in Figure 6D. By way of example and not limitation, heat exchanger **256** can comprise a stainless steel sleeve **280** surrounding coils **130**, while heat exchanger **256'** can comprise a stainless steel sleeve **282** surrounding coils **130** and having an interior cavity. By providing an adaptable platform the chillers provided herein are suitable for use with numerous types of heat exchanger designs and orientations, and are thereby suitable for use in various laboratory and field applications, as discussed further herein.

Figures 7A-7D illustrate an exemplary heat exchanger configured to be used with the disclosed chillers. As depicted in Figure 1 for example, a heat exchanger system as depicted in Figure 7A can comprise a coiled lines **130** which can be connected to refrigeration lines through which cooled refrigerant can pass. Coils **130** can have an incoming line for receiving a flow of chilled coolant or refrigerant to pass through the coils, and an outgoing line configured as a conduit for the outgoing coolant or refrigerant after having passed through the coils and acting as a heat exchanger. The incoming line and outgoing line are configured to be connected to the integrated refrigeration system of the chiller. Coiled lines **130** are illustrated as a single looped coil in Figure 7A, but can also comprise in some embodiments double, triple or more coils. An effect of coiling the refrigerant lines of coiled lines **130** is to increase the surface area for cooling a medium in contact with the coils or in contact with a surface proximate to the coils. Thus, doubling or tripling, for example, the coils in some embodiments can

increase cooling capacity of a heat exchanger. Coiled lines **130** can be configured to complete a continuous loop along with the refrigeration system of the chiller, such as depicted in Figures 2A and 2B. Coiled lines **130** can be made from a copper tubing material in some embodiments, or alternatively stainless steel, or other suitable metal alloys such as titanium. In some embodiments coils **130** can comprise a titanium material with an inner coating of copper. In some embodiments coils **130** can comprise stainless steel, titanium, and/or a combination thereof.

While in some embodiments coil **130** can be exposed for direct cooling of a medium or evaporate (vapor), in some embodiments, and as depicted in Figures 7B, 7C and 7D, it can be concealed by sleeve **280** that can comprise a chemically-resistant vapor trap made of titanium (including commercial pure grade titanium), stainless steel, metal alloys, plastic, glass, rubber, such as neoprene rubber, and/or combinations thereof. Sleeve **280** can comprise a cylindrical housing with a first end having a coupling element **258**, including a locking mechanism **284** and collar **282** for securing to heat exchanger arm **106** (see Figure 1 for example) and securing a housing **300** (see Figure 7D for example). At an opposing or second end sleeve **280** can comprise a conical or tapered portion **286** terminating in a tip portion **288**. As depicted in Figure 7C, sleeve **280** can be configured to slide over coils **130** so as to be in direct contact or close proximity to the coils, whereby sleeve **280** can be cooled by the refrigerant passing through the coils thereby acting as a heat exchanger with respect to medium and/or vapor coming into contact with sleeve **280**.

Housing **300** can comprise a glass vessel enclosing the heat exchanger that includes condenser coil **130** and sleeve **280**. Housing **300** can attach to heat exchanger arm **106** by a clamp or other securing mechanism, including coupling element **258** on sleeve **280**, to create an air-tight seal. Housing **300** can in some embodiments comprise an entry port **304** for receiving an evaporate, vapor or other medium from a rotary evaporator or other machine, equipment or apparatus, and in some embodiments a second entry port **306**. A vacuum port **302** can in some embodiments be provided (in some cases near the top) and configured to

receive a vacuum line from a vacuum pump to thereby cause a vacuum on the inner environment of housing **300**. An evaporate or vapor that comes into contact with the heat exchanger, and particularly sleeve **280** can condenses into a liquid can collect into collection flask **310** by passing through conduit **308**. In some embodiments a joint **312** can be positioned on conduit **308** that can be configured to allow for removal of a collection flask (receiving flask) **310** without breaking a vacuum to the system during operation. Such joint **312** can comprise a valve to maintain the vacuum while removing collection flask **310**.

Thus, in some embodiments a heat exchanger used with a chiller as disclosed herein can comprise coiled lines **130**, sleeve **280** and/or housing **300**. Coils **130** can be configured to fit or slide inside sleeve **280** to form a heat exchanger or "cold finger". Since coiled lines **130** can be fluidly connected to the integrated refrigeration system in the chiller cooled refrigerant can pass through coils **130** causing a cooling effect on sleeve **280**. Any medium, evaporate or vapor entering housing **300** can come into contact with the cold surface of sleeve **280** thereby causing the medium to cool and/or the vapor to condense into a liquid to be collected in collection flask **310**. The configuration of such a heat exchanger can provide an efficient mechanism for trapping all or substantially all vapors and condensing them such that environmental impacts are lessened.

As depicted in Figures 2A and 2B, in order to achieve a stand alone fully integrated system that minimizes space utilization, chiller **100**, including mechanical refrigeration system, can be mechanically linked to and fixed with the heat exchanger **104** such that the two are provided in a single unitary device.

Figures 8A-8D illustrate an alternative embodiment of an exemplary heat exchanger configured to be used with the disclosed chillers. As depicted in Figure 1 for example, a heat exchanger system as depicted in Figure 8A can comprise coiled lines **130** which can be connected to refrigeration lines through which cooled refrigerant can pass. Coils **130** can have an incoming line for receiving a flow of chilled coolant or refrigerant to pass through the coils, and an outgoing line configured as a conduit for the

outgoing coolant or refrigerant after having passed through the coils and acting as a heat exchanger. The incoming line and outgoing line are configured to be connected to the integrated refrigeration system of the chiller. Coiled lines **130** are illustrated as a single looped coil in Figure 8A, but can also comprise in some embodiments double, triple or more coils. An effect of coiling the refrigerant lines of coiled lines **130** is to increase the surface area for cooling a medium in contact with the coils or in contact with a surface proximate to the coils. Thus, doubling or tripling, for example, the coils in some embodiments can increase cooling capacity of a heat exchanger. Coiled lines **130** can be configured to complete a continuous loop along with the refrigeration system of the chiller, such as depicted in Figures 2A and 2B. Coiled lines **130** can be made from a copper tubing material in some embodiments, or alternatively stainless steel, or other suitable metal alloys such as titanium. In some embodiments coils **130** can comprise a titanium material with an inner coating of copper. In some embodiments coils **130** can comprise stainless steel, titanium, and/or a combination thereof.

While in some embodiments coil **130** can be exposed for direct cooling of a medium or evaporate (vapor), in some embodiments, and as depicted in Figures 8B, 8C and 8D, it can be concealed by sleeve **320** that can comprise a chemically-resistant vapor trap made of titanium (including commercial pure grade titanium), stainless steel, metal alloys, plastic, glass, rubber, such as neoprene rubber, and/or combinations thereof. Sleeve **320** can comprise a cylindrical housing with a first end having a coupling element **258**, including a locking mechanism **284** and collar **282** for securing to heat exchanger arm **106** (see Figure 1 for example) and securing a housing **300** (see Figure 8D for example). At an opposing or second end sleeve **320** can comprise a conical or tapered portion terminating with an opening that returns into the interior of sleeve **320** to form an inner cavity **322**. Inner cavity **322** can provide additional surface area for a medium, evaporate or vapors to become exposed to the cooling surface of sleeve **320** to thereby increase cooling capacity of the “cold finger”.

As depicted in Figure 8C, sleeve **320** can be configured to slide over coils **130** so as to be in direct contact or close proximity to the coils, whereby sleeve **320** can be cooled by the refrigerant passing through the coils thereby acting as a heat exchanger with respect to medium and/or vapor coming into contact with sleeve **320**. Inner cavity **322** can be configured to slide inside the opening in coils **130** as depicted in Figure 8C.

Housing **300** can comprise a glass vessel enclosing the heat exchanger that includes condenser coil **130** and sleeve **320**. Housing **300** can attach to heat exchanger arm **106** by a clamp or other securing mechanism, including coupling element **258** on sleeve **320**, to create an air-tight seal. Housing **300** can in some embodiments comprise an entry port **304** for receiving an evaporate, vapor or other medium from a rotary evaporator or other machine, equipment or apparatus, and in some embodiments a second entry port **306**. A vacuum port **302** can in some embodiments be provided (in some cases near the top) and configured to receive a vacuum line from a vacuum pump to thereby cause a vacuum on the inner environment of housing **300**. An evaporate or vapor that comes into contact with the heat exchanger, and particularly sleeve **320** can condenses into a liquid can collect into collection flask **310** by passing through conduit **308**. In some embodiments a joint **312** can be positioned on conduit **308** that can be configured to allow for removal of a collection flask (receiving flask) **310** without breaking a vacuum to the system during operation. Such joint **312** can comprise a valve to maintain the vacuum while removing collection flask **310**.

Thus, in some embodiments a heat exchanger used with a chiller as disclosed herein can comprise coiled lines **130**, sleeve **320** and/or housing **300**, as depicted in Figures 8A-8D. Coils **130** can be configured to fit or slide inside sleeve **320** to form a heat exchanger or “cold finger”. Since coiled lines **130** can be fluidly connected to the integrated refrigeration system in the chiller cooled refrigerant can pass through coils **130** causing a cooling effect on sleeve **320**. Any medium, evaporate or vapor entering housing **300** can come into contact with the cold surface of sleeve **320** thereby causing the medium to cool and/or the vapor to condense into a liquid to be collected

in collection flask **310**. The configuration of such a heat exchanger can provide an efficient mechanism for trapping all or substantially all vapors and condensing them such that environmental impacts are lessened.

Figures 9-11 depict various devices to be used the disclose heat exchangers to increase the surface area for cooling/heat exchanging. Figure 9 is an illustration of a ring structure **330** configured to be used with sleeve **280** or **320** (sleeve **280** depicted in Figures 9-11). Ring structure **330** can comprise a series of rings **332** or disc-like structures made of a material, e.g. steel, aluminum, stainless steel, copper, etc., and arranged around the cylindrical housing of sleeve **280**. Rings **332** can be attached to vertical stays **334** to align and hold them into place along the cylindrical housing of sleeve **280**. Due to their contact with or proximity to the cylindrical housing of sleeve **280** rings **332** provide additional surface area for heat exchanging/cooling.

Figure 10 is an illustration of a fin structure **340** configured to be used with sleeve **280** or **320** (sleeve **280** depicted in Figures 10). Fin structure **340** can comprise horizontal, substantially horizontal, or angled fins or vanes wrapped around the cylindrical housing of sleeve **280**. Fin structure **340** can comprise a continuous wire, tubing or ribbon of material, e.g. steel, aluminum, stainless steel, copper, etc., wrapped around sleeve **280** and affixed at a first end **342** and second end **344** to sleeve **280**. In some embodiments, fin structure **340** can be further attached at period locations along the surface of sleeve **280**. Due to the contact with or proximity to the cylindrical housing of sleeve **280** fins **340** provide additional surface area for heat exchanging/cooling.

Figure 11 is an illustration of a vane structure **350** configured to be used with sleeve **280** or **320** (sleeve **280** depicted in Figure 11). Vane structure **350** can comprise a series of vertical (or substantially vertical) vanes **356** made of a material, e.g. steel, aluminum, stainless steel, copper, etc., and arranged around the cylindrical housing of sleeve **280**. Vanes **356** can be attached to an upper disc **352** and lower disc **354** to align and hold them into place along the cylindrical housing of sleeve **280**. Due to their

contact with or proximity to the cylindrical housing of sleeve **280** vanes **356** provide additional surface area for heat exchanging/cooling.

Figure 12 is an illustration of a freeze dryer apparatus **360** configured to be used with sleeve **280** or **320**. Freeze dryer apparatus **360** can comprise a cylinder **362** configured to slide over sleeve **280** or **320** (see Figures 7 and 8) and a series of rings **364** or disc-like structures made of a material, e.g. steel, aluminum, stainless steel, copper, etc., and arranged around cylinder **362**. Rings **364** can be attached to vertical stays **368** to align and hold them into place along cylinder **362**. Due to their contact with or proximity to sleeve **280** or **320** rings **364** provide additional surface area for heat exchanging/cooling. Openings **366** can be provided in rings **364,**, wherein the rings and openings can be configure to hold sample vials, wherein the sample vials can contain a sample to be freeze dried. Freeze dryer apparatus **360** can be configured to reside inside freeze dryer vacuum chamber **380**, wherein vacuum chamber **380** can be configured with one or more ports **382** configured to engage one or more sample vials containing a sample to be freeze dried.

Together freeze dryer apparatus **360** and vacuum chamber **380** can be configured to provide a sufficiently cold environment under vacuum such that water in the samples will sublimate from the solid phase to the gas phase. Freeze drying, also known as lyophilisation, lyophilization, or cryodesiccation, is a dehydration method. Freeze drying works by freezing the material and then reducing the surrounding pressure to allow the frozen water in the material to sublimate directly from the solid phase to the gas phase.

In some embodiments chiller **100** is configured to be used in conjunction with a rotary evaporator **400** as depicted in Figure 13. Rotary evaporator **400** can comprise an evaporating (sample) flask **410** configured to be immersed in a water bath **412**. Evaporating flask **410** can be rotated using a motor housed in mounting arm **414**, with the rotational force provided by the motor being transferred to evaporating flask **410** by rotary joint (vapor duct) **416**. Rotary joint **416** can pass/continue through mounting arm **414.** Rotary joint **416** provides a conduit through which the evaporate (vapor) from

a sample or solvent in evaporation flask **410** can pass into a dummy condenser **418**, and into heat exchanger **104** by way of vapor duct **420**. Heat exchanger **104** (in any desired configuration as disclosed herein) can be configured to act as a condenser. Once in heat exchanger **104** vapors can be cooled thereby causing them to re-condense and drop into collection flask **310**. Collection flask **310** can in some embodiments be removed by a releasable joint which can in some embodiments comprise a valve to maintain the vacuum in heat exchanger/condenser **104** and/or rotary evaporator **400** until collection flask **310** is reattached.

In some embodiments chiller **100** is configured to be used in conjunction with a rotary evaporator **400** simultaneously with a vacuum pump **500** to create a vacuum within the distillation system. For example, in some embodiments vacuum line **504** can connect a vacuum system or pump **500** from a port **502** on the pump to vacuum port **302** on housing **300.** In some embodiments vacuum system or pump **500** can be integrated within the housing of chiller **100** or can be a stand alone separate unit as depicted in Figure 13. With vacuum pump **500** a vacuum or negative pressure can be created on the inner environment of housing **300**. An evaporate or vapor that comes into contact with the heat exchanger, and particularly sleeve **280** can condenses into a liquid can collect into collection flask **310**.

Rotary evaporators, also referred to in some embodiments as distillers or distillation apparatuses, are used in laboratories throughout the world, for removing solvents from organic and inorganic solutions, to yield a liquid or solid product. Generally, such evaporators or distillers work by placing a sample in a round-bottom flask (referred to as a sample flask or evaporation flask), typically a pear-shaped flask, which spins on an axis at an angle while sitting in a water bath. The flask is attached to a motor, which can include a rotary joint that enables the flask to spin, while permitting the evaporated solvent to flow through the joint (vapor duct) and come into contact with one or more condensers. The condenser(s) can cool the vapor, and the resulting cooled vapor (i.e., liquid) then flows down to a flask below the condenser (a collection flask), where it can be collected.

A water bath can typically be provided to supply sufficient heat to the flask to evaporate the solvent. Typically, the rotor, the motor, the rotary joint, the condenser, the flask used to hold the original solvent, and the flask used to hold the condensed vapor as it is collected, are all connected while the unit is in operation. A mechanical arm is usually provided to raise and lower the connected parts, to bring the flask out of the water bath.

The condenser of the rotary evaporator can be connected to a water source, and water is frequently acceptable to condense the solvent of interest, particularly if the solvent has a relatively high boiling point. Users frequently leave the water flowing through the condenser throughout the day, which results in large volumes of waste water. Further, where the solvent has a particularly low boiling point, it can be advantageous to cool the vapor to temperatures cooler than a water condenser can provide. To only use a water-cooled condenser might create an environmental issue, as a significant volume of volatile organic solvent would not be collected, and could instead enter into the environment.

Particularly when low boiling solvents are used, efforts have been made to improve on the condensation of the vapors so as to trap a significant portion of the solvents. In such cases, one approach is to use a dry-ice condenser, which is packed with dry ice, and, optionally, a solvent that forms a slurry with dry ice to maintain a given temperature (for example, dry ice-acetone maintains a temperature of -78°C). However, since glass is a poor conductor of heat, the "cold finger" glass of the dry-ice condenser provides warmer than -78°C cooling surface on which vapors are condensed. Also, in normal laboratory operating temperatures (ambient) dry ice evaporates very fast, which requires constant or frequent replenishing of dry ice in the dry-ice condenser. This is costly, burdensome and negatively impacts productivity.

The chillers provided herein can in some embodiments comprise integrated cooling systems, such as for example a refrigerated condensing unit. Thus, in some embodiments rotary evaporators used in conjunction with the disclosed chillers can be capable of cooling evaporated solvents without using a dry ice trap, a continuous flow of water, and/or a recirculating

chiller. By using a mechanically refrigerated cooling/freezing system, or chiller, to provide a cool reservoir capable of condensing vapors arising from solvent evaporation the waste of a continuous flow of water can be avoided, and the use of dry ice and compatible solvents such as acetone and isopropyl alcohol can be avoided, both of which provide for a more environmentally friendly alternative to existing rotary evaporators. Moreover, the configuration and design of the disclosed chillers provides for the use of refrigeration cooling/heat exchange system in an integrated and compact design, particularly as compared to existing cooling devices with built-in water baths that comprise multiple components and require substantially more space to operate.

A rotary evaporator can in some aspects comprise a sample container, such as a sample flask, which is rotated integrally with a rotary joint. The sample flask can be soaked within a water bath, in some embodiments a heated water bath. The sample flask can be connected to one end of the rotary joint through a vapor duct that can be insertedly supported by a rotor of a motor through a sleeve. On the other side of the rotary joint there can in some embodiments be one or more condensers connected by a vapor duct to receive and thereby condense vapors evaporated from the sample flask.

In some embodiments a main body of the motor can be structured by a stator and a motor housing. As the motor is engaged, for example by supplying a current to the motor, a rotational force can be applied to the sample flask within the water bath through the rotary joint. In some embodiments the rotary joint can be insertedly supported by the sleeve in an insertion area. The sleeve can be fixed in engagement with the motor rotor. Furthermore, the sleeve can be rotatably supported by the motor main body at both ends thereof by bearings or the like. In some aspects a fastening member can be arranged within the sleeve for engaging and fastening the rotary joint (vapor duct) to the sleeve. The fastening member can comprise a fastening cap engaged with the sleeve. In some aspects the a coupling member can comprise a plurality of bushes slidably mounted on the outer peripheral surface of the rotary joint and an elastically deformable O-ring

disposed between the bushes so that the O-ring can be pressured by the fastening force through the bushes such that the O-rings can be tightly contacted to the outer peripheral surface of the rotary joint and to the inner surface of the sleeve by elastic deformation. An air tight seal can be created at the junction of the rotary joint and rotational motor.

The rotation of the motor rotor can be transmitted to the rotary joint to rotate the rotary joint and thereby rotate the sample container or sample flask. Where the sample flask is at least partially submerged within the water heated water bath the sample can be evaporated and steam or vapor generated within the sample container. This evaporate can then pass through the rotary joint (vapor duct) and to the condenser.

Once at the condenser the evaporate or vapor can come into contact with a cooled surface, such as for example a heat exchanger, to thereby cause the evaporate or vapor to cool and condense into a liquid. Once in liquid form the condensed sample drips or falls by way of gravity into a collection flask positioned below the condenser. In some aspects the condenser can comprise a joint or other conduit to connect the condenser to a collection flask. The condenser can in some embodiments also comprise a port, tube or hose configured to connect the condenser to a vacuum line, such that the sample or solvent of interest can be evaporated under vacuum. The vacuum can in some embodiments be applied near the top of the condenser to provide the maximum opportunity for the vapor to be cooled, thus minimizing the opportunity that solvent vapors will pass on to the vacuum system, such as to the vacuum pump or vacuum trap.

In some embodiments chiller **100** is configured to be used in conjunction with a vacuum oven **550** as depicted in Figure 14. Vacuum oven **550** can comprise an oven configured to receive samples in a vacuum chamber and can be attached to heat exchanger **104** by conduit **552**. Samples to be dried are placed in the oven chamber at the desired drying temperature. Vacuum is applied to the system and vapors (evaporates) from the samples in the oven are condensed by heat exchanger **104**. Vacuum ovens are used for further drying of samples to remove any residual solvents (or undesired liquids) that are left in samples. Vacuum ovens have a sample

heating chamber where samples are placed there are ports to connect tubing to a condenser and vacuum release. To prevent fumes and vapors from entering into the vacuum pump and environment, condenser (heat exchanger **104**) or chiller **100** can be connected between the vacuum oven and vacuum pump. Any vapor from the vacuum oven is condensed by chiller **100**. In some embodiments chiller **100** is configured to be used in conjunction with a vacuum oven **550** simultaneously with a vacuum pump **500** to create a vacuum within the system. For example, in some embodiments vacuum line **504** can connect a vacuum system or pump **500** from a port **502** on the pump to vacuum port **302** on housing **300.** In some embodiments vacuum system or pump **500** can be integrated within the housing of chiller **100** or can be a stand alone separate unit as depicted in Figure 14. With vacuum pump **500** a vacuum or negative pressure can be created on the inner environment of housing **300**.

In some embodiments chiller **100** is configured to be used in conjunction with a centrifugal concentrator **580** as depicted in Figure 15. Centrifugal concentrator **580** can comprise a centrifuge configured to operate under centrifugal force to separate solids from liquid phase, reducing the final volume. In some embodiments, centrifugal concentrator **580** can be used, for example, for protein extraction and purification, DNA concentration, buffer exchange, and deproteinization. By connecting centrifugal concentrator **580** to heat exchanger **104** by conduit **582** vapors (evaporates) from samples in centrifugal concentrator **580** are condensed. Centrifugal concentration is the process of concentrating samples by spinning the sample vials under vacuum and the resulting vapors (evaporates) that are pulled by the vacuum pump are condensed (vapors turned into liquid) by a condenser (heat exchanger **104**). In some embodiments this prevents the evaporates from entering the vacuum pump and/or the environment.

In some embodiments chiller **100** is configured to be used in conjunction with a centrifugal concentrator **580** simultaneously with a vacuum pump **500** to create a vacuum within the system. For example, in some embodiments vacuum line **504** can connect a vacuum system or pump **500** from a port **502** on the pump to vacuum port **302** on housing **300.** In

some embodiments vacuum system or pump **500** can be integrated within the housing of chiller **100** or can be a stand alone separate unit as depicted in Figure 14. With vacuum pump **500** a vacuum or negative pressure can be created on the inner environment of housing **300**.

In some embodiments chiller **100** can help protect the accessory vacuum pump from the corrosive effects of vapors and fumes as they evaporate from the samples. Chiller **100** can provide protection from low freezing point solvents. In some embodiments the term "cold trap" is used to describe condensation of vapors and fumes evaporating from samples under centrifugal force.

Likewise, in some embodiments chiller **100** and related components disclosed herein can be with gel dryers, DNA sample concentration, and/or acid sample concentrations (heat exchanger **104** is resistant to acids). Similar to the other embodiments disclosed herein, chiller **104** can provide to these applications a cooling capacity to cool reactions and/or condense evaporates (vapors). Given the universal and stand alone nature of the disclosed chiller **100** it is configured to be used with a plurality of laboratory components and/or systems requiring a cooling effect and/or condenser capacity.

In some embodiments the chillers, cooling devices and related apparatuses provided herein can be used in methods of cooling materials, liquids, vapors, evaporates and other mediums. By way of example and not limitation, methods are provided for condensing an evaporate, such as from a rotary evaporator, including providing a chiller, providing a rotary evaporator, evaporating a sample via the rotatory evaporator, and condensing the evaporate using a chiller and/or cooling system/apparatus as disclosed herein. As another example, a tankless chiller as provided herein can be used in a method of cooling a sample or reaction, including providing a tankless chiller, providing a separate water bath of a desired size and configuration suitable for the reaction cooling, and aligning the chiller (with external heat exchanger) and water bath such that the water bath is cooled by the chiller to thereby cool the sample/reaction. Similar methods using the disclosed cooling systems and accompanying laboratory/research

equipment, as would be appreciated and understood by one of ordinary skill in the art, are provided herein.

While the following terms are believed to be well understood by one of ordinary skill in the art, the following definitions are set forth to facilitate explanation of the presently disclosed subject matter.

Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood to one of ordinary skill in the art to which the presently disclosed subject matter belongs. Although any methods, devices, and materials similar or equivalent to those described herein can be used in the practice or testing of the presently disclosed subject matter, representative methods, devices, and materials are now described.

Following long-standing patent law convention, the terms “a”, “an”, and “the” refer to “one or more” when used in this application, including the claims. Thus, for example, reference to "a cell" includes a plurality of such cells, and so forth.

Unless otherwise indicated, all numbers expressing quantities of ingredients, reaction conditions, and so forth used in the specification and claims are to be understood as being modified in all instances by the term “about”. Accordingly, unless indicated to the contrary, the numerical parameters set forth in this specification and attached claims are approximations that can vary depending upon the desired properties sought to be obtained by the presently disclosed subject matter.

As used herein, the term “about,” when referring to a value or to an amount of a composition, dose, sequence identity (*e.g.*, when comparing two or more nucleotide or amino acid sequences), mass, weight, temperature, time, volume, concentration, percentage, *etc.*, is meant to encompass variations of in some embodiments ±20%, in some embodiments ±10%, in some embodiments ±5%, in some embodiments ±1%, in some embodiments ±0.5%, and in some embodiments ±0.1% from the specified amount, as such variations are appropriate to perform the disclosed methods or employ the disclosed compositions.

The term “comprising”, which is synonymous with “including” “containing” or “characterized by” is inclusive or open-ended and does not exclude additional, unrecited elements or method steps. “Comprising” is a term of art used in claim language which means that the named elements are essential, but other elements can be added and still form a construct within the scope of the claim.

As used herein, the phrase “consisting of” excludes any element, step, or ingredient not specified in the claim. When the phrase “consists of” appears in a clause of the body of a claim, rather than immediately following the preamble, it limits only the element set forth in that clause; other elements are not excluded from the claim as a whole.

As used herein, the phrase “consisting essentially of” limits the scope of a claim to the specified materials or steps, plus those that do not materially affect the basic and novel characteristic(s) of the claimed subject matter.

With respect to the terms “comprising”, “consisting of”, and “consisting essentially of”, where one of these three terms is used herein, the presently disclosed and claimed subject matter can include the use of either of the other two terms.

As used herein, the term “and/or” when used in the context of a listing of entities, refers to the entities being present singly or in combination. Thus, for example, the phrase “A, B, C, and/or D” includes A, B, C, and D individually, but also includes any and all combinations and subcombinations of A, B, C, and D.

It will be understood that various details of the presently disclosed subject matter may be changed without departing from the scope of the presently disclosed subject matter. Furthermore, the foregoing description is for the purpose of illustration only, and not for the purpose of limitation.

CLAIMS

What is claimed is:

1. A chiller apparatus configured to cool a liquid, vapor or other medium, comprising:

a condenser;

a compressor;

a temperature controller; and

a heat exchanger,

wherein the condenser, compressor and temperature controller are contained inside a housing, wherein the heat exchanger is external to the housing, wherein the heat exchanger is configured to be exposed to a liquid, vapor or other medium in a vessel, and from which heat is to be removed by the heat exchanger,

wherein the condenser, compressor, temperature controller and heat exchanger are integrated into a single stand alone chiller apparatus, and wherein the chiller is configured to be universally used with any vessel containing liquids, vapors or other medium to be cooled.

2. The chiller of claim 1, wherein the heat exchanger is positioned outside of the housing but affixed to the housing and configured to be submerged or placed in the vessel.

3. The chiller of claim 1, further comprising a pump configured to be attachable to a vessel containing the liquids, vapors or other medium to be cooled, wherein the pump is configured to circulate the liquids, vapors or other medium in the vessel.

4. The chiller of claim 1, further comprising a vacuum pump and controller.

5. The chiller of claim 1, wherein the heat exchanger, condenser and compressor further comprise a refrigerant, and wherein the heat exchanger,

condenser and compressor are in fluid communication with one another and configured to circulate the refrigerant.

6. The chiller of claim 1, wherein the heat exchanger is configured as a condenser for use with a rotary evaporator.

7. The chiller of claim 1, wherein the heat exchanger is configured to be placed in a vessel comprising a circulating water bath or reaction bath.

8. The chiller of claim 1, further comprising a pump outside the chiller housing, wherein the pump is equipped with a detachable reservoir, wherein the pump is configured as a support structure for the reservoir, and wherein the heat exchanger is configured to be placed in the reservoir.

9. The chiller of claim 1, further comprising a double-walled vessel surrounding the heat exchanger.

10. The chiller of claim 1, wherein the heat exchanger comprises an evaporator coil.

11. The chiller of claim 10, wherein the evaporator coil comprises a titanium alloy.

12. The chiller of claim 10, wherein the evaporator coil comprises stainless steel.

13. The chiller of claim 10, wherein the evaporator coil comprises a copper pipe.

14. The chiller of claim 1, comprising a plurality of heat exchangers external to the housing and affixed to the housing.

15. The chiller of claim 1, wherein the chiller is tankless and is configured with a heat exchanger configured for contact and cool a liquid, vapor or other medium in a vessel detached from the chiller.

16. The chiller of claim 15, wherein the vessel comprises an enclosed tank, open container, sealed vessel, double-walled vessel, conduit, and/or water bath.

17. The chiller of claim 16, wherein the vessel comprises any size, volume and/or configuration so long as the liquid, vapor or other medium to be cooled comes into contact with the heat exchanger.

18. The chiller of claim 1, further comprising a rotary evaporator, wherein the chiller is configured to condense an evaporate from the rotary evaporator.

19. The chiller of claim 1, further comprising a vacuum oven, wherein the chiller is configured to attach to and cool the vacuum oven.

20. The chiller of claim 1, further comprising a centrifugal concentrator, wherein the chiller is configured to attach to and cool the centrifugal concentrator.

21. The chiller of claim 1, further comprising a freeze dryer, wherein the chiller is configured to attach to and cool the freeze dryer.

22. The chiller of claim 1, wherein the heat exchanger comprises a coolant coil and a chemical-resistant sleeve surrounding the coolant coil, wherein the coolant coil is configured to circulate a coolant from a refrigeration system to thereby cool a surface of the chemical-resistant sleeve.

23. The chiller of claim 22, wherein the chemical-resistant sleeve comprises a substantially cylindrical sleeve having an opening at a first end to receive the coolant coil.

24. The chiller of claim 23, wherein the chemical-resistant sleeve comprises an inner cavity extending from a second end, wherein the inner cavity is configured to extend inside the coolant coil when the coolant coil resides in the substantially cylindrical sleeve.

25. The chiller of claim 22, wherein the chemical-resistant sleeve comprises one or more structures extending from a surface of the chemical-resistant sleeve to increase a cooling surface area of the heat exchanger.

26. A chiller system comprising a chiller apparatus configured to cool a liquid and a separate reservoir, the chiller apparatus comprising:

a condenser;

a compressor;

a temperature controller; and

a heat exchanger,

wherein the condenser, compressor and temperature controller are contained inside a housing, wherein the heat exchanger is external to the housing, wherein the heat exchanger is configured to be exposed to a liquid from which heat is to be removed by the heat exchanger, and

the separate reservoir comprising a vessel configured to contain a liquid, wherein the reservoir is configured to place the liquid in contact with the heat exchanger, wherein the reservoir is separate from the chiller apparatus, and

wherein the chiller apparatus is configured to be universally used with a separate reservoir of any size, volume or configuration provided that the separate reservoir positions the liquid to be in contact with the heat exchanger.

27. The chiller system of claim 26, further comprising a plurality of separate reservoirs, wherein the plurality of separate reservoirs vary in size and/or liquid capacity but are configured to position the liquid in contact with the heat exchanger.

28. The chiller system of claim 26, wherein the reservoir further comprises a pump configured to circulate the liquid.

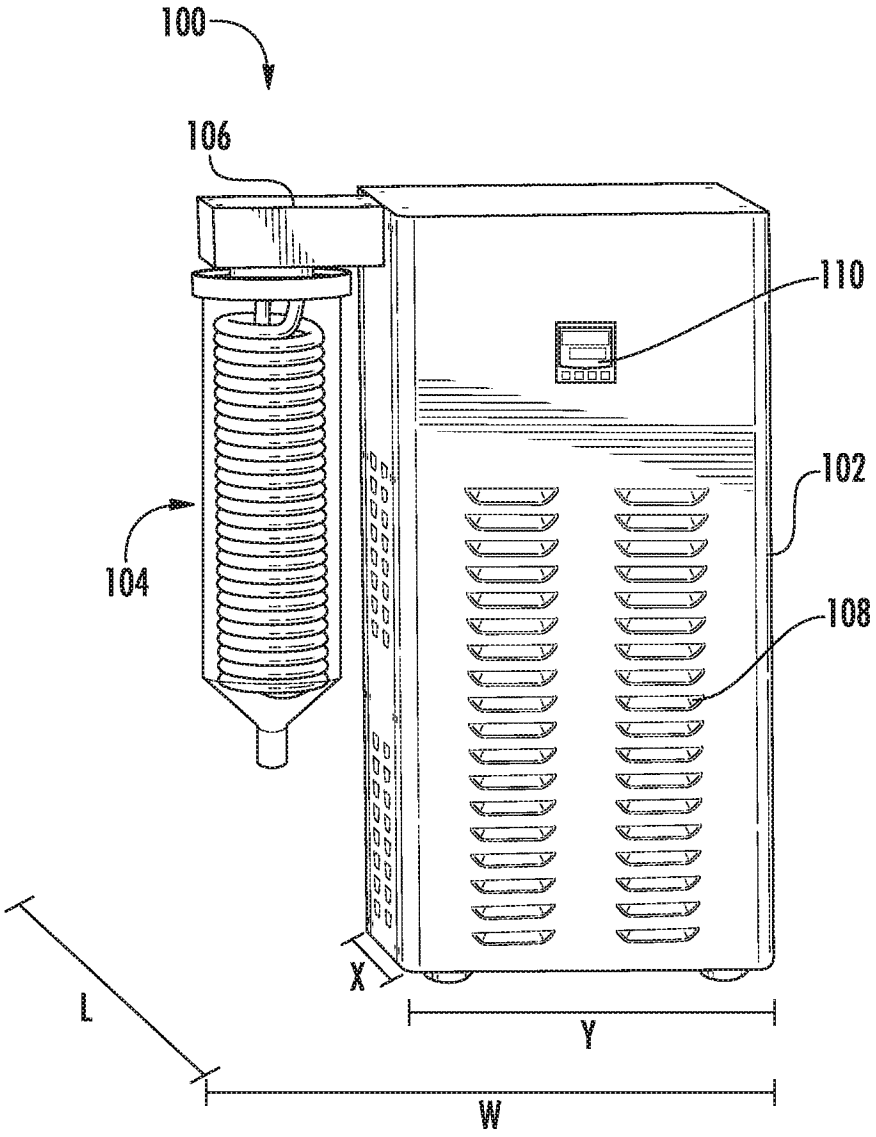


FIG. 1

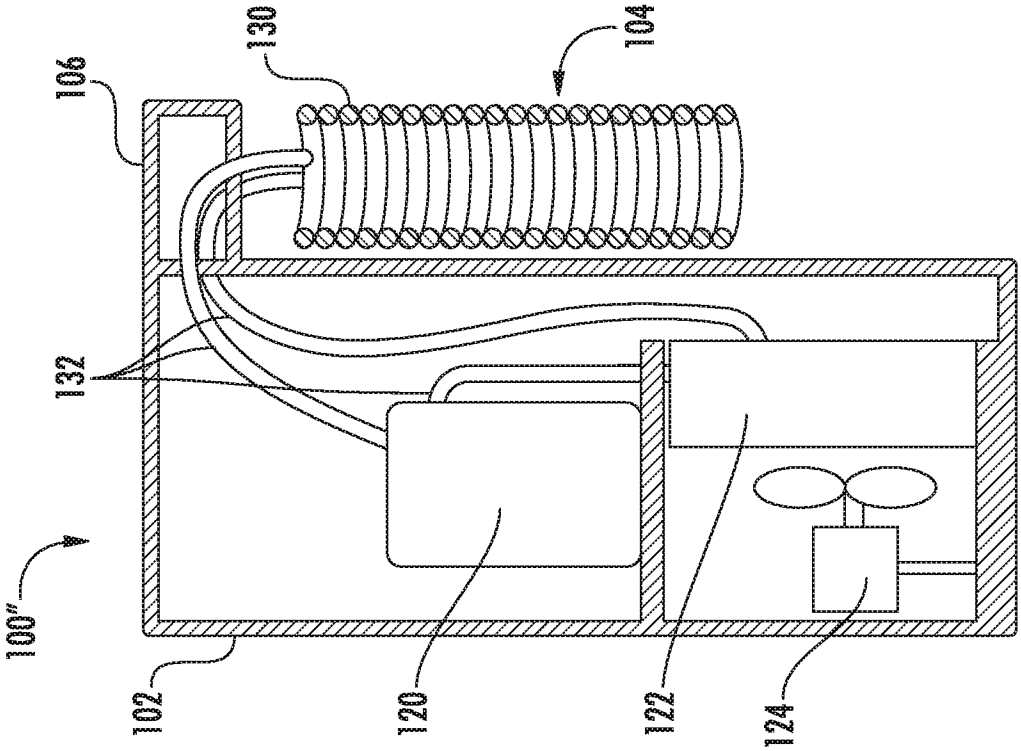

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FIG. 2B

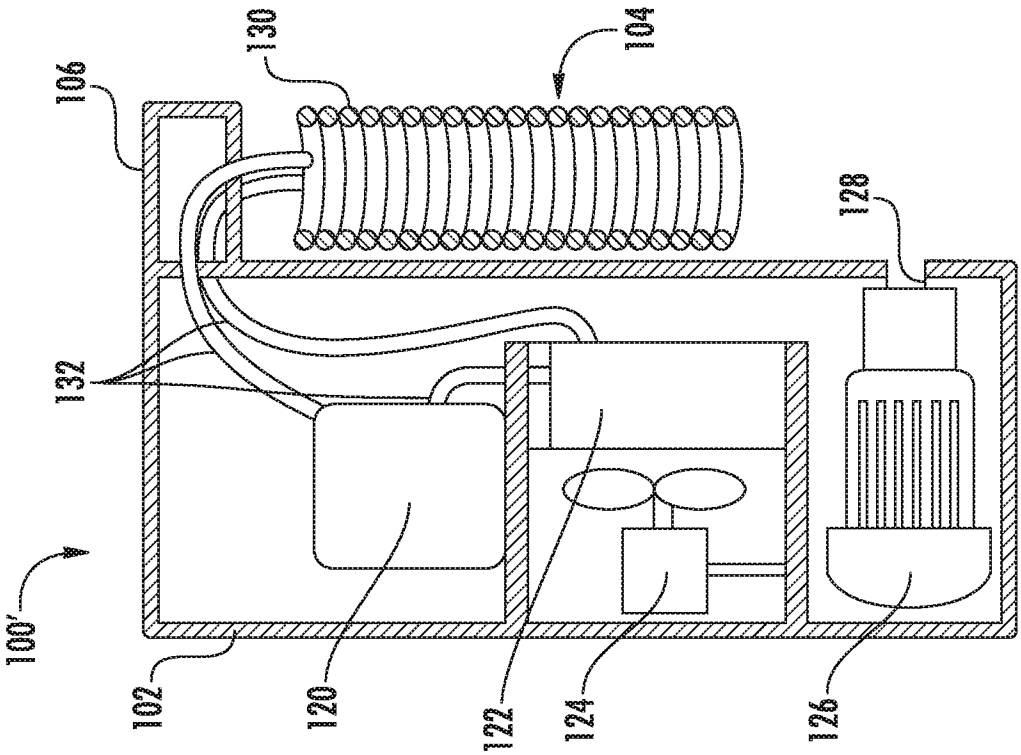

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FIG. 2A

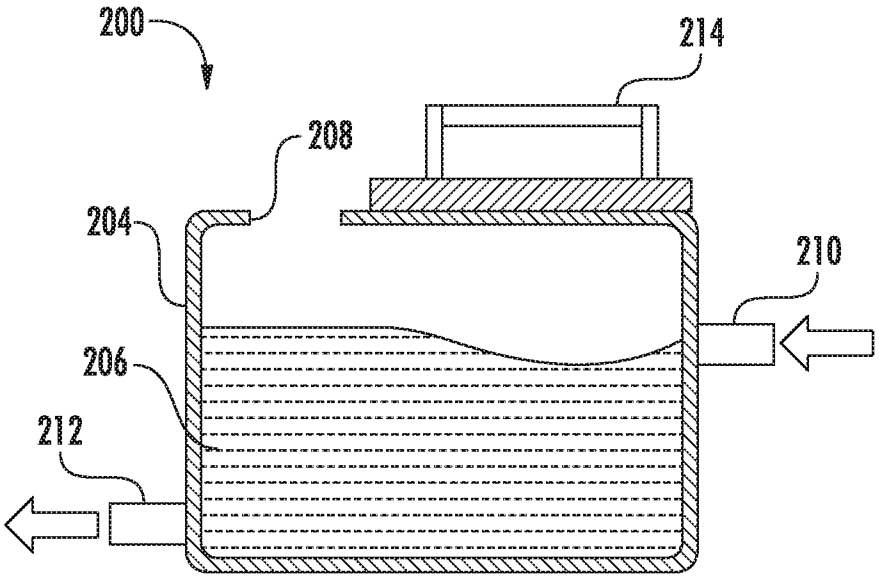


FIG. 3A

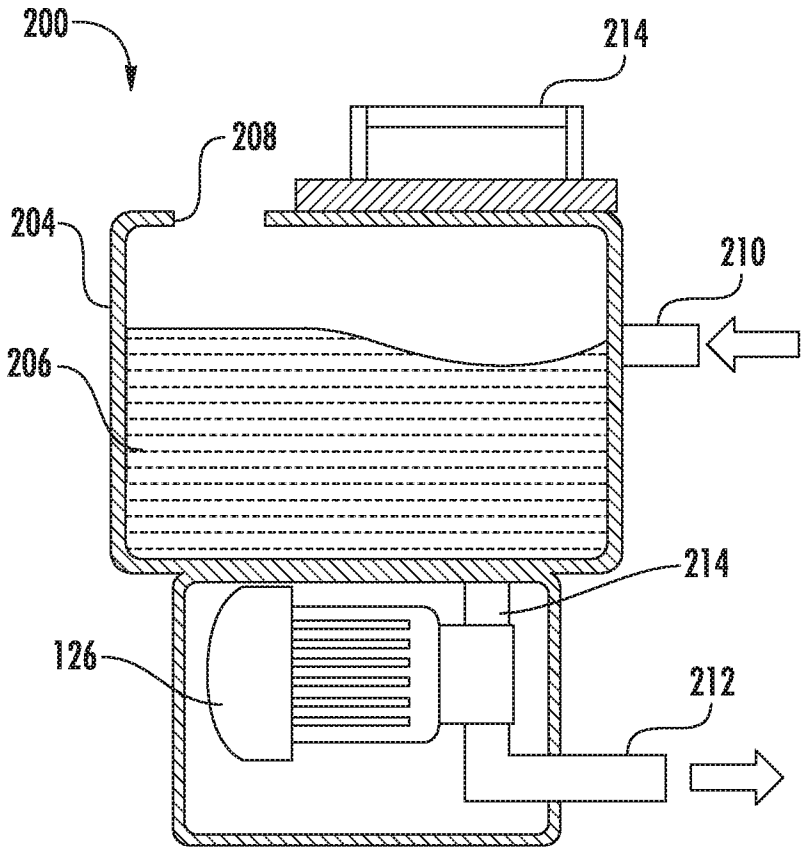


FIG. 3B

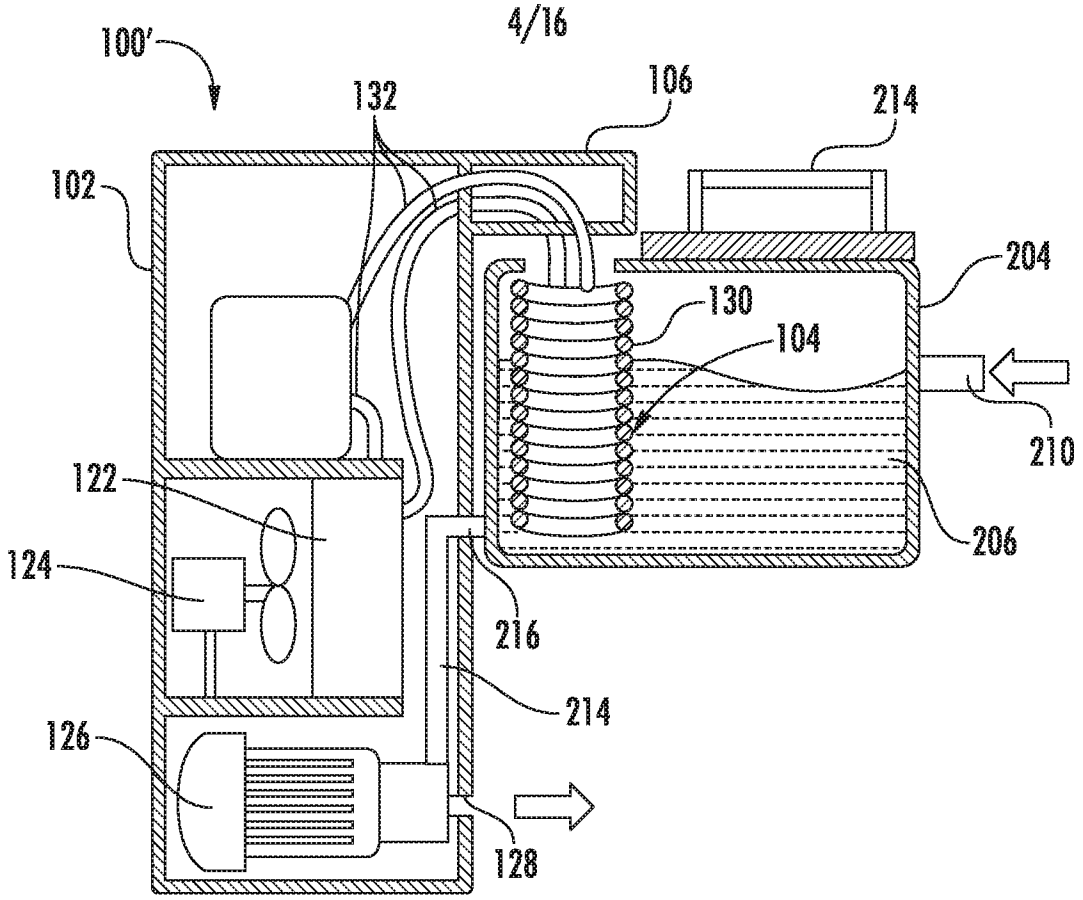

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FIG. 4A

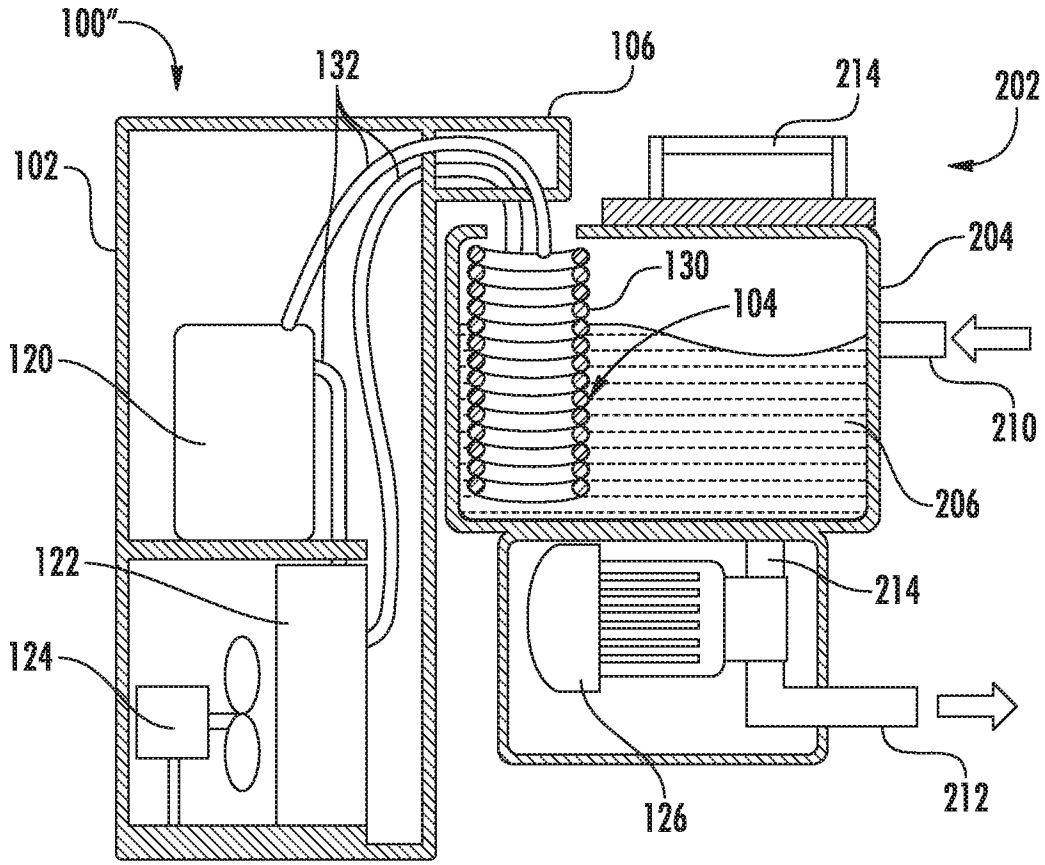

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FIG. 4B

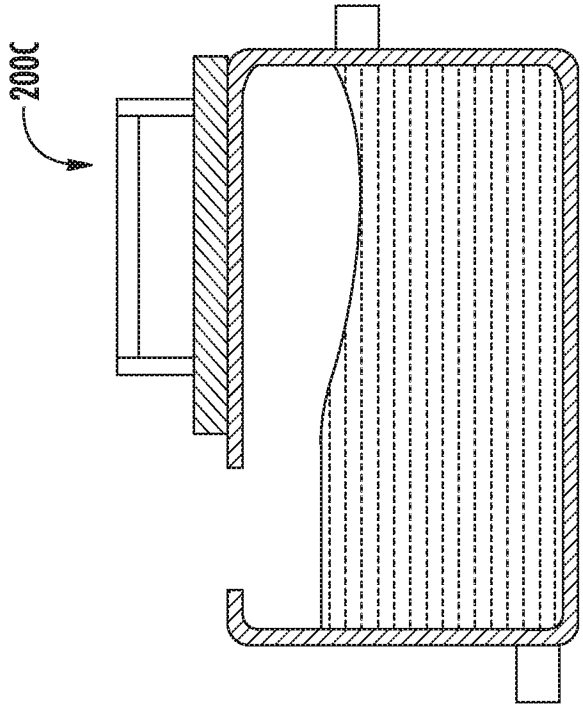


FIG. 5C

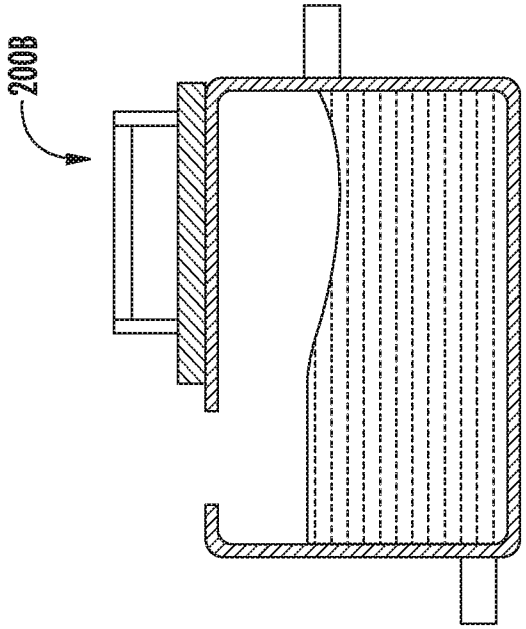


FIG. 5B

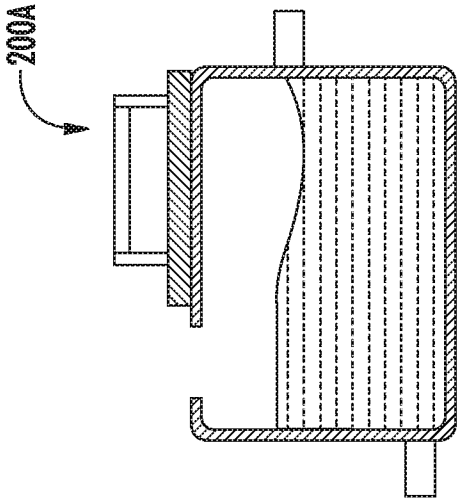


FIG. 5A

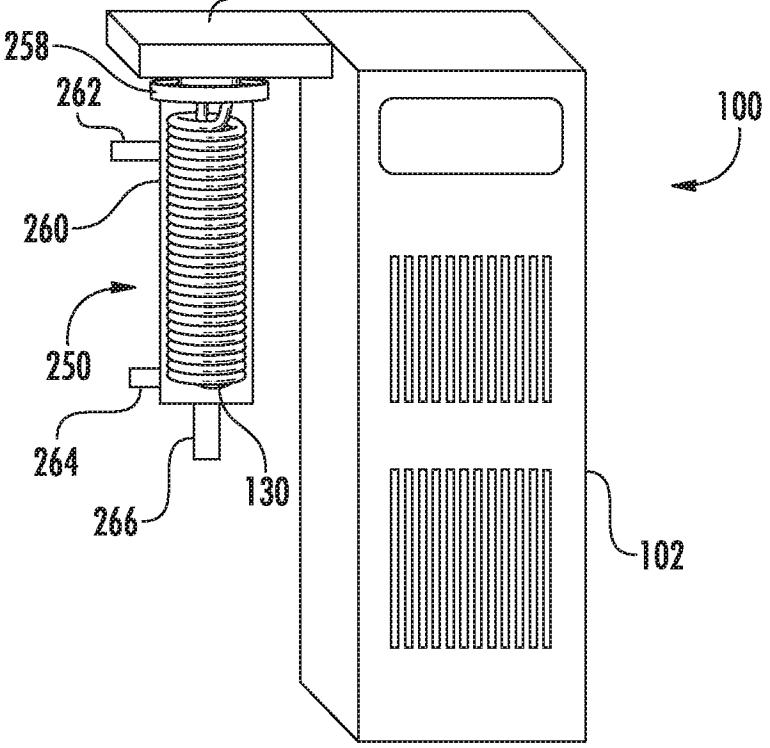

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FIG. 6A

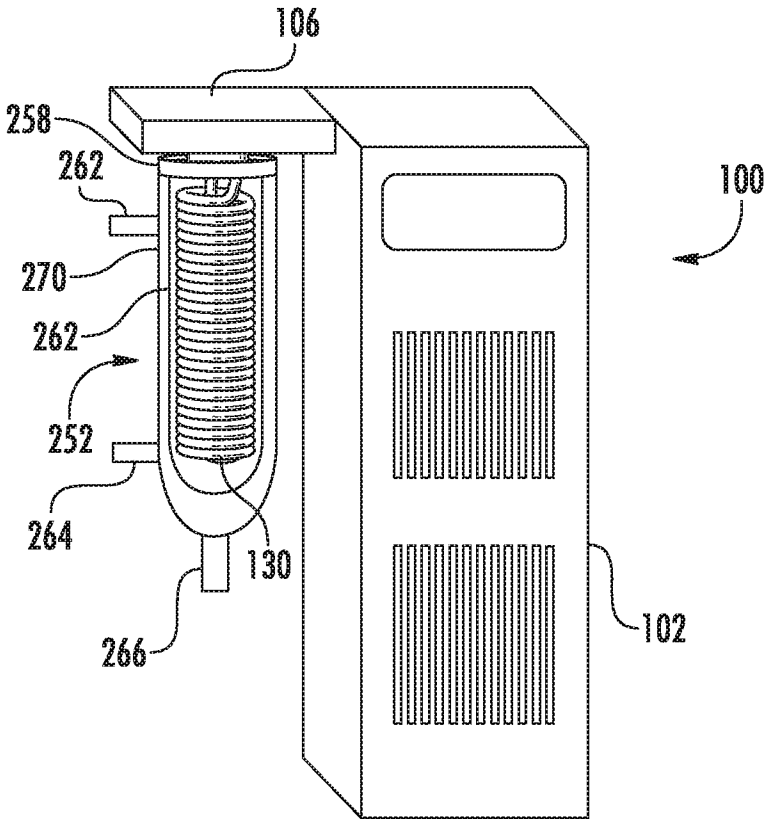

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FIG. 6B

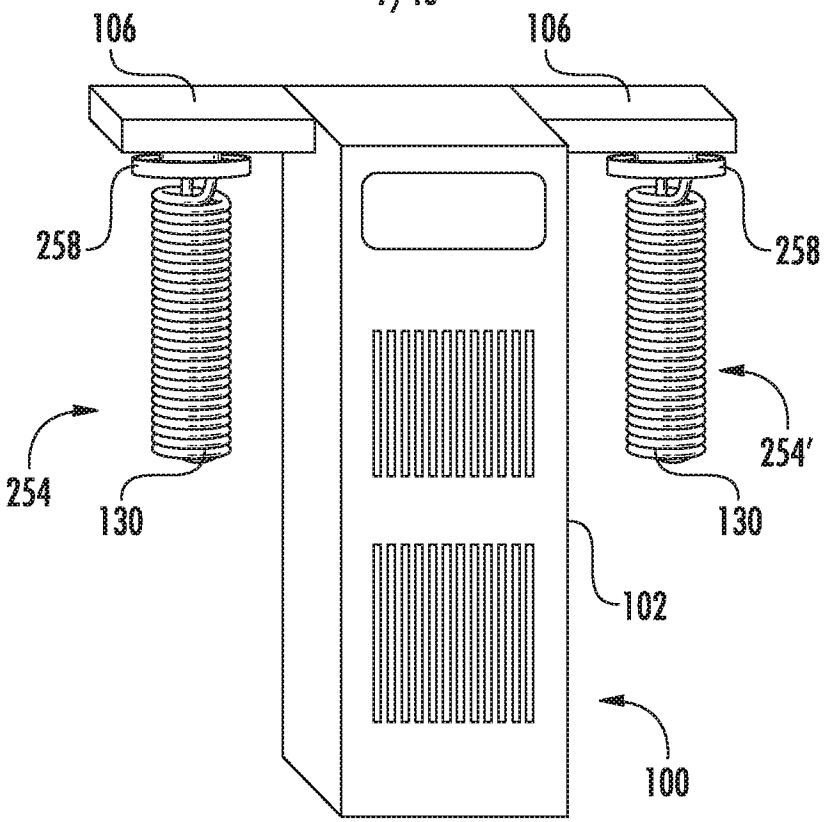

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FIG. 6C

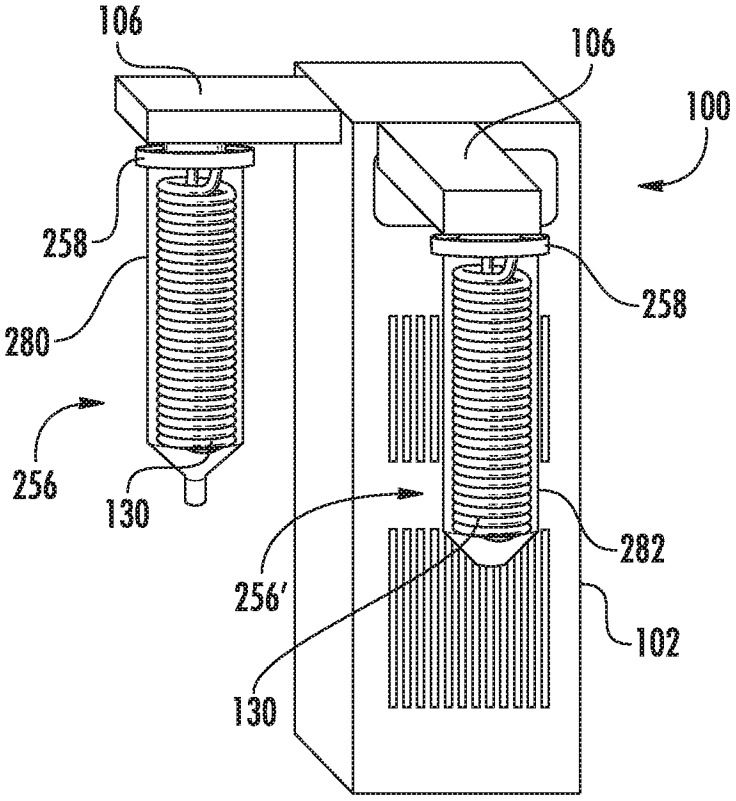

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FIG. 6D

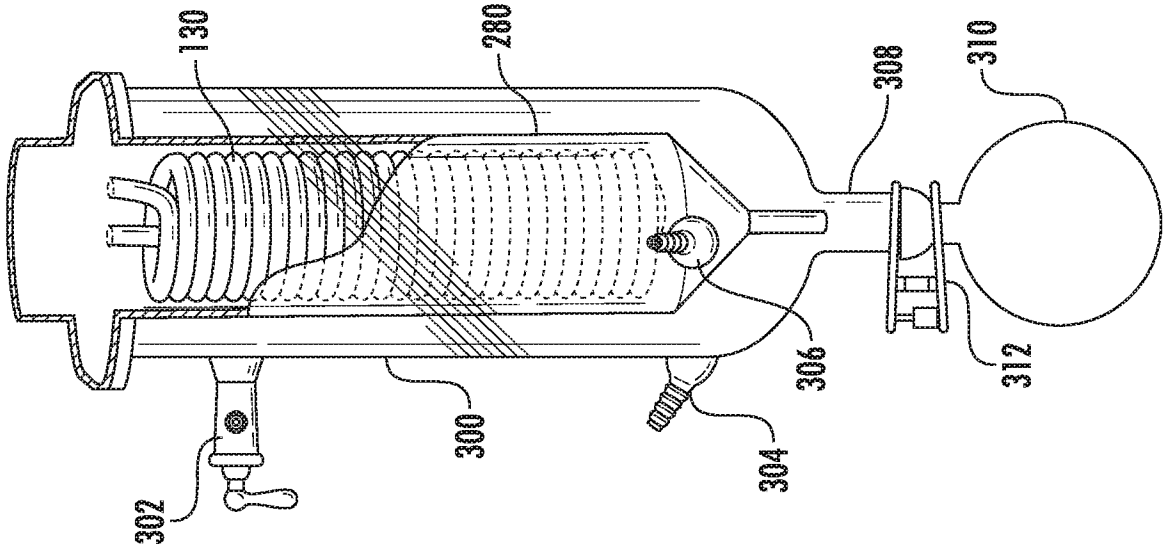


FIG. 7D

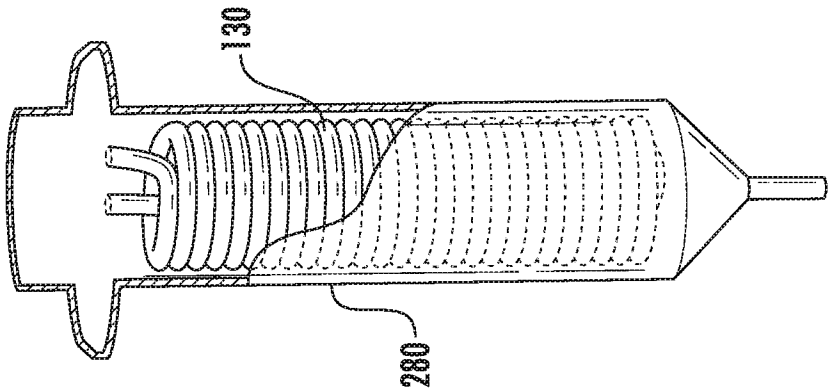


FIG. 7C

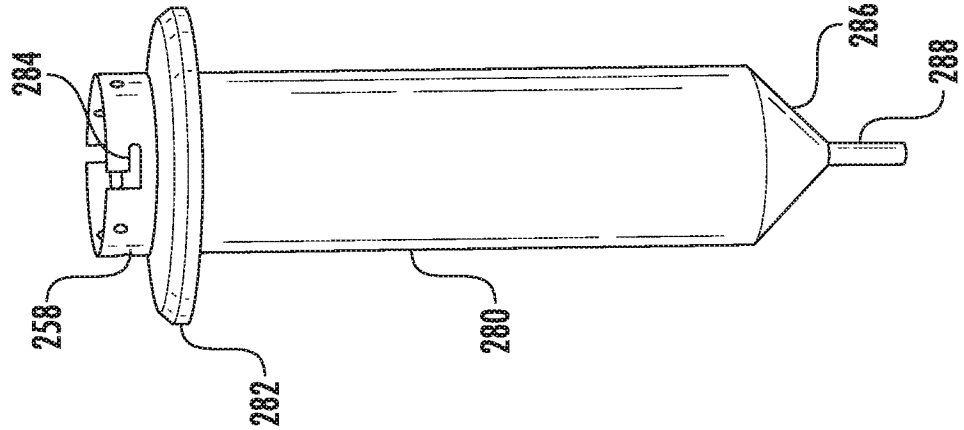


FIG. 7B

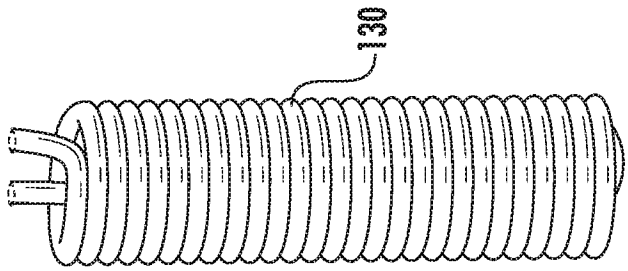


FIG. 7A

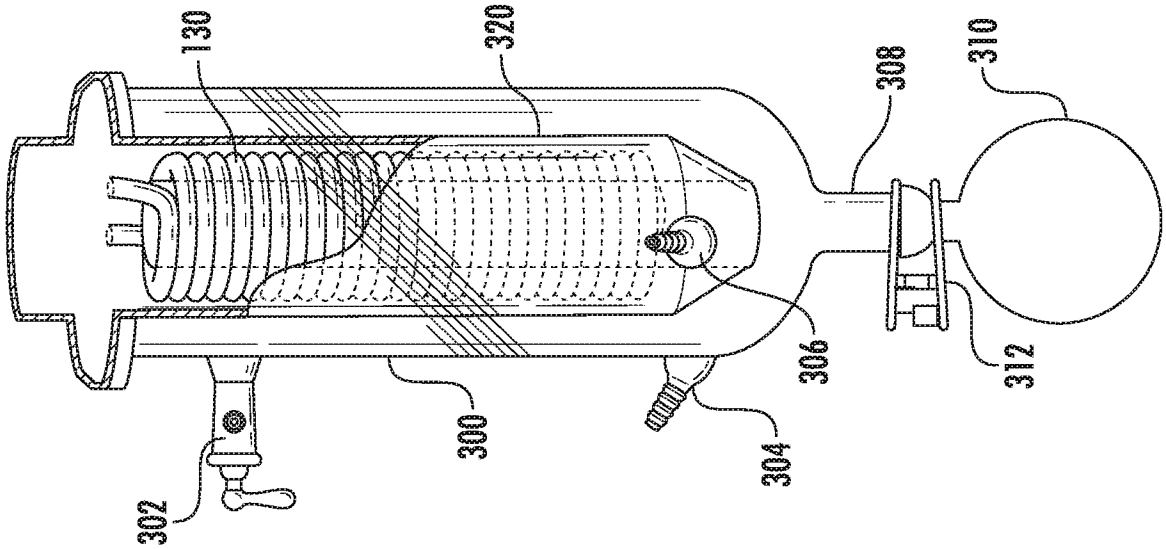


FIG. 8D

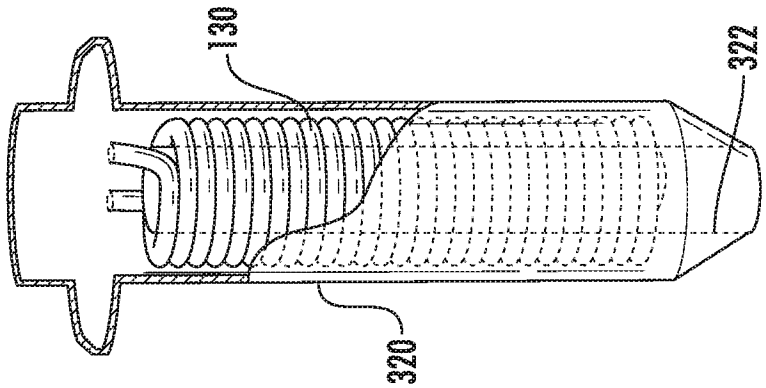


FIG. 8C

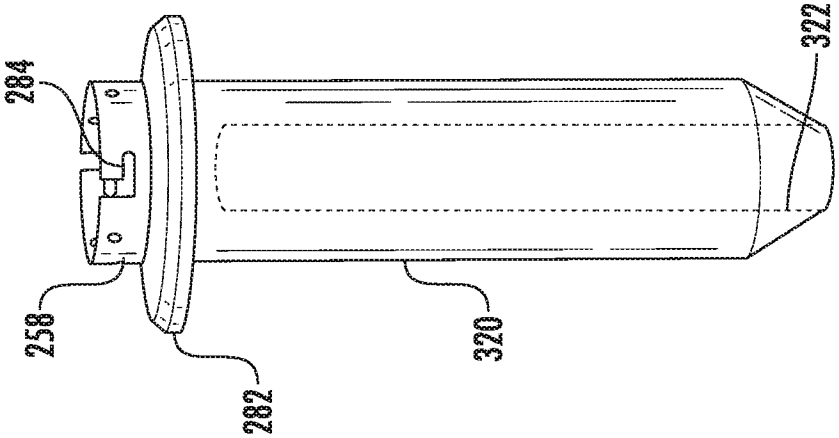


FIG. 8B

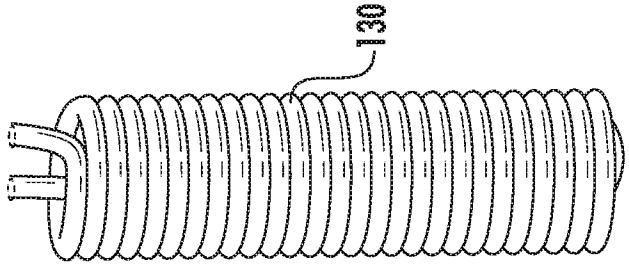


FIG. 8A

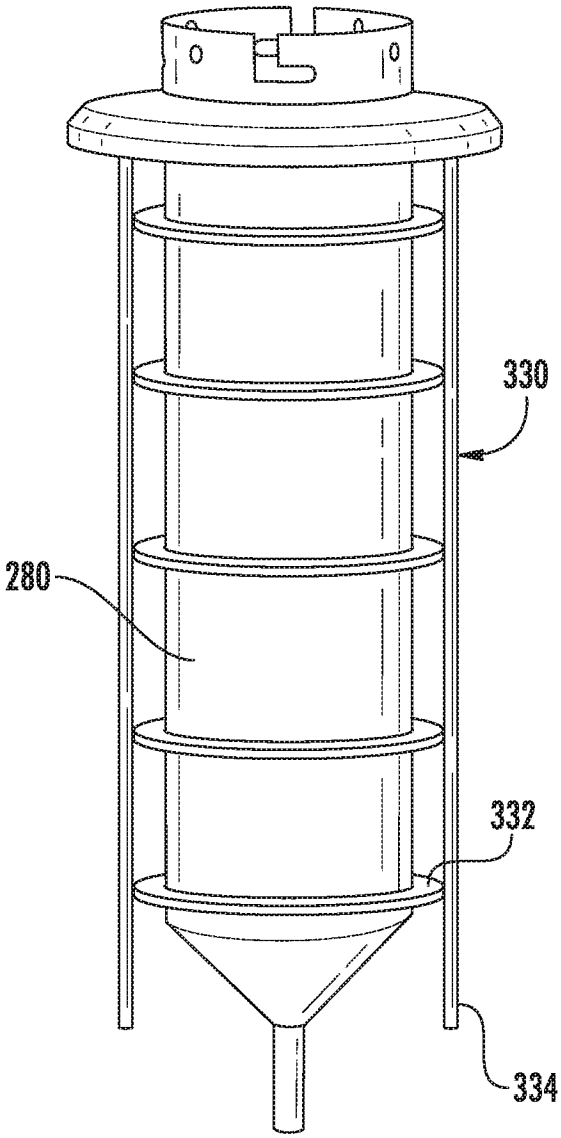


FIG. 9

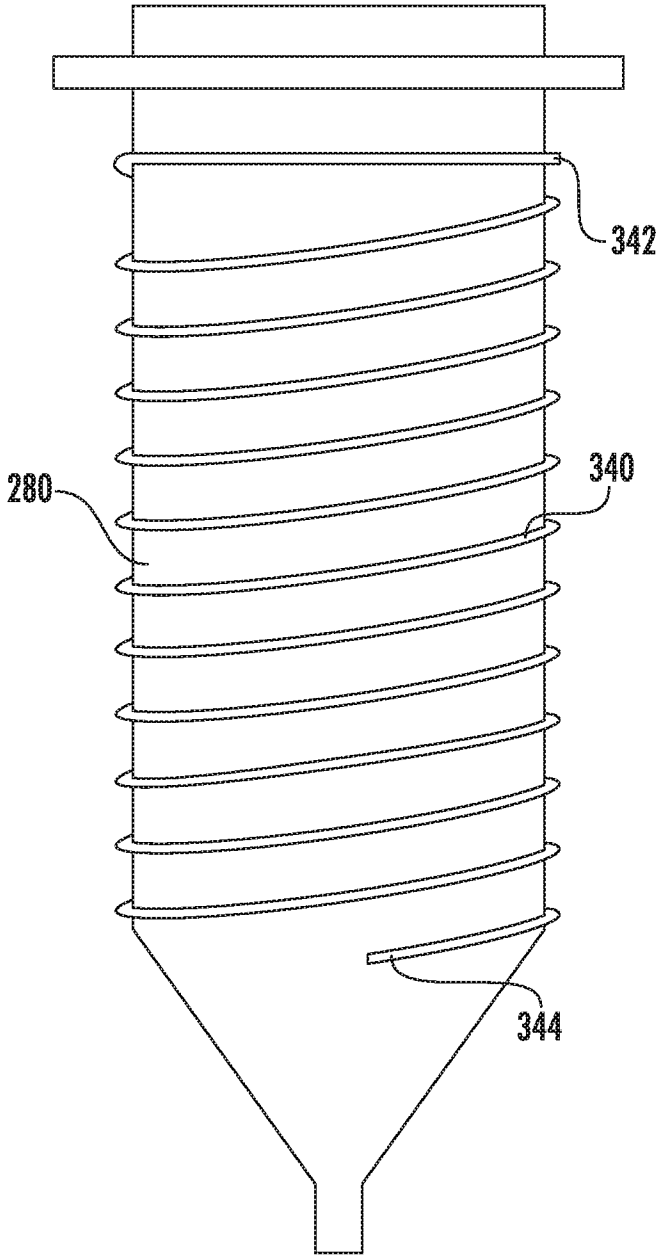


FIG. 10

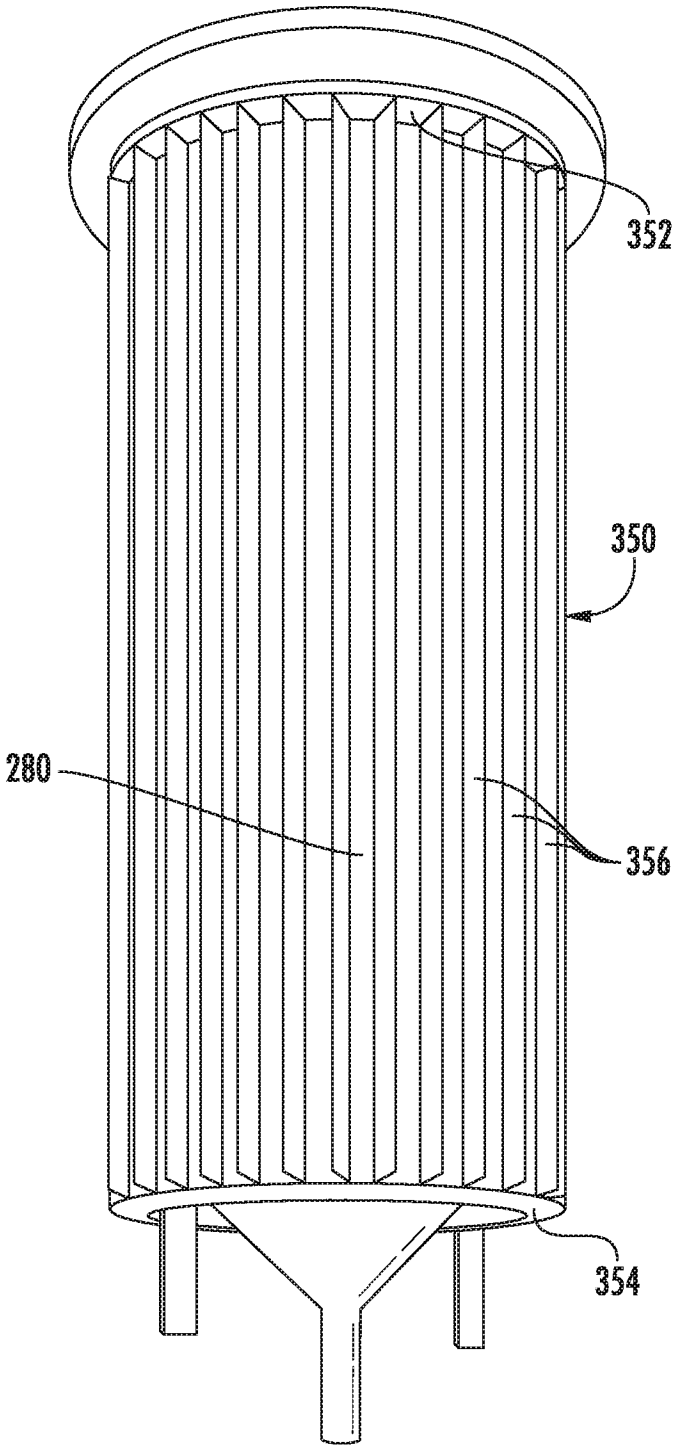


FIG. 11

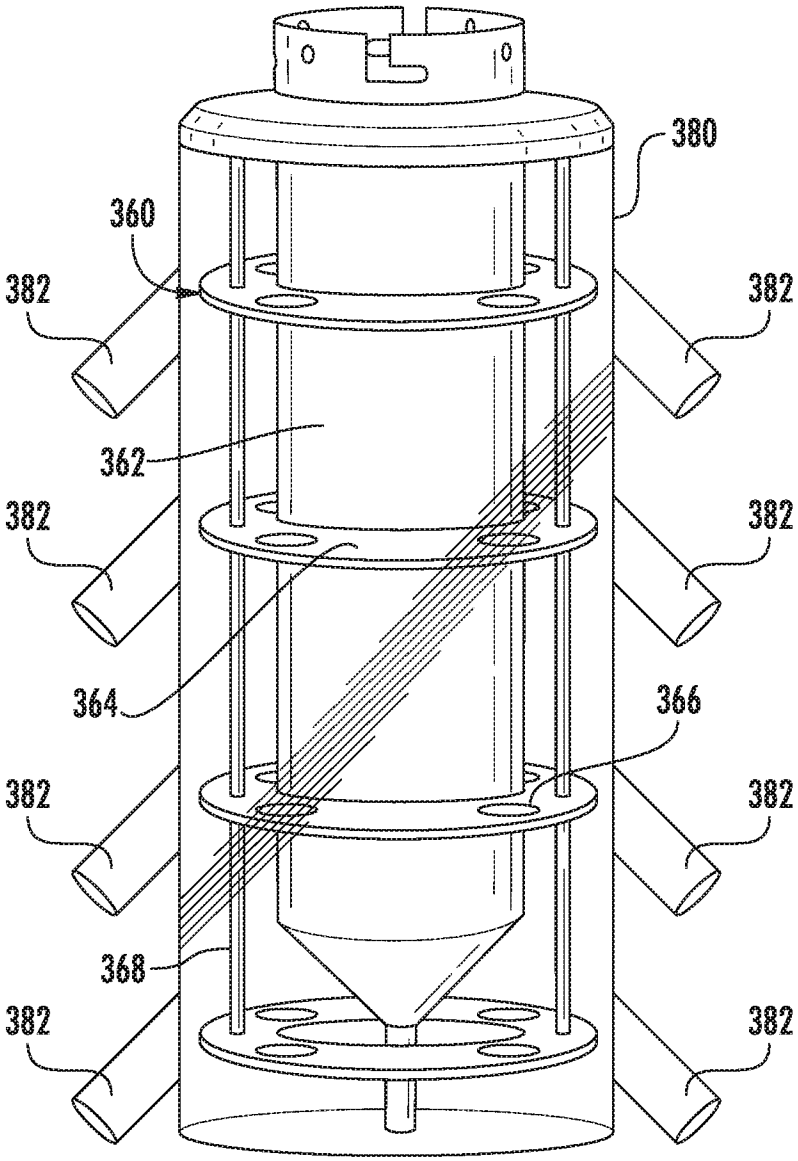


FIG. 12

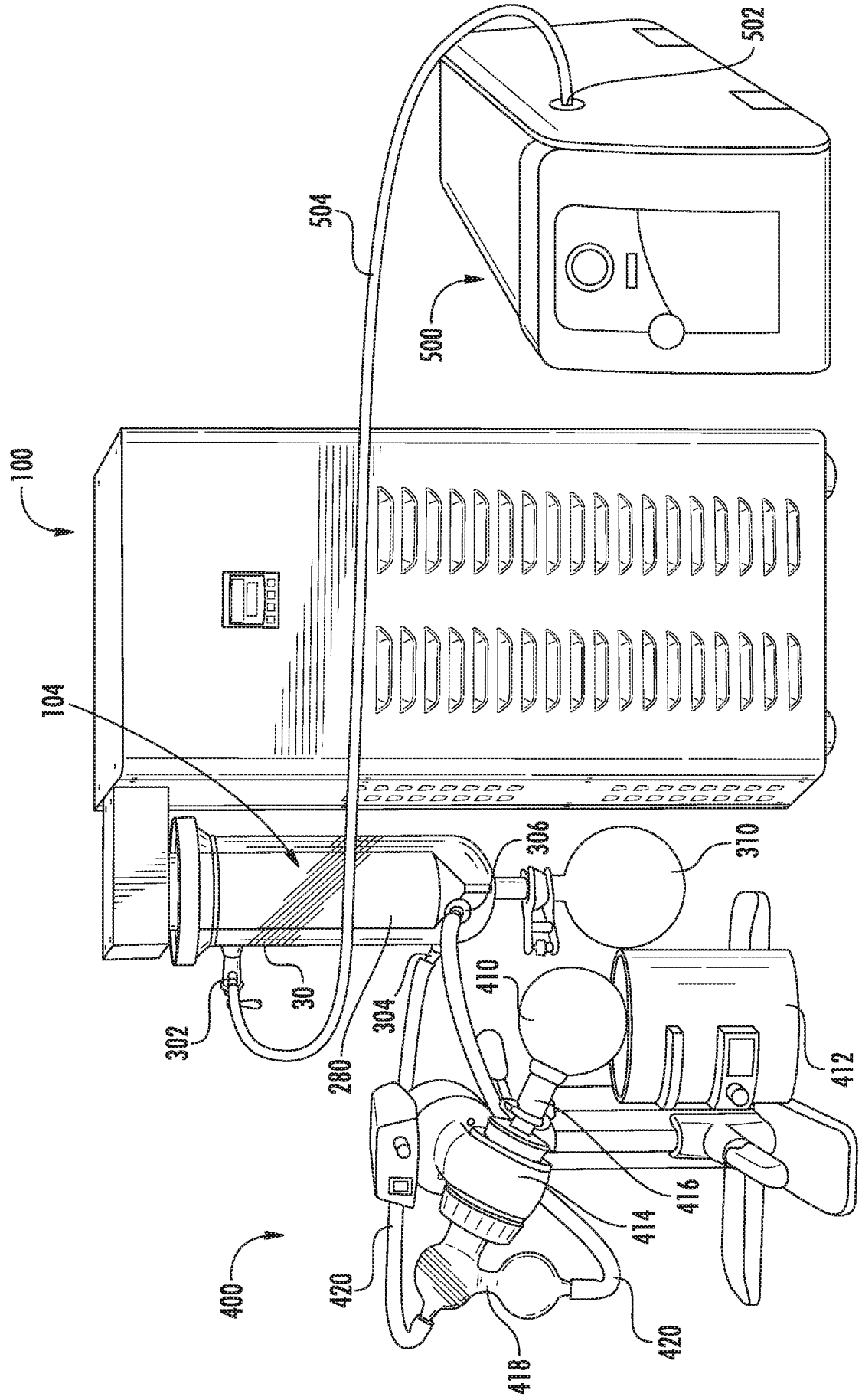

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FIG. 13

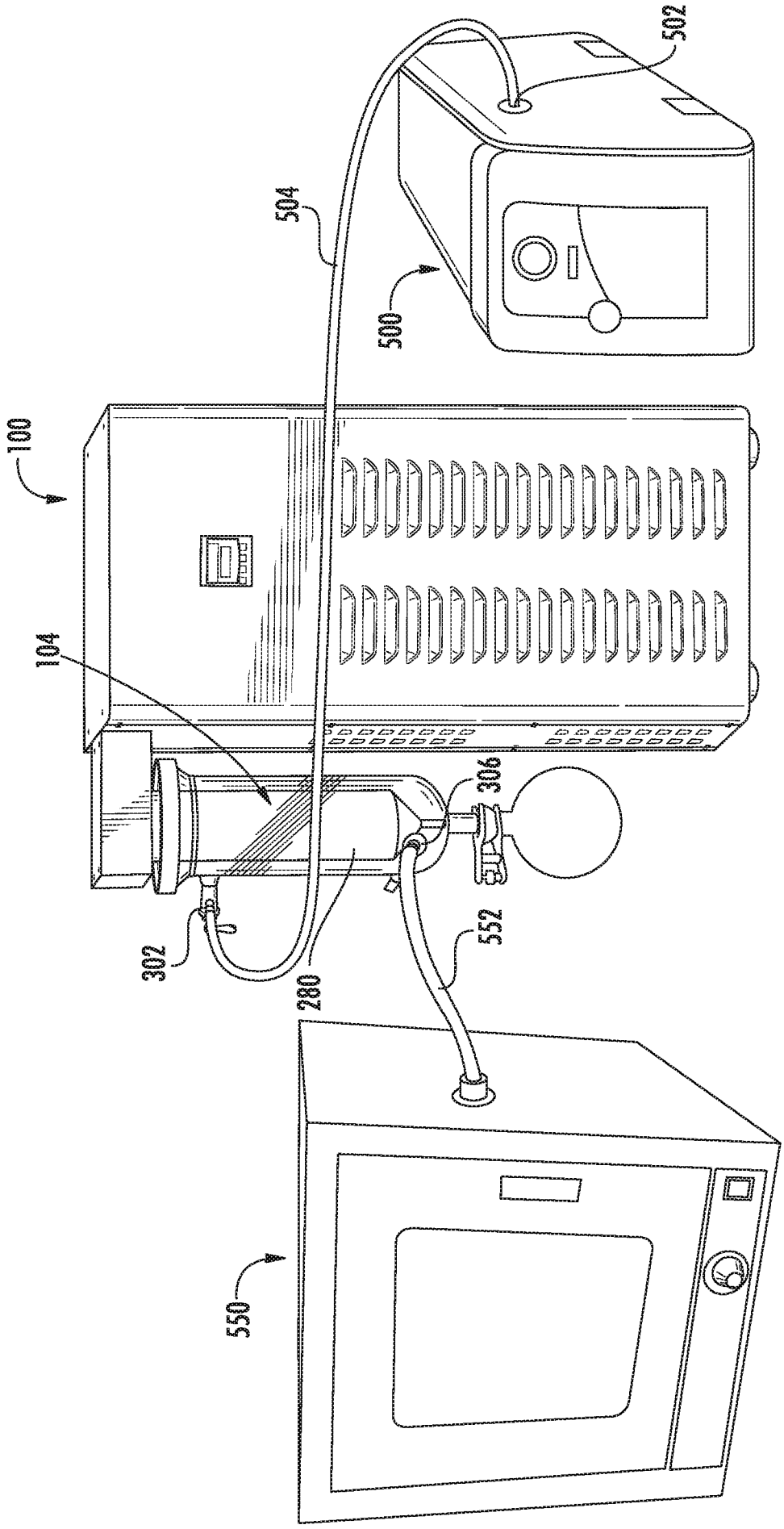


FIG. 14

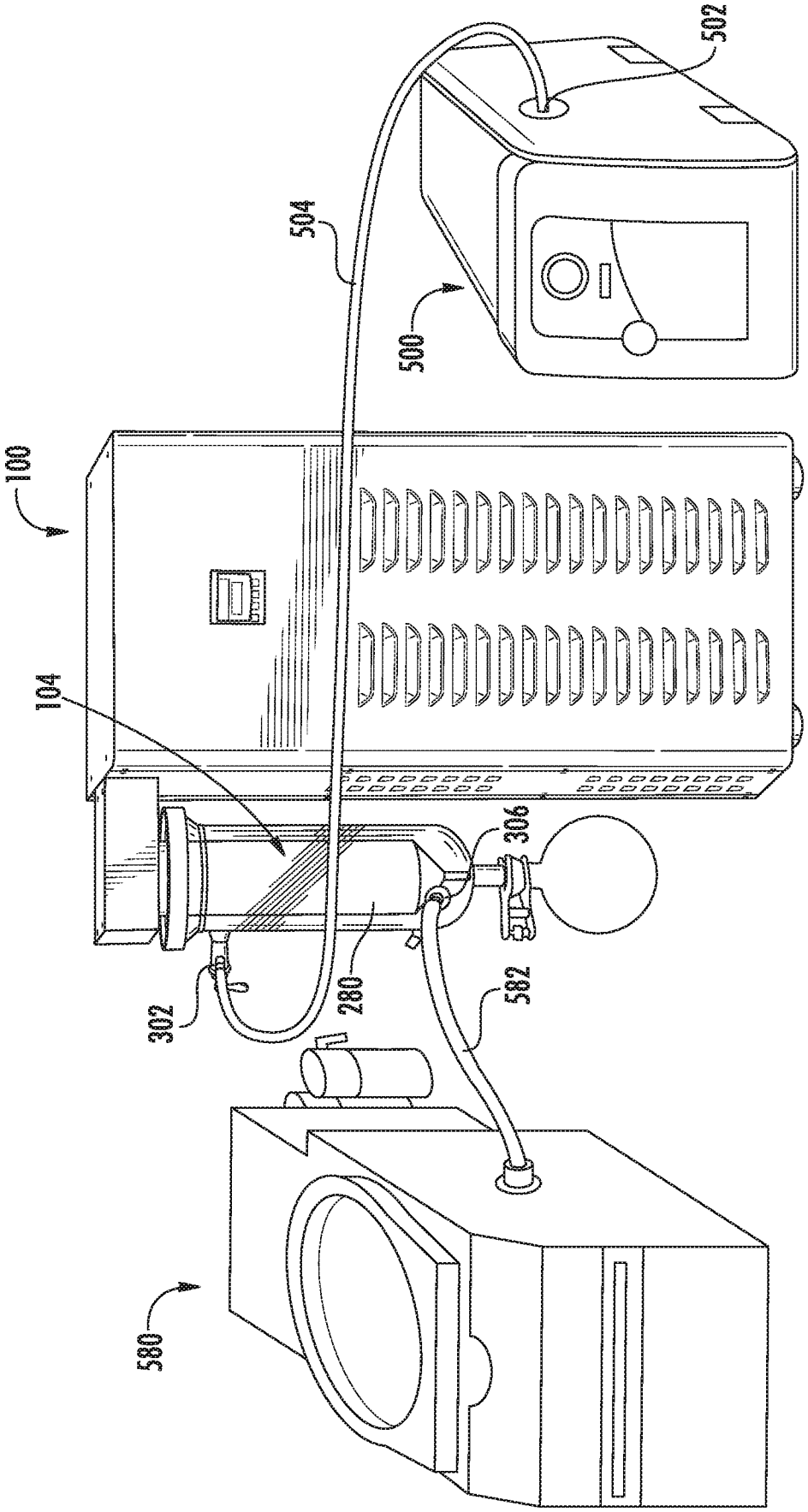


FIG. 15

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US16/36886

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - B01D 5/00; F25B 40/00 (2016.01)
CPC - B01D 5/0003; F25B 40/00
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC(8) - B01D 5/00; F25B 21/02, 40/00, 41/00; F28B 9/00; F28F 17/00 (2016.01)
CPC - B01D 5/0003, 5/0075; F25B 40/00

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PatSeer, EBSCO, Google Scholar, Science Direct
search terms: chiller, cooler, refrigerating, condenser, moisture, compressor, temperature, controller, processor, heat exchanger, heat sink, housing, enclosure, immersion, exterior, external, stand-alone, self-contained, portable

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 3 726 669 A1 (NOLTE) 23 February 1989 (23.02.1989), see machine translation, paragraphs [0005] - [0013]	1, 3-6, 10-18
X -- Y	US 2,566,865 A (WINGERTER) 04 September 1951 (04.09.1951), column 1, line 13 - column 3, line 73.	1, 2, 7, 9, 26-28 --- 19-21
Y	US 7,713,421 B2 (GALBRAITH) 11 May 2010 (11.05.2010), column 29, lines 15-23; column 35, lines 14-30	19-21
A	US 5,584,187 A (WHALEY) 17 December 1996 (17.12.1996), entire document	8
A	US 2,128,784 A (TULL et al) 18 December 1936 (18.12.1936), entire document	8
A	WO 2005/113100 A1 (PASSONI) 1 December 2005 (01.12.2005), entire document	22
A	DE 4 231 458 A1 (HEIJDEN) 24 March 1994 (24.03.1994) see machine translation	1-28
A	US 5,937,662 A (SCHULAK et al) 17 August 1999 (17.08.1999) entire document	1-28
A	US 2011/0073459 A1 (ADJABENG) 31 March 2011 (31.03.2011) entire document	1-28
P, X	WO 2016/086101 A1 (ECODYST, INC) 2 June 2016 (02.06.2016) entire document	1-28

☐ 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	Date of mailing of the international search report
13 August 2016 (13.08.2016)	07 SEP 2016
Name and mailing address of the ISA/ Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Authorized officer Shane Thomas PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/210 (second sheet) (January 2015)