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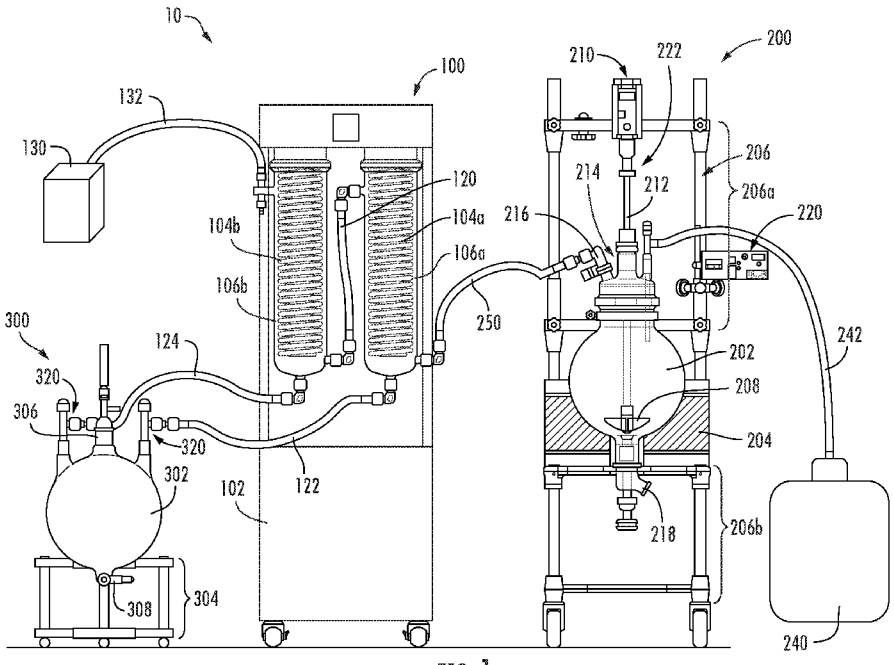


FIG. 1

(57) Abstract: Integrated rotary evaporator apparatuses are provided. Such rotary evaporators include a vertically oriented evaporator for evaporating a sample to form a sample evaporate, a mixing apparatus for mixing the sample in the evaporator, a condenser for condensing the evaporated sample into a condensate, a collection vessel for collecting the condensate, a vacuum pump to create a vacuum in the evaporator, and a refrigeration system integrated into the condenser, where all components are integrated into a single apparatus. Standalone large-scale chillers for cooling a liquid, vapor or other medium are also provided. Such chillers include a heat exchanger or evaporator, a condenser, a compressor, and a temperature controller, all integrated into a single standalone chiller usable with any vessel or reservoir containing liquids, vapors or other medium from which heat is to be removed. Methods of using such devices to distill, evaporate and/or cool a sample or medium are provided.

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DESCRIPTION

LARGE SCALE STANDALONE CHILLERS, ALL-IN-ONE ROTARY EVAPORATORS AND RELATED METHODS

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of and priority to U.S. Provisional Patent Application Serial No. 62/480,657, filed April 3, 2017, the disclosure of which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

The presently disclosed subject matter relates to large scale standalone chillers, all-in-one rotary evaporators and related methods. The presently disclosed subject matter also relates to high-capacity and/or high-speed distillation systems and devices.

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.

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.

Chillers are used for example 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.

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. As a result of various cooling needs of laboratories and industries, several versions of chillers with different temperature ranges exist today.

What are needed are 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.

In some cases high capacity chillers are needed to cool large volumes of coolant and/or liquid in industrial applications and laboratory settings. Coupling the above advantages with high capacity cooling in a large stand-alone chiller is needed.

Rotary evaporators are also in widespread use in laboratories throughout the world, for removing solvents from organic and inorganic solutions, to yield a liquid or solid product.

Generally speaking, such evaporators or distillers work by placing a sample in a round-bottom flask, typically a pear-shaped flask, which spins on an axis at an angle while sitting in a heated water bath. The flask is attached to a motorized 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) cool the vapor, and

the resulting cooled vapor (i.e., liquid) then flows down to a flask below the condenser, 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). This can be a burden since the dry ice has to be replenished frequently.

What is needed are rotary evaporator designs and systems, and/or distillation systems, that provide sufficient cooling and condensing capabilities that are cost effective and easy to use. Additionally, rotary evaporator designs that are fully integrated and easier to use are needed, particularly where improved yield and efficiencies can be realized. Moreover, rotary evaporator designs that are coupled with a high capacity chiller can provide for needed high capacity distillation requirements in some

industrial and laboratory settings. Finally, completely integrated continuous alcohol extraction and evaporation systems are needed.

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 herein in some embodiments are integrated rotary evaporator apparatuses, comprising a vertically oriented evaporator configured to evaporate a sample to form a sample evaporate, a mixing apparatus configured to mix the sample in the evaporator, a condenser configured to condense the evaporated sample into a condensate, a collection vessel configured to collect the condensate, a vacuum pump configured to create a vacuum in the evaporator, and a refrigeration system integrated into the condenser, wherein the vertically oriented evaporator, mixing apparatus, condenser, collection vessel, vacuum pump and refrigeration system are integrated into a single apparatus.

In some embodiments, the mixing apparatus comprises an overhead stirrer configured to stir the sample at about 500 to about 6,000 revolutions per minute (rpm). In some embodiments, the vertically oriented evaporator comprises a large volume vessel having a volume of about 6L to about 100L. In some embodiments, the vertically oriented evaporator comprises a product drain valve, wherein the vertically oriented evaporator comprises a sample valve.

In some embodiments, such systems can further comprise a heating mantle configured to heat the sample in the vertically oriented evaporator. In some embodiments, such systems can further comprise a cooling coil configured to engage the condenser so as to provide the condenser with the ability to cool and condense the sample evaporate coming into contact with the condenser.

In some embodiments, the refrigeration system comprises a condenser and refrigerant, wherein the refrigeration system provides coolant to the condenser to thereby condense the sample evaporate from the evaporator. In some embodiments, the coolant is provided to a double coil inside the condenser, wherein the double coil inside the condenser is configured to contact the sample evaporate.

In some embodiments, such a system can further comprise a structural frame configured to integrate all components into a single apparatus. In some embodiments, the condenser comprises two or more condensers in a series.

In some embodiments, such a system further comprises an adaptive cooling regulator configured to increase or decrease the cooling capacity of the condenser and/or refrigeration system. In some embodiments, the adaptive cooling regulator comprises a digitized expansion valve. In some embodiments, the adaptive cooling regulator increases the cooling capacity of the condenser and/or refrigeration system upon detecting an increased heat load from the evaporator, and the adaptive cooling regulator decreases the cooling capacity of the condenser and/or refrigeration system upon detecting a decreased heat load from the evaporator.

In some embodiments, provided herein are standalone large-scale chiller configured to cool a liquid, vapor or other medium in a vessel or reservoir, comprising: a heat exchanger or evaporator configured to be placed or submerged in a vessel or reservoir containing liquids, vapors or other medium from which heat is to be removed, a condenser, a compressor, and a temperature controller, wherein each of the components are integrated into a single standalone chiller, and wherein the chiller is configured to be universally used with any vessel or reservoir containing liquids, vapors or other medium from which heat is to be removed, and wherein the chiller has a cooling capacity of about 4000 watts at -10°C.

In some embodiments, such chillers can further comprise a housing enclosing the condenser, compressor and temperature controller, wherein the heat exchanger is positioned outside of the housing such that it can be submerged or placed in a vessel or reservoir. In some embodiments, such

chillers can further comprise a pump for circulating the liquids, vapors or other medium in the vessel or reservoir. In some embodiments, such chillers 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. In some embodiments, such chillers can further comprise a heat exchanger configured to be used as a condenser in a rotary evaporator. In some embodiments, such chillers 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, such chillers can further comprise a double wall vessel surrounding the heat exchanger.

In some embodiments, the heat exchanger comprises an evaporator coil, wherein the evaporator coil comprises a material selected from a titanium alloy, stainless steel, copper and combinations thereof. In some embodiments, the chiller can comprise a plurality of heat exchangers and/or evaporators in a series. In some embodiments, the temperature controller comprises an adaptive cooling regulator configured to increase or decrease the cooling capacity of the condenser. In some embodiments, the adaptive cooling regulator comprises a digitized expansion valve. In some embodiments, the adaptive cooling regulator increases the cooling capacity of the condenser upon detecting an increased heat load, and the adaptive cooling regulator decreases the cooling capacity of the condenser upon detecting a decreased heat load.

Also provided herein are methods of distilling a sample into a distillate or extract, comprising providing a sample to be distilled, providing an integrated rotary evaporator apparatus as disclosed herein, and distilling the sample to provide a distillate or extract. In such methods the sample to be distilled can be provided in quantities ranging from about 6L to about 100L at a time. In such methods the sample can be provided to the integrated rotary

evaporator continuously, wherein the integrated rotary evaporator is configured to contain about 6L to about 100L at a time.

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 schematic illustration of a rotary evaporation system as disclosed herein;

Figure 2 is a schematic illustration of a stand-alone chiller as disclosed herein;

Figure 3 is a schematic illustration of a vertical evaporation system as disclosed herein;

Figure 4 is a schematic illustration of a fully integrated rotary evaporation and/or distillation system as disclosed herein;

Figure 5 is a schematic illustration of a fully integrated rotary evaporation and/or distillation system as disclosed herein; and

Figure 6 is a schematic illustration of a fully integrated rotary evaporation and/or distillation system as disclosed herein.

DETAILED DESCRIPTION

The presently disclosed subject matter now will be described more fully hereinafter, in which some, but not all embodiments of the presently disclosed subject matter are described. Indeed, the disclosed subject matter can be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will satisfy applicable legal requirements.

Provided herein are devices and systems for cooling, exchanging heat, or "chilling" materials, liquids, gases, and other compositions, particularly in laboratory and/or research settings. 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 rotary evaporator designs and systems, also referred to as rotavaps, and/or distillation systems, that provide sufficient cooling and condensing capabilities that are cost effective and easy to use. Rotary evaporator designs that are fully integrated and easier to use are also provided. Moreover, rotary evaporator designs configured to provide high capacity evaporation and condensation capabilities, or distillation capabilities, particularly as compared to existing technology, are provided herein. By way of example and not limitation, rotary evaporator systems as

provided herein, including evaporator, chiller and collection components, can provide about 6,000 ml, or 6 L, up to about 50,000 ml, or 5L, of evaporative and condensing capacity. Such systems can provide a significant need for high capacity distillation in industrial and laboratory settings that is unmet with existing rotavap systems.

In some embodiments, 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 to both fully integrated and configured to handle varying chilling capacities as needed, including high capacity chilling needs (e.g., about 6,000 ml, or 6 L, up to about 50,000 ml, or 5L). 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 an all-in-one 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 requires significant laboratory space, which is expensive and in limited supply.

Conversely, chillers designed with the heat exchanger on the outside of the housing, as disclosed herein, can be used directly as a condenser in

rotary evaporators. Notably, no coolant is required. Vapors are condensed on the heat exchanger (refrigerant inside the heat exchanger pipes/coils cool the pipes/coils which in turn removes heat from the medium, e.g. vapors, liquid, etc.). Such a configuration results in unlimited and flexible use. 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 more cost effective for researchers or users 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 evaporator outside the housing the disclosed chillers can be used in place of at least 4 pieces of equipment (circulating chillers, circulating baths, rotary evaporator condensers, and immersion coolers).

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, e.g. in rotary evaporators. In traditional chillers the coolant is pumped through hoses from the chiller to the rotary evaporator condenser. Coolant gets warm 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.

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. Such cooling temperatures can be rapidly achieved even for large volumes of material by using the disclosed chillers.

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 an evaporator positioned outside the housing of the compressor so that the 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 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.

To elaborate, 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 large-scale, or high-capacity, 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, 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, PCT International Application No. PCT/US2015/062615, published as International Publication No. WO 2016/086101, and PCT International Application No. PCT/US2016/036886, published as International Publication No. WO 2016/201223, each of which is incorporated herein by reference in

their 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 illustrates a rotary evaporation system **10**, also referred to as a rotavap, or distillation system. Rotavap system **10** can in some embodiments, and as depicted in Figure 1, include a chiller **100**, vertical evaporator **200** and receiving unit **300**. In some embodiment the rotavap system **10**, including chiller **100**, vertical evaporator **200** and receiving unit **300**, is configured to be a high-capacity or high-volume distillation system as described further herein. As depicted in Figure 1, chiller **100**, vertical evaporator **200** and receiving unit **300** are configured to work together and/or be integrated in a series to function as one system, i.e. a rotavap system or distillation apparatus, to evaporate, condense and distill a composition.

To elaborate, vertical evaporator **200** can comprise an evaporator flask **202** at least partially surrounded by and/or adjacent to a heating element or mantle **204**, both of which are mounted on a frame unit **206**. Evaporator flask **202** is vertically or substantially vertically oriented, i.e. upright as opposed to angled. In some embodiments, evaporator flask **202** can comprise a large volume vessel, e.g. 6L to 100L, with an upper enclosure secured by way of a clamp mechanism. An overhead stirring mechanism **222**, comprising an electric motor **210**, drive shaft **212** and agitator **208** can be provided for agitating or stirring the contents of the evaporating flask **202**. A conduit of vapor tube **250** can be provided to transfer the evaporate or vapor to the one or more condensers on a chiller **100**. Feedstock container **240** can be positioned proximate to vertical evaporator **200** and configured to provide an extract, sample or composition to be distilled. A controller **220** can be provided to control and/or automate functionalities of vertical evaporator **200**, including for example controlling

and/or regulating the speed of the overhead stirring mechanism **222** and/or the heating element **204**.

Continuing with Figure 1, large-scale multifunctional chiller **100** is in some embodiments a component of rotary evaporation system **10**. Chiller **100** can comprise a housing **102** with a heat exchanger **104** connected to but extending from housing **102**. In some embodiment chiller **100** can comprise one, two, three, four or more heat exchangers, including for example two heat exchangers **104a** and **104b** as shown in Figure 2. Heat exchangers **104a** and **104b** can in some embodiments be connected in series by vapor line **120**, i.e. a hose or other conduit for passing an evaporate from one heat exchanger **104a** to another heat exchanger **104b**. One or more ports 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 (See, e.g. Figure 2 for further details). For example, vapors produced by vertical evaporator **200** can pass through conduit **250** and into sleeve **106a** to come into contact with heat exchange coils **104a** to thereby cool/condense the compounds, vapors or fluids. Any vapors not condensed can pass into any further heat exchanger in series, e.g. heat exchanger **104b** where such vapors have a further opportunity to be cooled and condensed. The condensate can pass through drain ports and out corresponding drain lines to a collection flask **300**, as described further below. A vacuum **130** can in some embodiments also be provided to create a vacuum or negative pressure inside the system, including for example inside heat exchangers **104a**/**104b**, vertical evaporator **200** and/or collection vessel **300**.

Collection or receiving unit **300** can in some embodiments comprise a collection flask **302**, a frame or support structure **304** for securing and/or holding collection flask **302** and a manifold **306**. Collection flask **302** can comprise a glass or polymer container, or other suitable material, in some embodiments in a round-bottom or pear-shaped configuration. collection flask **302**, a frame or support structure **304**.

In some embodiments, rotary evaporation system **10** or distillation system can comprise a footprint or operational area defined by the length L,

width W, and/or combination thereof (area in square inches for example) of the outer dimensions of the apparatus/system, e.g. the distance across the front of each of chiller **100**, vertical evaporator **200** and receiving unit **300** as assembled together in Figure 1, by the width (or depth) of they assembled system. In some embodiments the height H of the system can also be factored into calculating a total footprint of the system, including for example the height of the tallest component(s). By way of example and not limitation, the presently disclosed chiller apparatuses rotary evaporation system **10**, as shown in Figure 1, can in some embodiments comprise a total footprint or operational area of about 60 x 66 x 20 inches (L x H x W), for a 22 liter system, about 70 x 66 x 30 inches (L x H x W), for a 50 liter system, about 70 x 72 x 30 inches (L x H x W), for a 72 liter system, or about 80 x 83 x 40 inches (L x H x W), for a 100 liter system.

Figure 2 is a perspective view of a large-scale multifunctional chiller **100** as disclosed herein. Such a chiller can in some embodiments be used as part of, or a component of, a rotary evaporation system **10** or distillation system, as shown in Figure 1. Chiller **100** can comprise a housing **102** with a heat exchanger **104** connected to but extending from housing **102**. In some embodiment chiller **100** can comprise one, two, three, four or more heat exchangers, including for example two heat exchangers **104a** and **104b** as shown in Figure 2. Heat exchangers **104a** and **104b** can in some embodiments be connected in series by vapor line **120**, i.e. a hose or other conduit for passing an evaporate from one heat exchanger **104a** to another heat exchanger **104b**.

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 arrange the elements in such a way that provides for an effective and efficient cooling/chilling system, even for a high-capacity or large scale version, while minimizing the operational area and/or footprint.

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**. Heat exchangers **104a**/**104b** can be substantially enclosed within an outer periphery of housing **102**, or can be arranged to extend away from housing **102**. Manifold **112** can support and mechanically connect heat exchanger **104a**/**104b** to chiller **100**. Manifold **112** can comprise a clamp or other attachment mechanism, e.g. threads, screws, bolts, pressure fitting, etc. for securing heat exchanger **104a**/**104b**. 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.

Chiller **100** can comprise an integrated refrigeration system housed within housing **102** and continuing through heat exchanger **104a**/**104b** to provide a cooled refrigerant to heat exchanger **104a**/**104b**, also referred to as heat exchanger coils. For example, chiller **100** can comprise a compressor, refrigeration condenser and fan. In some embodiments a refrigeration dryer may also be included. In some embodiments a compressor, a refrigeration condenser and a heat exchanger coil, e.g. heat exchanger **104a**/**104b** (and optionally dryer) can be connected by refrigeration lines (copper tubing) by feeding through manifold **112**. Heat exchanger **104a**/**104b** can comprise single or double coiled lines connected to refrigeration lines fed through manifold **112**. Thus, refrigeration coolant can pass through the refrigeration system (e.g. compressor, refrigeration

condenser) and into the coiled lines of heat exchanger **104a**/**104b** in a closed or continuous circuit such that heat absorbed by heat exchanger **104a**/**104b** from a surrounding media, e.g. cooling liquid or vapors, can be removed by the refrigeration system to thereby cool the surrounding media. 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 can be adapted to run off of the same refrigeration system.

By way of example and not limitation, heat exchanger **104a**/**104b**, as depicted in Figure 2, can each comprise a sleeve **106a**/**106b**, where each sleeve **106a**/**106b** comprises a single-walled enclosure surrounding and enclosing coils **104a**/**104b**. Single-walled sleeves **106a**/**106b** can in some embodiments comprise a glass canister configured to slide over heat exchanger coils **104a**/**104b** and securely attach to housing **102** via manifold **112** to create a sealed enclosure. Manifold **112** can include a collar or other securing element, e.g. threads, screws, bolts, pressure fitting, etc. as discussed herein. One or more ports **132**, **134**, and/or **142** 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. For example, compounds, vapors or fluids entering sleeve **106a** can come into contact with heat exchange coils **104a**, or a cooling sleeve surrounding the coils, to thereby cool the compounds, vapors or fluids. Any vapors not condensed can pass into any further heat exchanger in series, e.g. heat exchanger **104b** shown in Figure 2, by port **142** and line **120** into port **140** on sleeve **106a** where such vapors have a further opportunity to be cooled and condensed. The condensate can pass through drain ports, e.g. ports **132** and/or **134**, and out corresponding drain lines, e.g. lines **122** and/or **124**, to a collection flask (see, e.g. Figure 1).

A vacuum port **142** can in some embodiments be provided (in some cases near the top) and configured to receive a vacuum line **132** from a vacuum pump to thereby cause a vacuum on the inner environment of sleeves **106a**/**106b**.

As depicted in Figure 1 for example, a heat exchanger system can comprise coiled lines **104a**/**104b** which can be connected to refrigeration lines through which cooled refrigerant can pass. Heat exchanger coiled lines **104a**/**104b** 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 as disclosed herein. Heat exchanger coiled lines **104a**/**104b** are illustrated as a single looped coil in Figure 1, but can also comprise in some embodiments double, triple or more coils. An effect of coiling the refrigerant lines of heat exchanger coiled lines **104a**/**104b** 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 **104a**/**104b** can be configured to complete a continuous loop along with the refrigeration system of the chiller. Coiled lines **104a**/**104b** 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 **104a**/**104b** can comprise a titanium material with an inner coating of copper. In some embodiments coils **104a**/**104b** can comprise stainless steel, titanium, and/or a combination thereof.

In some embodiments the condensers, or heat exchanger coils **104a**/**104b**, can comprise an evaporator coil comprising a titanium alloy, stainless steel and/or copper pipe. While in some embodiments heat exchanger coils **104a**/**104b** can be exposed for direct cooling of a medium or evaporate (vapor), in some embodiments, stainless steel coil, can be coated with perfluoroalkoxy alkanes (PFA) for additional chemical corrosion protection. With the inclusion of a PFA, or other protective coating, a wide range of metals or materials can be used in the coils since corrosion can be substantially reduced and/or eliminated. In some embodiments, heat exchanger coils **104a**/**104b** can be coated with any chemical resistant

polymer or material, including for example a fluoropolymer. In some aspects, such a fluoropolymer can include for example Halar® ECTFE, a copolymer of ethylene and chlorotrifluoroethylene (Solvay Group, Belgium).

Figure 3 illustrates a vertical evaporator **200**, in some embodiments configured as a high-speed or high-capacity vertical evaporator **200** capable of evaporating significantly greater quantities of sample or extract than existing evaporative systems due to its configuration and design. Existing rotary evaporators, or rotavaps, use round bottom, or pear shaped flasks oriented at an angle to allow for heating of the contents of the flask to thereby vaporize the same. Applicant has discovered a more efficient and effective approach using an upright vessel configured to engage a heating mantle.

To elaborate, vertical evaporator **200** can comprise an evaporator flask **202** at least partially surrounded by and/or adjacent to a heating element or mantle **204**, both of which are mounted on a frame unit **206**. Evaporator flask **202** is vertically or substantially vertically oriented, i.e. upright as opposed to angled. In some embodiments, evaporator flask **202** can comprise a large volume vessel, e.g. 6L to 100L, with an upper enclosure secured by way of a clamp mechanism. An overhead stirring mechanism **222**, comprising an electric motor **210**, drive shaft **212** and agitator **208** can be provided for agitating or stirring the contents of the evaporating flask **202**. A conduit of vapor tube **250** can be provided to transfer the evaporate or vapor to the one or more condensers on a chiller **100**. Feedstock container **240** can be positioned proximate to vertical evaporator **200** and configured to provide an extract, sample or composition to be distilled. A controller **220** can be provided to control and/or automate functionalities of vertical evaporator **200**, including for example controlling and/or regulating the speed of the overhead stirring mechanism **222** and/or the heating element **204**.

Overhead stirring mechanism **222** can be provided for agitating or stirring the contents, e.g. extra, sample, composition, etc., of the evaporating flask **202**. Electric motor **210** can in some aspects be mounted on frame **206** and aligned directly or substantially above evaporating flask **202** such that

drive shaft **212** extends vertically downward through an upper portion of evaporating flask **202**. Drive shaft **212** can extend into the interior of evaporating flask **202**, in some embodiments, substantially toward the bottom of the interior of evaporating flask **202**, and can terminate with an agitator **208**. Agitator **208** can comprise a paddle, propeller, blade or other structure suitable for stirring, agitating and/or mixing the contents of evaporating flask **202** to be evaporated. Drive shaft **212**, directionally and mechanically connected to both electric motor **210** and agitator **208** translates a rotational force from the electric motor **210** to the agitator **208**. As such, overhead stirring mechanism **222**, comprising an electric motor **210**, drive shaft **212** and agitator **208**, can allow for a more rapid evaporation of the contents of evaporating flask **202** since the flask can be heated more evenly and at a higher temperature. The speed or rate at which the sample or extract is evaporated can be significantly increased as compared to a rotavap using a traditional angles flask rotating in a water bath. Thus, with the disclosed system there is no need to rotation the evaporating flask **202**.

Instead, evaporating flask **202** is nested within heating mantle **204**, in some embodiments in direct contact with heating mantle to thereby efficiently transfer heat from heating mantle **204** to flask **202**. Thus, in some aspects heating mantle **204** can comprise a substantially cylindrical housing with an inner bowl-shaped heating element configured to match the size and shape of evaporating flask **202** so as to stably contain evaporating flask **202** and efficiently heat the same. Heating mantle **204** can be mounted on a frame **206** or similar structure.

Frame **206** can comprise a lower portion **206b** configured to securely hold in place heating mantle **204**, and upper portion **206a** extending vertically from lower portion **206b** and configured to hold and position overhead stirring mechanism **222** above heating mantle **204** and/or evaporating flask **202**. Frame **206** can further comprise wheels or casters to provide mobility. Frame **206** can be advantageous in that it can lift and align the evaporating flask **202**, particularly with heavy large volume evaporating flask, e.g. 22 liters to 100 liters.

In some aspects a manifold **214** can be provided to enclose an opening on the top portion of evaporating flask **202** and collect evaporates from evaporating flask **202**. Manifold **214** can be configured to allow drive shaft **212** to pass therethrough while maintaining an air-tight or substantially air-tight seal. Port **216** can be provided, along with any number of other ports or access points, in manifold **214** to allow captured evaporates to pass from evaporating flask **202** and into the chiller/condenser via a conduit or hose.

In some embodiments, and as shown in Figure 3 as well as Figure 1, a drain valve **218** can be provided in the evaporating flask. This is an advantage over existing round bottom flasks that cannot be drained while in place. Moreover, a sample/addition valve **224** can be provided at the top and/or in manifold **214** for the addition of substances and/or taking of samples from the flask. With one or both of the draining and/or filling ports the fully integrated system can in some embodiments be operated continuously. That is, with a filling port and/or draining port the system can be continuously operated.

The disclosed vertical evaporator **200** allows for the replacement of a water bath as required by round bottom flasks with a heating mantle **204** for efficient and faster heating.

Although depicted as a vertically aligned round-bottom flask in Figures 1 and 3, in some embodiments evaporating flask **202** can be any shape or suitable configuration, including for example a substantially cylindrical beaker-like vessel as shown in Figures 4 and 5, and discussed further hereinbelow.

At least one advantageous aspect of the disclosed rotavap system is the vertical orientation of the evaporating flask. That is, the instant rotary evaporation system is configured with a vertically, or substantially vertically oriented evaporation flask, as opposed to an angled or diagonal evaporation flask as in traditional rotovaps. This vertical orientation also allows for high speed stirring of the contents, thereby resulting in high speed evaporation. For example, the evaporation flask contents can be stirred by an overhead stirrer at about 500 to about 6,000 revolutions per minute (rpm). This is in

contrast to a traditional system that rotates the round bottom flask at about 300 rpm or less. The design of the disclosed rotavap system allows for a significantly larger volume of sample to be processed, i.e. distilled in a much shorter amount of time due to its design and configuration, including for example the vertically oriented evaporation system with internal stirring mechanism that can be stirred and evaporated at high speed. The absence of having to rotate the evaporation flask removes a significant impediment in existing systems in the speed and volume they are able to handle.

An evaporate or vapor that comes into contact with the heat exchanger, and particularly coils **104a**/**104b**, can condense into a liquid and pass through drain ports, e.g. ports **132** and/or **134**, and out corresponding drain lines, e.g. lines **122** and/or **124**, to a collection or receiving unit **300** (see Figures 1 and 2). In some embodiments one or more joints **320** can be positioned on conduits or drain lines **122** and/or **124** that can be configured to allow for easy removal of a collection unit (receiving unit) **300**, and in some aspects removal without breaking a vacuum to the system during operation. Such joint **320** can comprise a valve to maintain the vacuum while removing collection flask **302** from receiving unit **300**.

Collection or receiving unit **300** can in some embodiments comprise a collection flask **302**, a frame or support structure **304** for securing and/or holding collection flask **302** and a manifold **306**. Collection flask **302** can comprise a glass or polymer container, or other suitable material, in some embodiments in a round-bottom or pear-shaped configuration, or any other suitable configuration. Additional access ports, for taking samples or adding components, can be included on collection flask **302** as depicted in Figure 1.

In some embodiments the large scale, high-speed rotavap systems and devices disclosed herein further comprise an intelligent cooling capacity configured to adapt the cooling capacity to the heat load applied to the chiller. Thus, using Figure 1 as an example, in some embodiments the heat load provided by evaporator **200** can be detected and used to calibrate the cooling capacity needed to be provided by chiller **100**. Thus, the cooling capacity provided by chiller **100** can be adapted, or proportionally applied, to the heat load delivered by evaporator **200**. The heat load can be defined as

the amount of evaporate, or vapor, or evaporated/vaporized sample coming from evaporator **200** via conduit **250**. In some embodiments such an intelligent cooling system can comprise an expansion valve configured to increase or decease the cooling capacity of the chiller, and particularly the heat exchanger coils, e.g. coils **104a**/**104b** of Figure 1, proportional to the heat load delivered by the evaporator. In some embodiments the expansion valve can be digitized, and in some embodiments in electrical communication with a computerized controller.

The components of a large scale, high-speed rotavap system as disclosed herein can be oriented or configured as depicted in Figures 1 through 3, but can also be configured in alternative arrangements such as depicted in Figures 4 and 5. By way of example and not limitation, Figures 4 and 5 show fully integrated rotavap and/or distillation systems **20** and **30**, respectively, comprising a high-capacity chiller/condenser combined with a high-speed evaporation flask/system with a stirring mechanism. Rotavap systems **20** and **30** can be contained in a single unit and/or housed within a structural frame and/or enclosed for additional safety as needed. A fully enclosable system, such as depicted in Figure 5, can contain all of the chemicals and evaporates to provide an additional measure of safety for technicians using the equipment.

In Figures 4 and 5 rotary evaporation systems **20** and **30**, also referred to as a rotavap, or distillation system, can in some embodiments include a chiller/condenser **400** and a vertical evaporator **500**. In some embodiment the rotavap system **10**, including chiller/condenser **400** and a vertical evaporator **500**, is configured to be a high-capacity or high-volume distillation system as described further herein. As depicted in Figures 4 and 5, chiller/condenser **400** and a vertical evaporator **500** are configured to work together and/or be integrated in a series to function as one system, i.e. a rotavap system or distillation apparatus, to evaporate, condense and distill a composition.

To elaborate, vertical evaporator **500** can comprise an evaporator flask **502** at least partially surrounded by and/or adjacent to a heating element or mantle **504**, both of which are mounted on a base unit **230**.

Evaporator flask **502** is vertically or substantially vertically oriented, i.e. upright as opposed to angled. In some embodiments, evaporator flask **502** can comprise a large volume vessel, e.g. 6L to 100L, with an upper enclosure **514** (or manifold) secured by way of a clamp mechanism **518**. An overhead stirring mechanism **522**, comprising an electric motor **510**, drive shaft **512** and agitator **508** can be provided for agitating or stirring the contents of the evaporating flask **502**. A conduit of vapor tube **550** can be provided to transfer the evaporate or vapor to the one or more condensers on a chiller **400**. A feedstock container can be positioned proximate to vertical evaporator **500** and configured to provide an extract, sample or composition to be distilled (see Figure 1). A controller can be provided to control and/or automate functionalities of vertical evaporator **500**, including for example controlling and/or regulating the speed of the overhead stirring mechanism **522** and/or the heating element **504**.

Continuing with Figures 4 and 5, large-scale multifunctional chiller **400** can comprise a housing **402** with a heat exchanger **404** connected to but extending from housing **402**. In some embodiment chiller **400** can comprise one, two, three, four or more heat exchangers, including for example two heat exchangers **404a** and **404b** as shown in Figures 4 and 5. Heat exchangers **404a** and **404b** can in some embodiments be connected in series by vapor line, i.e. a hose or other conduit for passing an evaporate from one heat exchanger **404a** to another heat exchanger **404b**. One or more ports 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 (See, e.g. Figure 2 for further details). For example, vapors produced by vertical evaporator **500** can pass through conduit **550** and into sleeve **406a** to come into contact with heat exchange coils **404a** to thereby cool/condense the compounds, vapors or fluids. Any vapors not condensed can pass into any further heat exchanger in series, e.g. heat exchanger **404b** where such vapors have a further opportunity to be cooled and condensed. The condensate can pass through drain ports and out corresponding drain lines to a collection flasks **450a** and **450b**. A vacuum **430** can in some embodiments also be provided to create a vacuum

or negative pressure inside the system, including for example inside heat exchangers **404a**/**404b**, vertical evaporator **500** and/or collection flasks **450a** and **450b**. As shown in Figure 4, vacuum **430** can in some embodiments be contained within housing **402** such that all components of rotavap system **20**/**30** is contained in a single unit. Alternatively, an exterior vacuum source could be used and connected to vacuum port **442**, as needed and as shown in other embodiments herein.

Collection or receiving units/flasks **450a** and **450b** can in some embodiments comprise a collection flask or other suitable container or vial, e.g. a glass or polymer container, or other suitable material, in some embodiments in a round-bottom or pear-shaped configuration, for collecting condensate from heat exchangers **404a**/**404b**. As depicted in Figures 4 and 5, such collection or receiving units/flasks **450a** and **450b** can extend directly from the heat exchangers via a conduit or connection **452**, or can be external from the main unit as depicted in Figure 1. However, in the embodiments of Figures 4 and 5, collection or receiving units/flasks **450a** and **450b** can be positioned to be contained within housing **402** so as to provide a fully contained stand-alone rotavap unit.

Continuing with Figures 4 and 5, vertical evaporator **500** can comprise an evaporator flask **502** having a substantially cylindrical shape, or flask-like shape, that is configured to nest within or otherwise be surrounded by and/or adjacent to heating element or mantle **504**. Heating element **504** can be continued within housing **506**, which can be mounted on a base unit **230**. Base unit **230** can be supported by floor **232**, which can be integrally joined with housing **402** of chiller/condenser **400** so as to provide all components on one fully contained stand-alone unit. Base unit **230** can in some embodiments comprise an adjustable functionality or adjustable member, e.g. vertically raised and lowered, so as to allow for adjustability of the height of high-speed evaporator **500**. Such adjustability can provide for the use of varying sizes of flasks **502** within the same rotavap system **20**/**30**.

The rotavap system of Figure 5 can in some embodiments comprise an additional framing/housing **234** configured to further contain the system, and particularly evaporator **500** within a single unit. Framing/housing **234**

can further provide structural support for an enclosure material, e.g. glass, Plexiglas, composite materials, etc., to fully enclose the evaporation and distillation system for both safety and environmental security purposes.

By way of example and not limitation, Figure 6 illustrates yet another embodiment of a fully integrated rotavap and/or distillation system **40**, comprising a high-capacity chiller/condenser **600** combined with a high-speed vertical evaporation flask/system **500** with a stirring mechanism. Rotavap systems **20** and **30** can be housed within a structural frame and/or enclosed for additional safety as needed.

The components of a large scale, high-speed rotavap system as disclosed herein can be oriented or configured as depicted in Figures 1 through 5, but can also be configured in alternative arrangements such as depicted in Figure 6. By way of example and not limitation, Figure 6 shows a fully integrated rotavap and/or distillation system **40** comprising a high-capacity chiller/condenser combined with a high-speed evaporation flask/system with a stirring mechanism. Rotavap system **40** can be contained in a single unit and/or housed within a structural frame and/or enclosed for additional safety as needed.

In Figure 6 rotary evaporation system **40**, also referred to as a rotavap, or distillation system, can in some embodiments include a chiller/condenser **600** and a vertical evaporator **500**. In some embodiment the rotavap system **40**, including chiller/condenser **600** and a vertical evaporator **500**, is configured to be a high-capacity or high-volume distillation system as described further herein. As depicted in Figure 6, chiller/condenser **600** and a vertical evaporator **500** are configured to work together and/or be integrated in a series to function as one system, i.e. a rotavap system or distillation apparatus, to evaporate, condense and distill a composition.

To elaborate, vertical evaporator **500** can comprise an evaporator flask **502** mounted centrally on the main housing of chiller/condenser **600**, and at least partially surrounded by and/or adjacent to a heating element or mantle **504**. Evaporator flask **502** is vertically or substantially vertically oriented, i.e. upright as opposed to angled. In some embodiments,

evaporator flask **502** can comprise a large volume vessel, e.g. 6L to 100L, with an upper enclosure **514** (or manifold) secured by way of a clamp mechanism **518**. An overhead stirring mechanism **522**, comprising an electric motor **510**, drive shaft **512** and agitator **508** can be provided for agitating or stirring the contents of the evaporating flask **502**. A conduit of vapor tube **550** can be provided to transfer the evaporate or vapor to the one or more condensers on chiller **600**. A feedstock container can be positioned proximate to vertical evaporator **500** and configured to provide an extract, sample or composition to be distilled (see Figure 1). A controller can be provided to control and/or automate functionalities of vertical evaporator **500**, including for example controlling and/or regulating the speed of the overhead stirring mechanism **522** and/or the heating element **504**.

Continuing with Figure 6, large-scale multifunctional chiller **600** can comprise a housing **602** with a heat exchanger **604** connected to but extending from housing **602**. In some embodiments chiller **600** can comprise one, two, three, four or more heat exchangers, including for example two heat exchangers **604a** and **604b** as shown in Figure 6. Heat exchangers **604a** and **604b** can in some embodiments be connected in series by vapor line **552**, i.e. a hose or other conduit for passing an evaporate from one heat exchanger **604a** to another heat exchanger **604b**. One or more ports 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 (See, e.g. Figure 2 for further details). For example, vapors produced by vertical evaporator **500** can pass through conduit **550** and into sleeve **606a** to come into contact with heat exchange coils **604a** to thereby cool/condense the compounds, vapors or fluids. Any vapors not condensed can pass into any further heat exchanger in series, e.g. heat exchanger **604b** where such vapors have a further opportunity to be cooled and condensed. The condensate can pass through drain ports and out corresponding drain lines to a collection flasks **450a** and **450b**. A vacuum can in some embodiments also be provided to create a vacuum or negative pressure inside the system, including for example inside heat exchangers **604a**/**604b**, vertical evaporator **500** and/or collection flasks **450a** and **450b**.

As shown in Figure 4, a vacuum can in some embodiments be contained within the rotavap housing, e.g. housing **602**, such that all components of rotavap system **40** is contained in a single unit. Alternatively, an exterior vacuum source could be used and connected to a vacuum port as described further herein.

Collection or receiving units/flasks **450a** and **450b** can in some embodiments comprise a collection flask or other suitable container or vial, e.g. a glass or polymer container, or other suitable material, in some embodiments in a round-bottom or pear-shaped configuration, for collecting condensate from heat exchangers **604a**/**604b**. As depicted in Figure 6, such collection or receiving units/flasks **450a** and **450b** can extend directly from the heat exchangers via a conduit or connection **452**, or can be external from the main unit as depicted in Figure 1. However, in the embodiments of Figure 6, collection or receiving units/flasks **450a** and **450b** can be positioned to be contained within and/or as part of the rotavap unit so as to provide a fully contained stand-alone rotavap unit.

Summarily, there are notable differences between existing rotovaps, particularly those with larger capacities, and the disclosed integrated and large capacity systems, are summarized below. For example, existing systems allow for rotation (spinning) of 20L or 50L glass flasks at a maximum speed of 100 rpm along an axis of rotation. This approach is a slow and inefficient process. Bumping (foaming) of a sample can often prevent maximizing vacuum pressure. Moreover, spinning a large flask with large volumes of chemicals is dangerous. Particularly, handling 5L to 200L round bottom flasks is problematic, and can lead to breaking and/or loss of product. Finally, heated water (e.g. a water bath) is needed to heat the flask in such systems.

In marked contrast, in the disclosed systems and apparatuses, no spinning of large flasks, e.g., 20L, 50L or 100L, is needed. Instead, the large volume flasks in the disclosed systems are stationary. The sample (solvent) in the flask is stirred using an overhead stirrer at about 200 to about 6,000 rpm. With the disclosed design, bumping (foaming) is eliminated at high rpm. As such, vacuum pressure can be maximized, which speeds up the

evaporation rate and shortens evaporation time. Since the flask is not rotated, cylindrical glassware that is equipped with an inlet and outlet for continuous sample filling and product draining, respectively, can be used. In such a system, flask volume can be as large as a 100L cylindrical flask. Finally, no heated water, or water bath is needed in the disclosed system. Instead, non-liquid base heating, such as heating mantle or ceramic heating blocks, can be used. This approach is more efficient and reduces energy consumption.

The disclosed systems and apparatuses can be used for condensing and/or distilling compounds, compositions, samples and extracts. In some embodiments the disclosed systems and apparatuses, including the disclosed rotavaps, vertical evaporators and/or chillers can be used in conjunction with other equipment and systems requiring evaporation, condensation and/or chilling, including for example freeze dryers for lyophilizing samples. They can also be used with refrigerated condensing units/systems for 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. In some embodiments the disclose systems and apparatuses can be used with centrifugal concentrators for protein extraction and purification, DNA concentration, buffer exchange, and deproteinization. Likewise, in some embodiments the disclosed systems and devices can be used with gel dryers, DNA sample concentration, and/or acid sample concentrations

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 coil" includes a plurality of such coils, 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, 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. An integrated rotary evaporator apparatus, comprising:

a vertically oriented evaporator configured to evaporate a sample to form a sample evaporate;

a mixing apparatus configured to mix the sample in the evaporator;

a condenser configured to condense the evaporated sample into a condensate;

a collection vessel configured to collect the condensate;

a vacuum pump configured to create a vacuum in the evaporator; and

a refrigeration system integrated into the condenser,

wherein the vertically oriented evaporator, mixing apparatus, condenser, collection vessel, vacuum pump and refrigeration system are integrated into a single apparatus.

2. The integrated rotary evaporator apparatus of claim 1, wherein the mixing apparatus comprises an overhead stirrer configured to stir the sample at about 500 to about 6,000 revolutions per minute (rpm).

3. The integrated rotary evaporator apparatus of any of claims 1 to 2, wherein the vertically oriented evaporator comprises a large volume vessel having a volume of about 6L to about 100L.

4. The integrated rotary evaporator apparatus of any of claims 1 to 3, wherein the vertically oriented evaporator comprises a product drain valve, wherein the vertically oriented evaporator comprises a sample valve.

5. The integrated rotary evaporator apparatus of any of claims 1 to 4, further comprising a heating mantle configured to heat the sample in the vertically oriented evaporator.

6. The integrated rotary evaporator apparatus of any of claims 1 to 5, further comprising a cooling coil configured to engage the condenser so as to provide the condenser with the ability to cool and condense the sample evaporate coming into contact with the condenser.

7. The integrated rotary evaporator apparatus of any of claims 1 to 6, wherein the refrigeration system comprises a condenser and refrigerant, wherein the refrigeration system provides coolant to the condenser to thereby condense the sample evaporate from the evaporator.

8. The integrated rotary evaporator apparatus of any of claims 1 to 7, wherein the coolant is provided to a double coil inside the condenser, wherein the double coil inside the condenser is configured to contact the sample evaporate.

9. The integrated rotary evaporator apparatus of any of claims 1 to 8, further comprising a structural frame configured to integrate all components into a single apparatus.

10. The integrated rotary evaporator apparatus of any of claims 1 to 9, wherein the condenser comprises two or more condensers in a series.

11. The integrated rotary evaporator apparatus of any of claims 1 to 10, further comprising an adaptive cooling regulator configured to increase or decrease the cooling capacity of the condenser and/or refrigeration system.

12. The integrated rotary evaporator apparatus of any of claims 1 to 11, wherein the adaptive cooling regulator comprises a digitized expansion valve.

13. The integrated rotary evaporator apparatus of any of claims 1 to 12, wherein the adaptive cooling regulator increases the cooling capacity of the condenser and/or refrigeration system upon detecting an increased heat

load from the evaporator, and the adaptive cooling regulator decreases the cooling capacity of the condenser and/or refrigeration system upon detecting a decreased heat load from the evaporator.

14. A standalone large-scale chiller configured to cool a liquid, vapor or other medium in a vessel or reservoir, comprising:

a heat exchanger or evaporator configured to be placed or submerged in a vessel or reservoir containing liquids, vapors or other medium from which heat is to be removed;

a condenser;

a compressor; and

a temperature controller,

wherein each of the components are integrated into a single standalone chiller, and wherein the chiller is configured to be universally used with any vessel or reservoir containing liquids, vapors or other medium from which heat is to be removed; and

wherein the chiller has a cooling capacity of about 4,000 watts at -10°C.

15. The standalone large-scale chiller of claim 15, further comprising a housing enclosing the condenser, compressor and temperature controller, wherein the heat exchanger is positioned outside of the housing such that it can be submerged or placed in a vessel or reservoir.

16. The standalone large-scale chiller of any of claims 14 to 15, further comprising a pump for circulating the liquids, vapors or other medium in the vessel or reservoir.

17. The standalone large-scale chiller of any of claims 14 to 16, further comprising a vacuum pump and controller.

18. The standalone large-scale chiller of any of claims 14 to 17, 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.

19. The standalone large-scale chiller of any of the claims 14 to 18, further comprising a heat exchanger configured to be used as a condenser in a rotary evaporator.

20. The standalone large-scale chiller of any of claims 14 to 19, 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.

21. The standalone large-scale chiller of any of claims 14 to 20, further comprising a double wall vessel surrounding the heat exchanger.

22. The standalone large-scale chiller of any of claims 14 to 21, wherein the heat exchanger comprises an evaporator coil, wherein the evaporator coil comprises a material selected from a titanium alloy, stainless steel, copper and combinations thereof.

23. The standalone large-scale chiller of any of claims 14 to 22, comprising a plurality of heat exchangers and/or evaporators in a series.

24. The standalone large-scale chiller of any of claims 14 to 23, wherein the temperature controller comprises an adaptive cooling regulator configured to increase or decrease the cooling capacity of the condenser.

25. The standalone large-scale chiller of any of claims 14 to 24, wherein the adaptive cooling regulator comprises a digitized expansion valve.

26. The standalone large-scale chiller of any of claims 14 to 25, wherein the adaptive cooling regulator increases the cooling capacity of the condenser upon detecting an increased heat load, and the adaptive cooling regulator decreases the cooling capacity of the condenser upon detecting a decreased heat load.

27. A method of distilling a sample into a distillate or extract, comprising:

providing a sample to be distilled;

providing an integrated rotary evaporator apparatus of any of claims 1 to 13; and

distilling the sample to provide a distillate or extract.

28. The method of claim 27, wherein the sample to be distilled is provided in quantities ranging from about 6L to about 100L at a time.

29. The method of claim 27, wherein the sample is provide to the integrated rotary evaporator continuously, wherein the integrated rotary evaporator is configured to contain about 6L to about 100L at a time.

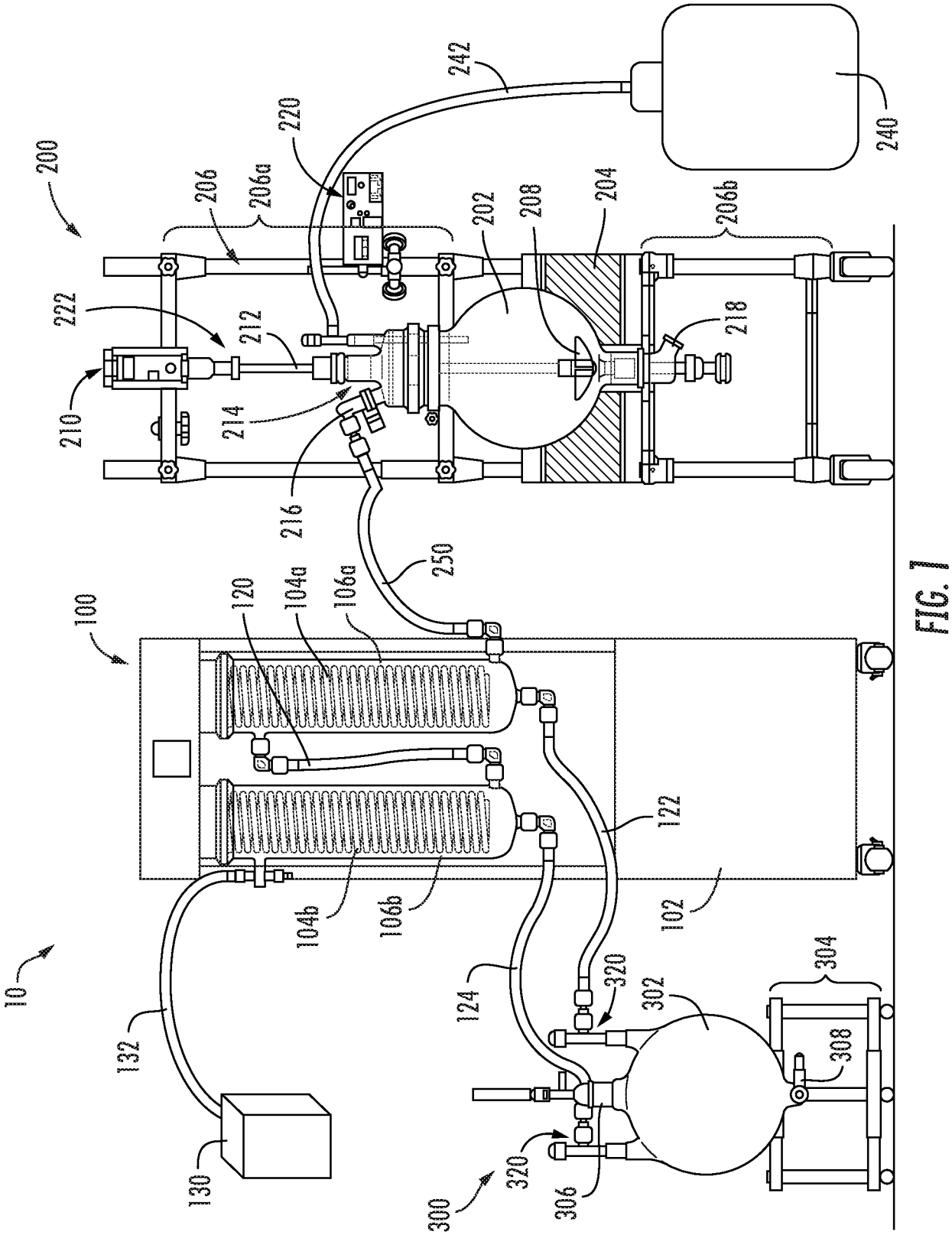

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FIG. 1

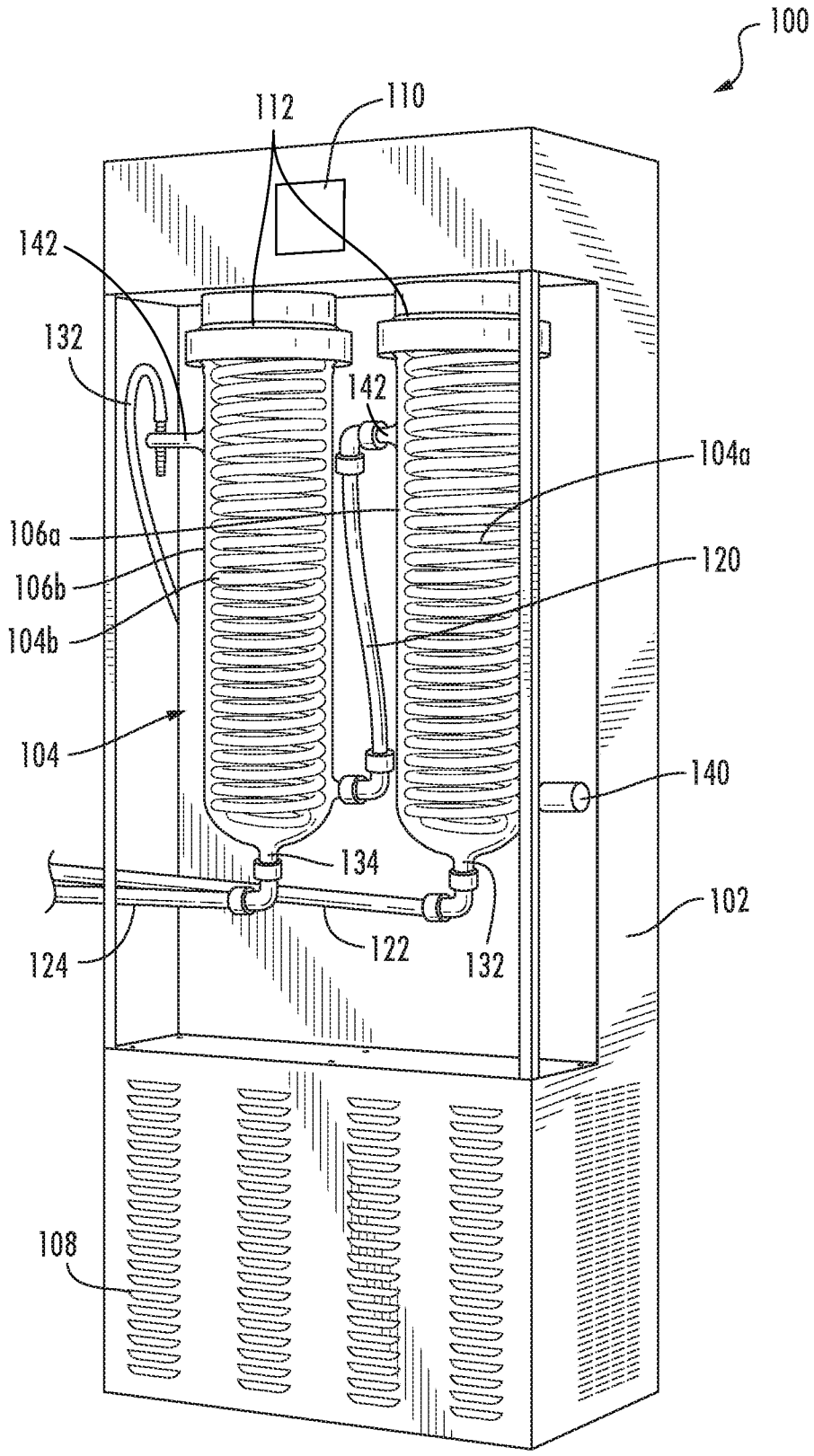

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FIG. 2

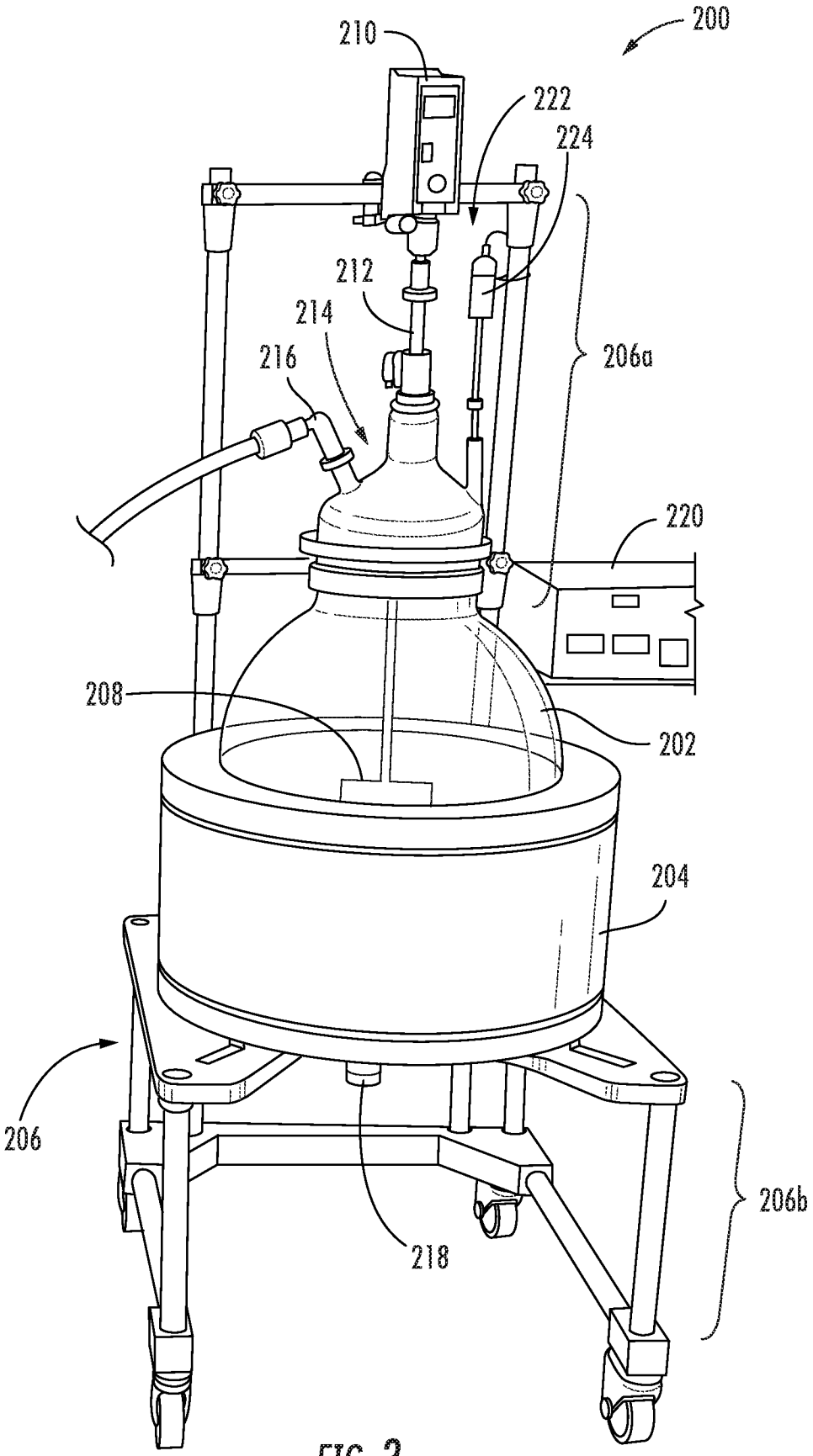


FIG. 3

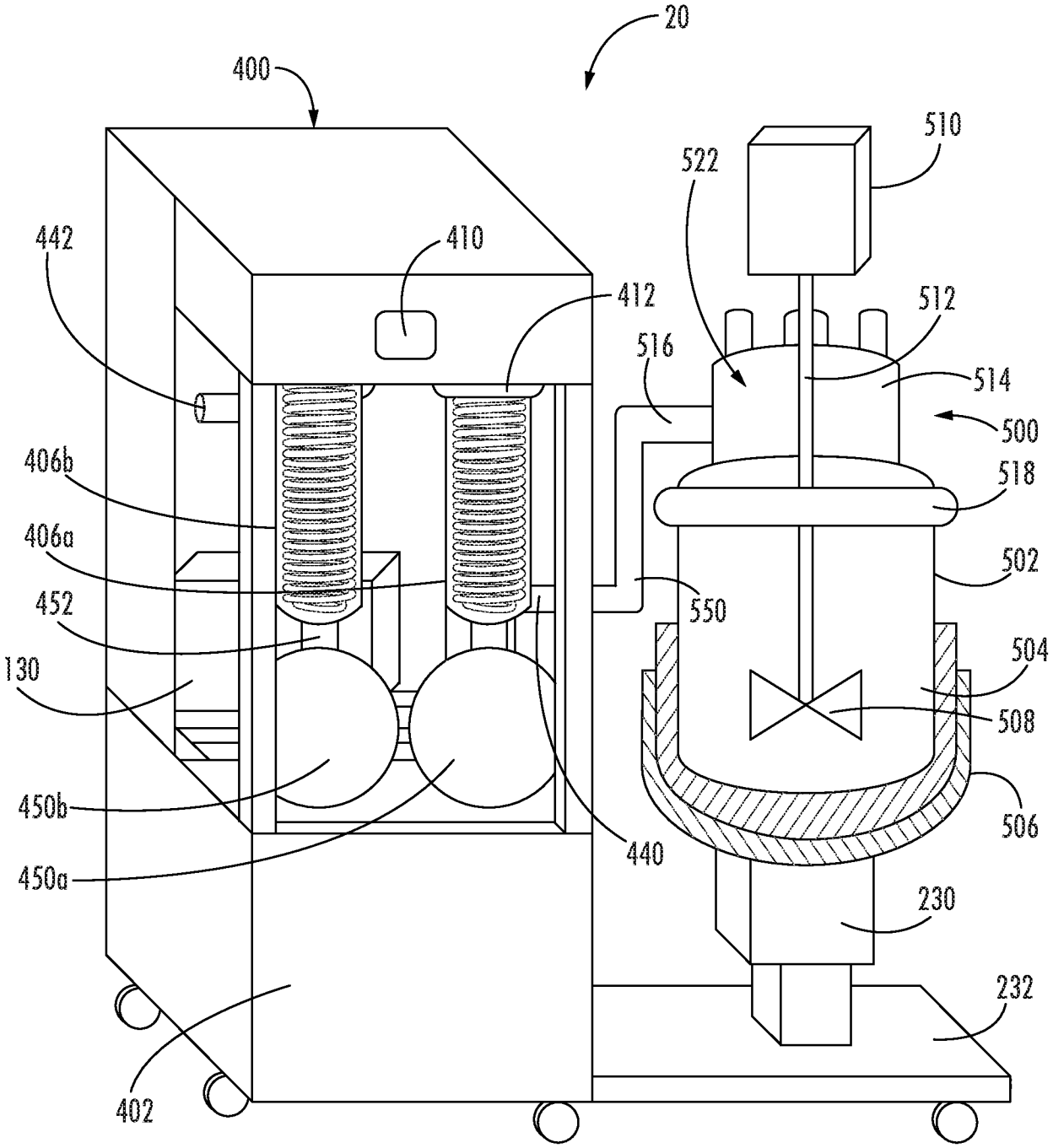

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FIG. 4

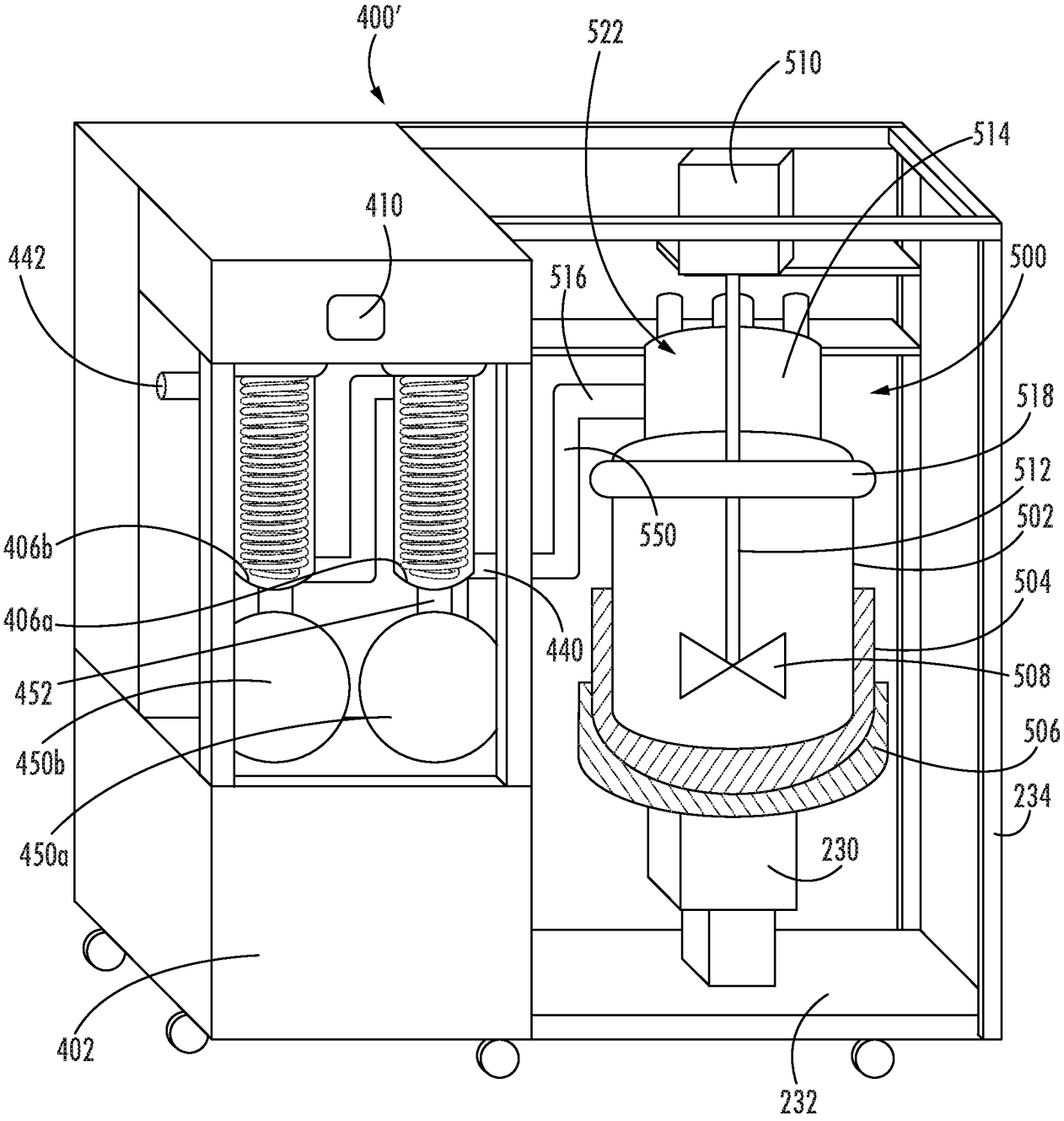

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FIG. 5

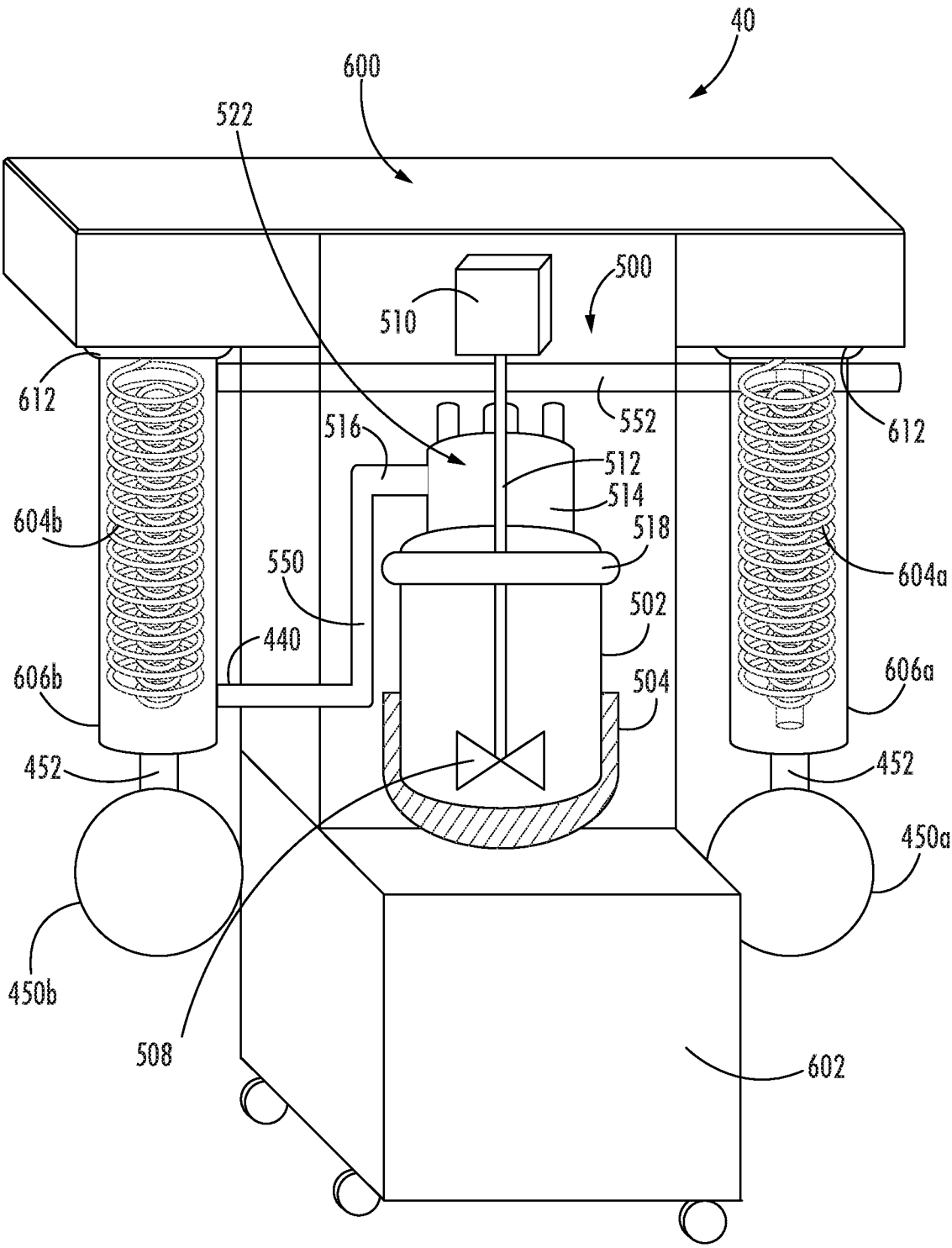

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FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2018/025812

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

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

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☒ Claims Nos.: 4-13, 17-29
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 additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2018/025812

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - B01D 3/02; B01D 1/00; B01D 3/00; B01D 3/08; B01D 3/10; B01D 5/00 (2018.01)
CPC - B01D 3/085; B01D 1/22; B01D 3/00; B01D 5/006 (2018.05)

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
See Search History document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC - 159/25.1; 159/25.2; 202/185.1; 202/185.6; 202/238 (keyword delimited)

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2011/0073459 A1 (ADJABENG) 31 March 2011 (31.03.2011) entire document	1-3
X	WO 2016/201223 A1 (ECODYST INC) 15 December 2016 (15.12.2016) entire document	14-16
A	US 2012/0085635 A1 (HAYNES) 12 April 2012 (12.04.2012) entire document	1-3, 14-16
A	US 5,176,799 A (ROE et al) 05 January 1993 (05.01.1993) entire document	1-3, 14-16
A	WO 2011/151484 A1 (UNIVERSIDAD DE HUELVA) 08 December 2011 (08.12.2011) see machine translation	1-3, 14-16

☐ 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
29 May 2018	11 JUN 2018
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, VA 22313-1450 Facsimile No. 571-273-8300	Authorized officer Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774