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(71) Applicant (for all designated States except US): **SIGMA-ALDRICH CO.** [US/US]; 3050 Spruce St., St. Louis, MO 63103 (US).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **GEE, Peter** [GB/GB]; Conway Old Road, Dwygyfylchi LL34 6SP (GB). **ODEDRA, Rajesh** [GB/GB]; 221 Manchester Road, Altringham, Cheshire WA14 5NU (GB). **MCKIN-**

NELL, Elizabeth [GB/GB]; 5 Pendle Close, Upton, Wirral L49 6QN (GB). **HUGHES, Ann** [GB/GB]; Ham Cottage, Ickleton Road, Wantage, Oxfordshire OX12 9JA (GB).

(74) Agent: **PANKA, Brian, G.**; Harness, Dickey & Pierce, P.L.C., 7700 Bonhomme, Suite 400, St. Louis, MO 63105 (US).

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(54) Title: DELIVERY ASSEMBLIES AND RELATED METHODS

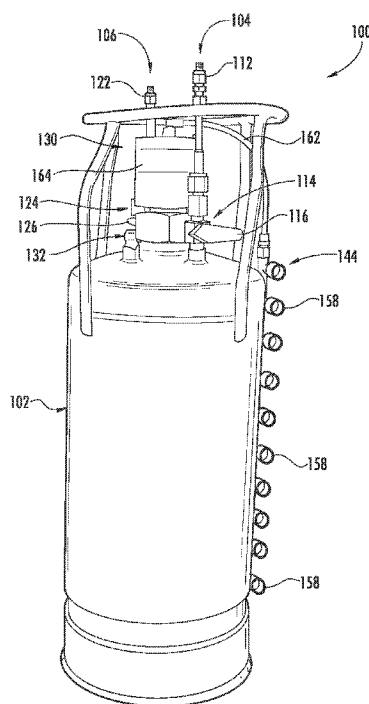


FIG. 1

(57) Abstract: A delivery assembly is provided for use in retrieving vapor product from precursor material. The delivery assembly generally includes a container configured to retain precursor material, vortex units configured to generate flow of gas, and a thermal transfer unit coupled to the container and in thermal communication with the vortex units. The thermal transfer unit is configured to direct the gas from the vortex units to the container to selectively heat or cool the precursor material in the container. The thermal transfer unit may include a probe coupled to the vortex units and configured to be positioned at least partly within the container to direct gas from the vortex units to the container. The thermal transfer unit may also include a manifold coupled to the probe and positioned along an outer portion of the container to direct gas from the vortex units generally around the container.



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DELIVERY ASSEMBLIES AND RELATED METHODS

Cross-Reference to Related Application

[0001] This application claims priority to U.S. Patent Application Serial No. 61/312,311 filed on 10 March 2010, the entire disclosure of which is incorporated herein by reference.

Field

[0002] The present disclosure relates to delivery assemblies for use in withdrawing vapor products from precursor materials disposed in the delivery assemblies, and more particularly to such delivery assemblies having temperature control systems for use in selectively and accurately heating or cooling the precursor materials disposed in the delivery assemblies, and related methods.

Background

[0003] This section provides background information related to the present disclosure which is not necessarily prior art.

[0004] In the semiconductor industry, electronic devices are often produced by means of a deposition process (e.g., chemical vapor deposition (CVD), atomic layer deposition (ALD), etc.). Typically, a precursor is supplied, for example, in a container of a bubbler assembly through which a carrier gas, such as nitrogen or hydrogen, may be bubbled so that the carrier gas becomes saturated with the precursor. The carrier gas/precursor vapor mixture is then passed at a controlled rate to a reactor for subsequent deposition. Monitoring and/or controlling temperature of the precursor in the container is desirable to help improve operational efficiency. Such bubbler assemblies can be used in the production of silicon semiconductors.

[0005] Temperature control systems are available that use baths in connection with the bubbler assemblies to control temperature of precursors in the bubbler assemblies. Typically in these systems, fluids are kept at constant temperature in the baths, and the bubbler assemblies (and precursors therein) are positioned in the fluids in order to control temperature of the precursors. However, such systems often use ethylene glycol as the fluid in the baths which can absorb water from the atmosphere and cause the baths to overflow and spill. Also, such

systems do not provide uniform temperature control to the precursors in the bubbler assemblies as typically only parts of the bubbler assemblies are submerged in the fluids (leaving parts not submerged subject to separate temperature control). And, there are can be issues with feedback control of the fluids in the baths such that temperature fluctuations can occur above desired ranges. Moreover, such systems can be bulky and space consuming, and submerging the bubbler assemblies in fluid baths in such systems leaves fluid on outer surfaces of the bubbler assemblies causing contamination concerns in fittings of the bubbler assemblies as well as gripping problems when handling the bubbler assemblies.

Summary

[0006] This section provides a general summary of the disclosure, and is not a comprehensive disclosure of its full scope or all of its features.

[0007] Example embodiments of the present disclosure generally relate to assemblies for use in retrieving vapor product from precursor material. In one example embodiment, an assembly generally includes a container configured to retain precursor material, at least one vortex unit configured to generate flow of gas, and a thermal transfer unit coupled to the container and in thermal communication with the at least one vortex unit. The thermal transfer unit is configured to direct the gas from the at least one vortex unit to the container to selectively heat or cool the precursor material in the container.

[0008] Example embodiments of the present disclosure generally relate to temperature control systems for use with precursor delivery assemblies to selectively heat or cool precursor material in containers of the precursor delivery assemblies. In one example embodiment, a temperature control system generally includes at least one vortex unit and a probe coupled to the at least one vortex unit. The probe is configured to be positioned at least partly within a container of a delivery assembly to direct gas from the at least one vortex unit to the container to selectively heat or cool precursor material in the container.

[0009] Example embodiments of the present disclosure also generally relate to methods for monitoring and/or controlling temperature of a precursor material in delivery assemblies. In one example embodiment, a method generally includes operating a first vortex unit and/or a second vortex unit to adjust a temperature of a precursor material in a delivery assembly to about a target

temperature, and selectively operating the first vortex unit and the second vortex unit to maintain the temperature of the precursor material in the delivery assembly at about the target temperature.

[0010] Further areas of applicability will become apparent from the description provided herein. The description and specific examples in this summary are intended for purposes of illustration only and are not intended to limit the scope of the present disclosure.

Drawings

[0011] The drawings described herein are for illustrative purposes only of selected embodiments and not all possible implementations, and are not intended to limit the scope of the present disclosure.

[0012] FIG. 1 is a perspective view of an example embodiment of a delivery assembly including one or more aspects of the present disclosure;

[0013] FIG. 2 is a fragmentary rearward elevation view of the delivery assembly of FIG. 1 with a probe and a manifold of a temperature control system of the assembly removed and illustrating a thermocouple of the temperature control system positioned in a container of the assembly;

[0014] FIG. 3 is a fragmentary forward elevation view of the delivery assembly of FIG. 1 with the manifold of the temperature control system removed and illustrating the probe of the temperature control system positioned in the container of the assembly for use in selectively heating or cooling precursor material in the delivery assembly;

[0015] FIG. 4 is an enlarged fragmentary elevation view of a vortex unit of the delivery assembly of FIG. 3;

[0016] FIG. 5 is a fragmentary perspective view of a lower portion of the probe of FIG. 3 illustrating a thermal transfer head of the probe;

[0017] FIG. 6 is a longitudinal section view of the lower portion of the probe of FIG. 4;

[0018] FIG. 7 is a perspective view of a jacket configured to receive the delivery assembly of FIG. 1 therein during operation;

[0019] FIG. 8 is a schematic illustrating interconnection of a control unit with the delivery assembly of FIG. 1 as part of a temperature monitoring system of the delivery assembly;

[0020] FIG. 9 is a perspective view of another example embodiment of a delivery assembly including one or more aspects of the present disclosure and having a temperature control system that includes vortex units and a probe, but not an external manifold;

[0021] FIG. 10 is a perspective view of an example embodiment of a probe including one or more aspects of the present disclosure and suitable for use with the delivery assembly of FIG. 1 or the delivery assembly of FIG. 9 or the delivery assembly of FIG. 13;

[0022] FIG. 11 is a perspective view of another example embodiment of a probe including one or more aspects of the present disclosure and suitable for use with the delivery assembly of FIG. 1 or the delivery assembly of FIG. 9 or the delivery assembly of FIG. 13;

[0023] FIG. 12 is an enlarged longitudinal section view of inflow and outflow portions of a double wall pipe forming the probe of FIG. 11;

[0024] FIG. 13 is a fragmentary forward elevation view of another example embodiment of a delivery assembly including one or more aspects of the present disclosure and having a sleeve disposed around a probe of a temperature control system of the delivery assembly;

[0025] FIG. 14 is a graph illustrating temperature measurements of n-hexane over time in the container of the delivery assembly of FIG. 1 and during operation of a temperature control system thereof; and

[0026] FIG. 15 is a graph illustrating temperature of n-hexane over time in the container of the delivery assembly of FIG. 9 and during operation of a temperature control system thereof.

[0027] Corresponding reference numerals indicate corresponding parts throughout the several views of the drawings.

Detailed Description

[0028] Example embodiments will now be described more fully with reference to the accompanying drawings.

[0029] Example embodiments are provided so that this disclosure will be thorough, and will fully convey the scope to those who are skilled in the art. Numerous specific details are set forth such as examples of specific components, devices, and methods, to provide a thorough understanding of embodiments of the

present disclosure. It will be apparent to those skilled in the art that specific details need not be employed, that example embodiments may be embodied in many different forms and that neither should be construed to limit the scope of the disclosure. In some example embodiments, well-known processes, well-known device structures, and well-known technologies are not described in detail.

[0030] The terminology used herein is for the purpose of describing particular example embodiments only and is not intended to be limiting. As used herein, the singular forms "a", "an" and "the" may be intended to include the plural forms as well, unless the context clearly indicates otherwise. The terms "comprises," "comprising," "including," and "having," are inclusive and therefore specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof. The method steps, processes, and operations described herein are not to be construed as necessarily requiring their performance in the particular order discussed or illustrated, unless specifically identified as an order of performance. It is also to be understood that additional or alternative steps may be employed.

[0031] When an element or layer is referred to as being "on", "engaged to", "connected to" or "coupled to" another element or layer, intervening elements or layers may be present. In contrast, when an element is referred to as being "directly on", "directly engaged to", "directly connected to" or "directly coupled to" another element or layer, there may be no intervening elements or layers present. Other words used to describe the relationship between elements should be interpreted in a like fashion (e.g., "between" versus "directly between," "adjacent" versus "directly adjacent," etc.). As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items.

[0032] Although the terms first, second, third, etc. may be used herein to describe various elements, components, regions, layers and/or sections, these elements, components, regions, layers and/or sections should not be limited by these terms. These terms may be only used to distinguish one element, component, region, layer or section from another element, component, region, layer or section. Terms such as "first," "second," and other numerical terms when used herein do not imply a sequence or order unless clearly indicated by the context. Thus, a first element, component, region, layer or section discussed below could be termed a

second element, component, region, layer or section without departing from the teachings of the example embodiments.

[0033] Spatially relative terms, such as "inner," "outer," "beneath", "below", "lower", "above", "upper" and the like, may be used herein for ease of description to describe one element or feature's relationship to another element(s) or feature(s) as illustrated in the figures. Spatially relative terms may be intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures. For example, if the device in the figures is turned over, elements described as "below" or "beneath" other elements or features would then be oriented "above" the other elements or features. Thus, the example term "below" can encompass both an orientation of above and below. The device may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein interpreted accordingly.

[0034] With reference now to the drawings, FIGS. 1-8 illustrate an example embodiment of a delivery assembly 100 (*e.g.*, a bubbler assembly, etc.) including one or more aspects of the present disclosure. The example assembly 100 is configured (*e.g.*, sized, shaped, constructed, etc.) to, among other things, deliver precursor material disposed within the assembly 100 to a reactor site, in gas phase, for subsequent use at the reactor site (*e.g.*, via a carrier gas for subsequent use in a vapor deposition process, etc.). It should be noted that the example assembly 100 may be used with any precursor material within the scope of the present disclosure. For example, the illustrated assembly 100 is configured to be used with liquid precursor material such as, for example, trimethylgallium (TMG) ($\text{Ga}(\text{CH}_3)_3$), trimethylaluminum (TMA) ($\text{Al}(\text{CH}_3)_3$), triethylgallium (TEG) ($\text{Ga}(\text{CH}_2\text{CH}_3)_3$), diethylzinc (DEZ) ($\text{Zn}(\text{CH}_2\text{CH}_3)_2$), solution trimethylindium (TMI) ($\text{In}(\text{CH}_3)_3$) (in dimethyldodecylamine). Any suitable carrier gas may be used with the example assembly 100, including, for example, nitrogen gas, hydrogen gas, argon gas, carbon monoxide, etc. In other example embodiments, delivery assemblies may be used with solid precursor materials within the scope of the present disclosure.

[0035] As shown in FIGS. 1-3, the example delivery assembly 100 generally includes a container 102 for holding liquid precursor material (and vaporized liquid precursor material) in the container 102. The illustrated container 102 is generally cylindrical in shape and is formed as a generally substantially sealed structure, for example, to inhibit undesired flow of precursor material, vaporized

precursor material, carrier gas, etc. out of the container 102 and/or to inhibit undesired flow of contaminants, etc. into the container 102. The container 102 can be formed from any suitable material within the scope of the present disclosure including, for example, inert materials such as stainless steel, etc. In addition, the container 102 can have any desired volume within the scope of the present disclosure (e.g., about a twenty liter volume, etc.) suitable for holding a desired amount (e.g., about 10 kilograms, about 15 kilograms, etc.) of liquid precursor material (with a headspace volume typically left above the liquid precursor material in the container). Moreover, the container 102 may have any desired shape within the scope of the present disclosure (e.g., shapes other than cylindrical, etc.).

[0036] An inlet 104 and an outlet 106 are coupled to the container 102 for controlling, for example, carrier gas flow into the container 102 and vapor product (comprising carrier gas and vaporized liquid precursor material) flow out of the container 102 (e.g., vapor product retrieved from the container 102, etc.). The inlet 104 is configured to introduce (or deliver, or dispense, etc.) carrier gas into the container 102 via a sparging tube 108, and the outlet 106 is configured to transport (or remove) vapor product retrieved from the precursor material by the carrier gas out of the container 102. Carrier gas can thus generally flow from the inlet 104, through the container 102, and to the outlet 106 as desired. In the illustrated embodiment, the inlet 104 and the outlet 106 are coupled to an upper portion of the container 102 (in fluidic communication with the container 102) by suitable couplings, connections, etc. (e.g., a generally sealed gasket fitting, a welded connection, etc.). In other example embodiments, however, delivery assemblies may include inlets and outlets coupled to portions of containers other than upper portions, for example, side portions, lower portions, etc.

[0037] The inlet 104 generally includes a coupling 112 and a valve structure 114. The coupling 112 is configured to couple (e.g., via a threaded connection, etc.) the inlet 104 to a carrier gas supply line (not shown) for supplying carrier gas to the inlet 104. The valve structure 114 is configured to control the flow of carrier gas into the container 102 through the inlet 104. An actuator 116 of the valve structure 114 can be operated to selectively open a pathway (not shown) through the inlet 104 to allow the carrier gas to flow into the container 102, and to selectively close the pathway through the inlet 104 to inhibit the carrier gas from flowing into the container 102.

[0038] The sparging tube 108 is coupled to the inlet 104 within the container 102, for example, via a suitable coupling (e.g., a generally sealed gasket fitting, a welded connection, etc.). This allows carrier gas to flow through the inlet 104 and into the sparging tube 108 for discharge into the container 102. The sparging tube 108 includes a diffuser 118 at a lower end portion of the sparging tube 108. During operation of the delivery assembly 100, the diffuser 118 may be at least partly submerged in the liquid precursor material in the container 102 to introduce, inject, etc. carrier gas directly into the liquid precursor material. The diffuser 118 may include any suitable diffuser within the scope of the present disclosure operable, for example, to deliver, inject, etc. bubbles of carrier gas into liquid for use in retrieving vapor products from the liquid, etc.

[0039] The outlet 106 of the delivery assembly 100 generally includes a coupling 122 and a valve structure 124. The coupling 122 is configured to couple (e.g., via a threaded connection, etc.) the outlet 106 to a product transfer line (not shown) for receiving vapor product out of the container 102 (e.g., by drawing a vacuum through the product transfer line, etc.). The valve structure 124 is configured to control the flow of vapor product out of the container 102 through the outlet 106. An actuator 126 of the valve structure 124 can be operated to selectively open a pathway (not shown) through the outlet 106 to allow the vapor product to flow out of the container 102, and to selectively close the pathway through the outlet 106 to inhibit the vapor product from flowing out of the container 102.

[0040] With continued reference to FIGS. 1-3, the example delivery assembly 100 includes a temperature control system 130 (e.g., a temperature control insert, etc.) for use in measuring, monitoring, and/or controlling temperature of liquid precursor material (and vaporized liquid precursor material) in the container 102. The illustrated temperature control system 130 includes a thermocouple 132 (FIGS. 1 and 2) and first and second vortex units 134 and 136 (FIG. 3). The thermocouple 132 is provided at least partly within the container 102 (e.g., within a pocket/sheath defined in the container 102 to protect the thermocouple 132 and at least partly immersed in the liquid precursor material in the container 102, etc.) for use in measuring and/or monitoring temperature of liquid precursor material in the container 102. And, the first and second vortex units 134 and 136 are provided for generating flows of gas at different temperatures for use in adjusting and/or controlling (e.g., heating and/or cooling, etc.) the temperature of the liquid precursor

material in the container 102 (e.g., in response to measured temperatures from the thermocouple 132, etc.). Any suitable thermocouple and/or any suitable vortex unit may be used in connection with the temperature control system 130 of the present disclosure.

[0041] The temperature control system 130 may also include a control unit 140 (FIG. 8) for monitoring and controlling operation of the thermocouple 132 and vortex units 134 and 136. The control unit 140 is configured to control (and coordinate) operation of the thermocouple 132 and the vortex units 134 and 136 to help in measuring, monitoring, and/or controlling temperature of liquid precursor material in the container 102. The control unit 140 may include a central processor for processing information related to monitoring and controlling operation of the thermocouple 132 and vortex units 134 and 136. Such operation of the thermocouple 132 and vortex units 134 and 136 will be described in more detail hereinafter.

[0042] The temperature control system 130 also includes a probe 142 (FIG. 3) and a manifold 144 (FIG. 1) both in communication (e.g., thermal communication, etc.) with the vortex units 134 and 136 to thereby operate together to help adjust and/or control the temperature of the liquid precursor material in the container 102. More particularly, the probe 142 and the manifold 144 are both configured to operate with the vortex units 134 and 136 to direct the gas from the vortex units 134 and 136 to the container 102 to help adjust and/or control the temperature of the liquid precursor material in the container 102.

[0043] The probe 142 is located generally within the container 102 and includes a thermal transfer head 146 coupled to an inflow 148 and an outflow 150. During operation of the delivery assembly 100, the thermal transfer head 146 is configured to be in contact with the liquid precursor material in the container 102. The inflow 148 is configured to transport gas from the vortex units 134 and 136 to the thermal transfer head 146, and the outflow 150 is configured to transport gas from the thermal transfer head 146 out of the container 102 (e.g., to the manifold 144, etc.). As such, the probe 142 operates to circulate gas from the vortex units 134 and 136 through the probe 142 generally inside the container 102 (for adjusting and/or controlling temperature of the internal environment of the container 102). The probe 142 can be coupled to the container 102 by suitable couplings, fittings, connections, etc. In the illustrated embodiment, for example, the probe 142 is coupled to an upper neck 152 of the container 102 via a high-integrity flange and

gasket fitting 154 that substantially seals connection of the probe 142 to the container 102.

[0044] The manifold 144 is located generally along an outer portion of the container 102 and includes multiple discharge heads 158 for circulating the gas from the vortex units 134 and 136 outside the container 102 (for adjusting and/or controlling temperature of the external environment around the container 102). In the illustrated embodiment, the discharge heads 158 are aligned generally vertically along the container 102. However, the discharge heads 158 could be oriented differently within the scope of the present disclosure. The manifold 144 is coupled to the outer portion of the container 102 by suitable couplings, fittings, connections, etc.

[0045] The first and second vortex units 134 and 136 are coupled to the probe 142 via a shuttle valve 160 (e.g., including one or more suitable solenoid valves, etc.), and the probe 142 is coupled to the manifold 144 via tubing 162. The shuttle valve 160 operates to selectively allow gas from one of the first vortex unit 134 and the second vortex unit 136 to flow through the probe 142 (i.e., through the inflow 148, the thermal transfer head 146, and the outflow 150) and then through the manifold 144 (via the tubing 162) for use in adjusting and/or controlling the temperature of the liquid precursor material in the container 102. For example, the shuttle valve 160 can move to a first position as desired in which gas from the first vortex unit 134 flows through the probe 142 and the manifold 144. And, the shuttle valve 160 can move to a second position as desired in which gas from the second vortex unit 136 flows through the probe 142 and the manifold 144. It should be appreciated that the control unit 140 of the temperature control system 130 may be used to control operation of the shuttle valve 160 (e.g., to energize one or more solenoid valves to allow gas to flow from a select one of the vortex units 134 and 136, etc.).

[0046] In the illustrated embodiment, the first and second vortex units 134 and 136 are located together in a housing 164 toward an upper portion of the container 102 (FIG. 1). The vortex units 134 and 136, however, may be located differently (e.g., at locations other than toward an upper portion of the container 102, for example, at least partly within the container 102, along side portions of the container 102, etc.) within the scope of the present disclosure. Also in the illustrated embodiment, the vortex units 134 and 136 are oriented generally vertically within the housing (see, FIG. 3). The vortex units 134 and 136, however, may be oriented

differently (e.g., horizontally, etc.) within the scope of the present disclosure. As such, it should be appreciated that the location and/or orientation of the vortex units 134 and 136 are not a limitation of the present disclosure.

[0047] With reference now to FIG. 4, the first vortex unit 134 generally includes an inlet 168 through which pressurized gas (e.g., compressed gas, etc.) is injected, tangentially, into a tubular body 170 (arrows indicate flow of gas in the vortex unit 134 in FIG. 4). The body 170 centrifugally rotates the gas and accelerates it at a high rate of speed toward a control valve 172 located at a first end portion of the body 170. A portion of the gas exits the body 170 (e.g., vents, etc.) at the control valve 172. A silencer may be included to help control sound of the exiting gas. The remainder of the gas (now with reduced speed) returns centrally through the body 170 (through the incoming rotating gas) as it moves toward an outlet 174 (which is coupled to the shuttle valve 160) at a second end portion of the body 170 for discharge. The returning gas transfers heat to the rotating gas thereby substantially cooling the returning gas as it exits the vortex unit 134. The control valve 172 of the vortex unit 134 can be operated to adjust the amount of gas exiting/venting from the body 170 at the first end portion. This in turn adjusts the amount of gas returning centrally through the body 170 and thus the temperature of the gas exiting the vortex unit 134 at the outlet 174. As such, the vortex unit 134 can be adjusted, tuned, etc. as desired to output a flow of gas at a desired temperature. Any suitable pressurized gas may be used with the vortex unit 134 within the scope of the present disclosure, for example, helium at a pressure ranging from about eight bars to about ten bars.

[0048] The second vortex unit 136 is substantially the same as the first vortex unit 134. As such, it is understood that a description of the second vortex unit 136 is substantially the same as the description of the first vortex unit 134. A separate description of the second vortex unit 136 will therefore not be provided. However, it should be appreciated that in other example embodiments delivery assemblies may include temperature control systems in which one or more different vortex units are used.

[0049] In the illustrated embodiment, the first vortex unit 134 is configured to provide a flow of gas at a first temperature to the probe 142 and manifold 144, and the second vortex unit 136 is configured to provide a flow of gas at a second temperature different from the first temperature to the probe 142 and manifold 144. For example, the first vortex unit 134 may be configured (e.g., adjusted, tuned, etc.)

to provide a flow of gas at a temperature that is a desired amount (e.g., about ten degrees Celsius, etc.) above a target temperature to be attained for the liquid precursor material in the container 102. And, the second vortex unit 136 may be configured (e.g., adjusted, tuned, etc.) to provide a flow of gas at a temperature that is a desired amount (e.g., about ten degrees Celsius, etc.) below the target temperature to be attained for the liquid precursor material in the container 102. As such, the different flows of gas from the first and second vortex units 134 and 136 can be selectively used in conjunction to adjust the temperature of the liquid precursor material in the container 102 (via the probe 142 and the manifold 144) to achieve the target temperature and/or to control (or maintain) the temperature of the liquid precursor material in the container 102 at its target temperature. Providing two sources of gas at temperatures above and below the target temperature for the liquid precursor material can allow for more accurate control and maintenance of the target temperature. Moreover, the two sources of gas may allow for attaining and/or adjusting the target temperature quicker (i.e., allow faster response times) as one of the first and second vortex units 134 and 136 can quickly account for overshooting of target temperature by the other of the first and second vortex units 134 and 136.

[0050] It should be appreciated that the shuttle valve 160 (e.g., via the control unit 140, etc.) operates to control the selection between operation of the first and second vortex units 134 and 136 to adjust and/or control the temperature of the liquid precursor material in the container 102 (e.g., compensate for temperature changes of the liquid precursor material, etc.). Such selection can allow for a generally steady control and/or adjustment of the temperature of the liquid precursor material in the container 102. Thus, more finite control of the temperature of the liquid precursor material may be achieved.

[0051] The target temperature of the liquid precursor material in the container 102 is selected based on the type of liquid precursor material in the container 102 and the subsequent end use of the vapor product recovered from the liquid precursor material at the reactor site. For example, the target temperature for TMG is about ten degrees Celsius as at this temperature the vapor concentration exiting the container is correct for use in subsequent deposition equipment. Operating the delivery system of the present disclosure at such target temperatures with minimized variance from said temperature can provide more accurate control of concentrations of the vapor product supplied to the reactor site to enhance process

control. In addition, exceptionally uniform concentrations of the vapor product can be provided over a prolonged duration of operation of the delivery assembly 100. The concentrations of the vapor product supplied from the delivery assembly 100 during operation may be monitored and used as an input for use in controlling operation of the temperature control system 130 within the scope of the present disclosure.

[0052] Referring now to FIGS. 5 and 6, the thermal transfer head 146 of the probe 142 is shown. The thermal transfer head 146 is configured to receive gas from the vortex units 134 and 136 (via the inflow 148) and transfer heat between the thermal transfer head 146 and the liquid precursor material in the container 102, as desired (e.g., to cool the liquid precursor material in the container 102, to heat the liquid precursor material in the container 102, etc.). The thermal transfer head 146 generally includes a lower chamber 178 in fluidic communication with the inflow 148 to receive the gas into the thermal transfer head 146 and an upper chamber 180 in fluidic communication with the outflow 150 to remove the gas from the thermal transfer head 146. Multiple tubes 182 interconnect the upper chamber 180 and the lower chamber 178 (and are in fluidic communication with the upper and lower chambers 180 and 178) so that the gas from the lower chamber 178 can flow to the upper chamber 180 through each of the tubes 182. A venturi 184 is provided in the lower chamber 178 of the thermal transfer head 146 for accelerating flow of the gas in the lower chamber 178 and for promoting circulation of gas therein. Fins 186 are provided on the lower and upper chambers 178 and 180 and between the lower and upper chambers 178 and 180 and generally around the tubes 182 therebetween (e.g., with the tubes 182 extending through the fins 186, etc.) to promote contact between the thermal transfer head 146 and the liquid precursor material in the container 102 and thereby enhance thermal transfer (e.g., the fins 186 provide increased surface area to transfer heat between the thermal transfer head 146 and the liquid precursor material in the container 102, etc.).

[0053] FIG. 7 illustrates an insulated jacket 190 of the delivery assembly 100 within which the container 102 can be positioned during operation. The jacket 190 provides insulation around the container 102 to help inhibit undesired heat transfer between the environment around the container 102 and the liquid precursor material in the container 102. The jacket 190 also provides a generally contained environment around the container 102 for gas discharged by the manifold 144 of the temperature control system 130 to circulate around the container 102 (without

dissipating to the surrounding environment). As such, in this embodiment the jacket 190 also operates in conjunction with the manifold 144 to help adjust and/or control temperature of the liquid precursor material in the container 102. The illustrated jacket 190 is generally cylindrical in shape and is sized to provide a small amount of clearance (e.g., a few centimeters, etc.) around the container 102 when the container 102 is positioned in the jacket 190 to allow good circulation of gas discharged from the manifold 144. The jacket 190 can be made of any suitable insulating material or combination of materials having generally low heat conductance within the scope of the present disclosure.

[0054] Example operation of the illustrated delivery assembly 100 will be described next with additional reference to the diagram of FIG. 8 (illustrating example interconnection of the control unit 140, as part of the temperature control system 130, to the delivery assembly 100). To prepare the assembly 100 for operation, liquid precursor material is initially positioned within the container 102, and the container 102 is then positioned within the insulated jacket 190 for operation. The vortex units 134 and 136 are tuned to generate flows of gas having desired temperatures based on the target temperature to be attained for the liquid precursor material in the container 102. For example, the first vortex unit 134 can be tuned to generate a flow of gas having a temperature that is a desired amount above the target temperature for the liquid precursor material, and the second vortex unit 136 can be tuned to provide a flow of gas having a temperature that is a desired amount below the target temperature for the liquid precursor material.

[0055] Next, the target temperature to be attained for the liquid precursor material in the container 102 is programmed into the control unit 140, and the temperature control system 130 is activated. An initial temperature of the liquid precursor material in the container 102 is measured by the thermocouple 132 and compared to the target temperature for the liquid precursor material. If the temperature of the liquid precursor material is above or below the target temperature, one of the first vortex unit 134 and the second vortex unit 136 are activated by the control unit 140 to generate gas to flow through the probe 142 and through the manifold 144 to adjust the temperature as needed. For example, if the initial temperature of the liquid precursor material is above the target temperature, the second vortex unit 136 is activated and the shuttle valve 160 is operated to allow gas to flow from the second vortex unit 136 to the probe 142 and the manifold 144. If

the initial temperature of the liquid precursor material is below the target temperature, the first vortex unit 134 is activated and the shuttle valve 160 is operated to allow gas to flow from the first vortex unit 134 to the probe 142 and the manifold 144.

[0056] Once the liquid precursor material in the container 102 reaches its target temperature, carrier gas is introduced into the container 102 through the inlet 104 (e.g., via selective operation of the valve structure of the inlet 104, etc.) and sparging tube 108. In the container 102, the carrier gas bubbles through the liquid precursor material in the container 102 and becomes saturated with vaporized product from the liquid precursor material. The saturated carrier gas then exits the container 102 through the outlet 106 as desired for subsequent use. Concurrently with this operation of the carrier gas, the temperature control system 130 (e.g., the control unit 140, etc.) continues to monitor the temperature of the liquid precursor material in the container 102 (via the thermocouple 132) and, as necessary, activates one of the first vortex unit 134 and the second vortex unit 136 to adjust the temperature of the liquid precursor material to the target temperature. This operation can continue on a loop until the liquid precursor material in the container 102 is depleted.

[0057] It should be appreciated that the thermocouple 132, the vortex units 134 and 136, and/or the shuttle valve 160 are configured to communicate with the control unit 140 sending and/or receiving information regarding measuring, monitoring, controlling, and/or adjusting the temperature of the liquid precursor material in the container 102 of the delivery assembly 11. And, the thermocouple 132, the vortex units 134 and 136, and/or the shuttle valve 160 may be coupled to the control unit by suitable telecommunications links 192 (e.g., hardwired links, wireless links, wireless transceivers, network links, internet, intermediary components, etc.). Flow of carrier gas into and/or out of the container 102 may also be controlled by the control unit 140 within the scope of the present disclosure.

[0058] FIG. 9 illustrates another example embodiment of a delivery assembly 200 including one or more aspects of the present disclosure. The delivery assembly 200 of this embodiment is substantially similar to the delivery assembly 100 previously described and illustrated in FIGS. 1-8. In this embodiment, however, a temperature control system 230 of the delivery assembly 200 does not include a manifold for use in adjusting and/or controlling a temperature of liquid precursor

material in a container 202 of the assembly. Instead in this embodiment, vortex units (not visible) located in housing 264 are in communication with a probe (not visible) disposed within the container 202 to adjust and/or control the temperature of the liquid precursor material. Here, gas exiting the probe (after flowing through the probe in the container 202) may be vented outside the container using, for example, a silencer 294, etc. The delivery assembly 200 may be positioned in a jacket (similar to jacket 190 shown in FIG. 7 and previously described in connection with delivery assembly 100) during operation to provide insulation around the container 202 to help inhibit undesired heat transfer between the environment around the container 202 and the liquid precursor material in the container 202. In this embodiment, however, the jacket may be sized to receive the delivery assembly 200 such that walls of the container 202 are in contact with the jacket to improve thermal insulation consistency (as there is no need to accommodate an external manifold in this embodiment or to circulate gas around the container 202 in this embodiment).

[0059] FIG. 10 illustrates an example embodiment of a probe 342 (as part of a temperature control system) including one or more aspects of the present disclosure. The probe 342 is suitable for use with delivery assemblies (e.g., delivery assembly 100, delivery assembly 200, etc.) disclosed herein. For example, the probe 342 is configured to be located generally within a container of a delivery assembly and can be coupled to an upper neck of the container via a high-integrity flange and gasket fitting 354 that substantially seals connection of the probe 342 to the container.

[0060] In this embodiment, the probe 342 is formed by a pipe 395 (or tube, etc.) defining an inflow portion 348, an outflow portion 350, and a thermal transfer head 346 of the probe 342. As shown in FIG. 10, the thermal transfer head 346 includes multiple coils formed by the pipe 395.

[0061] In operation of a delivery assembly including the probe 342 of this embodiment, the inflow portion 348 of the probe 342 is configured to transport gas from vortex units of the temperature control system to the thermal transfer head 346. The outflow portion 350 of the probe 342 is configured to transport gas from the thermal transfer head 346 out of the container (e.g., to a manifold, to a vent, to a silencer, etc.). And, the thermal transfer head 346 is configured to contact liquid precursor material in a container (via the coils of the pipe 395) to promote contact between the thermal transfer head 346 (i.e., the coils of the pipe 395) and the liquid

precursor material to thereby enhance heat transfer between the liquid precursor material and the thermal transfer head 346. As such, the probe 342 operates to circulate gas received from vortex units through the pipe 395 forming the probe 342 (i.e., through the inflow portion 348, through the coiled thermal transfer head 346, and through the outflow portion 350) generally inside the container thereby helping to adjust and/or control the temperature of liquid precursor material in the container.

[0062] FIGS. 11 and 12 illustrate another example embodiment of a probe 442 (as part of a temperature control system) including one or more aspects of the present disclosure. The probe 442 is similar to the probe 342 previously described and illustrated in FIG. 10 and is suitable for use with delivery assemblies (e.g., delivery assembly 100, delivery assembly 200, etc.) disclosed herein. For example, the probe 442 is configured to be located generally within a container of a delivery assembly and can be coupled to an upper neck of the container via a high-integrity flange and gasket fitting 454 that substantially seals connection of the probe 442 to the container.

[0063] In this embodiment, the probe 442 is formed by a double wall pipe 495 (or tube, etc.) defining an inflow portion 448, an outflow portion 450, and a thermal transfer head 446. As shown in FIG. 11, the thermal transfer head 446 includes multiple coils formed by the double wall pipe 495.

[0064] With reference to FIG. 12 (which is an enlarged longitudinal section view of the inflow portion 448 and the outflow portion 450 of the double wall pipe 495), the double wall pipe 495 used in this embodiment to form the probe 442 includes a first pipe section 496 located within a second pipe section 497. The first pipe section 496 forms a channel 498 extending along a length of the probe 442. And, the second pipe section 497 (positioned around the first pipe section 496) forms a space 499 between the first and second pipe sections 496 and 497 extending along the length of the probe 442. The channel 498 formed by the first pipe section 496 allows gas to flow therethrough (from vortex units of the temperature control system) for use in adjusting and/or controlling the temperature of liquid precursor material in the container to which the probe 442 is coupled. The space 499 formed between the first and second pipe sections 496 and 497 is configured to be filled with an inert liquid. The inert liquid provides a barrier medium against gas in the channel 498 (generated by the vortex units) from moving through walls of the first and second

pipe sections 496 and 497 and into the container if a leak were to form in the pipe sections 496 and 497 (thereby inhibiting risks of contamination in the container).

[0065] In operation of a delivery assembly including the probe 442 of this embodiment, the inflow portion 448 of the probe 442 is configured to transport gas from the vortex units to the thermal transfer head 446. The outflow portion 450 of the probe 442 is configured to transport gas from the thermal transfer head 446 out of the container (e.g., to a manifold, to a vent, to a silencer, etc.). And, the thermal transfer head 446 is configured to contact liquid precursor material in a container (via the coils of the double wall pipe 495) to promote contact between the thermal transfer head 446 (i.e., the coils of the double wall pipe 495) and the liquid precursor material to thereby enhance heat transfer between the liquid precursor material and the thermal transfer head 446. As such, the probe 442 operates to circulate gas received from vortex units through the double wall pipe 495 forming the probe 442 (i.e., through the inflow portion 448, through the coiled thermal transfer head 446, and through the outflow portion 450) generally inside the container thereby helping to adjust and/or control the temperature of liquid precursor material in the container.

[0066] FIG. 13 illustrates another example embodiment of a delivery assembly 500 including one or more aspects of the present disclosure. The delivery assembly 500 of this embodiment is substantially similar to the delivery assembly 100 previously described and illustrated in FIGS. 1-8. For example, the delivery assembly 500 of this embodiment includes a temperature control system having first and second vortex units 534 and 536, a probe 542 disposed generally within a container 502 of the delivery assembly 500, and a manifold (not shown).

[0067] In this embodiment, however, a generally sealed sleeve 501 (e.g., a jacket, etc.) is provided generally around the probe 542 within the container 502. The sleeve 501 is configured to be filled with an inert heat transfer liquid. The inert heat transfer liquid provides a barrier medium against gas in the probe 542 (generated by the vortex units 534 and 536) from moving through walls of the probe 542 and into the container 502 (and reaching precursor material in the container 502) if a leak were to form in the probe 542. The sleeve 501 thereby provides secondary containment within the container 502 and inhibits risks of contamination in the container 502. The heat transfer liquid also provides heat transfer (within the sleeve 501) between the probe 542 and the precursor material in the container 502 such that the sleeve 501, the heat transfer liquid, and the probe 542 operate to adjust

and/or control temperature of the internal environment of the container 502 (and thus the precursor material in the container 502). Any suitable structure(s) may be included inside and/or outside the sleeve 501 to promote contact between the sleeve 501 and the precursor material in the container 502 and/or between the sleeve 501 and the heat transfer liquid within the sleeve 501 and thereby enhance thermal transfer (e.g., fins may be provided to increase surface area for transferring heat between the sleeve 501 and the precursor material in the container 502 and/or between the sleeve 501 and the heat transfer liquid within the sleeve 501, etc.).

[0068] It should be appreciated that delivery assemblies of the present disclosure can provide accurate temperature control of precursor materials within containers of the delivery assemblies, for example, within at least about 0.3 degrees Celsius, and more particularly within about 0.1 degrees Celsius. Control units of the delivery assemblies may be used to provide such temperature control. For example, the control units may be configured to establish optimal timing regimes for operating vortex units (and shuttle valves connecting the vortex units) to provide desired gas flows to the delivery assemblies. Shorter bursts of gas from the vortex units on more regular basis during operation of the delivery assemblies may provide more accurate control.

EXAMPLES

[0069] The following examples are merely illustrative, and are not limiting to the disclosure in any way.

Example 1

[0070] In one example, a container of a delivery assembly similar to the delivery assembly 100 illustrated in FIGS. 1-8 was charged with ten liters of n-hexane (to replicate precursor material in the container), which was maintained in the container at a pressure of about 500 milibars. The n-hexane was then cooled in the container to a temperature of about 10.7 degrees Celsius using a probe and a manifold of a temperature control system of the delivery assembly. Carrier gas was then introduced into the container through the inlet at a flow rate of about 400 Standard Cubic Centimeters per Minute. The carrier gas was allowed to circulate in the n-hexane in the container, and then was removed from the container through an outlet. A thermocouple of the temperature control system continued to monitor the

temperature of the n-hexane in the container and the probe and the manifold adjusted the temperature as necessary.

[0071] The delivery assembly was operated for about five hours in this example, and temperature of the n-hexane in the container was measured during operation. As shown in FIG. 14, temperature of the n-hexane in the container was maintained at a temperature of about 10.7 degrees Celsius for the duration of operation of the delivery assembly.

Example 2

[0072] In another example, a container of a delivery assembly similar to the delivery assembly 200 illustrated in FIG. 9 was charged with ten liters of n-hexane (to replicate precursor material in the container), which was maintained in the container at a pressure of about 500 milibars. The n-hexane was then cooled in the container to a temperature of about 10.3 degrees Celsius using only a probe (and a jacket) of a temperature control system of the delivery assembly. Carrier gas was then introduced into the container through an inlet at a flow rate of about 400 Standard Cubic Centimeters per Minute. The carrier gas was allowed to circulate in the n-hexane in the container, and then was removed from the container through an outlet. A thermocouple of the temperature control system continued to monitor the temperature of the n-hexane in the container and the probe adjusted the temperature as necessary.

[0073] The delivery assembly was operated for about two and one-half hours in this example, and temperature of the n-hexane in the container was measured during operation. As shown in FIG. 15, temperature of the n-hexane in the container was initially adjusted to a temperature of about 10.3 degrees Celsius (e.g., in the first about fifteen minutes of operation, etc.) and then maintained at a temperature of about 10.3 degrees Celsius for the duration of operation of the delivery assembly.

[0074] Specific dimensions and/or values disclosed herein are exemplary in nature and do not limit the scope of the present disclosure.

[0075] The foregoing description of the embodiments has been provided for purposes of illustration and description. It is not intended to be exhaustive or to limit the invention. Individual elements or features of a particular embodiment are

generally not limited to that particular embodiment, but, where applicable, are interchangeable and can be used in a selected embodiment, even if not specifically shown or described. The same may also be varied in many ways. Such variations are not to be regarded as a departure from the invention, and all such modifications are intended to be included within the scope of the invention.

Claims

What is claimed is:

1. An assembly for use in retrieving vapor product from precursor material, the assembly comprising:
 - a container configured to retain precursor material;
 - at least one vortex unit configured to generate flow of gas; and
 - a thermal transfer unit coupled to the container and in thermal communication with the at least one vortex unit, the thermal transfer unit configured to direct the gas from the at least one vortex unit to the container to selectively heat or cool the precursor material in the container.
2. The assembly of claim 1, wherein the at least one vortex unit includes two vortex units each in thermal communication with the thermal transfer unit.
3. The assembly of claim 1, wherein the thermal transfer unit is positioned at least partly within the container.
4. The assembly of claim 1, wherein the thermal transfer unit is positioned at least partly along an external portion of the container.
5. The assembly of claim 1, wherein the precursor material is a liquid.
6. The assembly of claim 1, wherein the assembly is a bubbler.
7. The assembly of claim 1, wherein the thermal transfer unit is a first thermal transfer unit positioned at least partly within the container, the assembly further comprising:
 - a second thermal transfer unit coupled to the container at least partly along an external portion of the container and in thermal communication with the at least one vortex unit;
 - wherein the at least one vortex unit and the first and second thermal transfer units operate together to selectively heat or cool the precursor material in the container.

8. The assembly of claim 7, further comprising a jacket configured to receive the container at least partly therein and to operate with the second thermal transfer unit to selectively heat or cool the precursor material in the container.

9. The assembly of any one of claims 1-8, wherein the thermal transfer unit includes a probe configured to be positioned at least partly within the container and in contact with the precursor material within the container.

10. The assembly of claim 9, wherein the probe includes a venturi configured to circulate the gas from the at least one vortex unit in the probe.

11. The assembly of claim 9, wherein the probe includes at least one fin configured to transfer thermal energy between the probe and the precursor material.

12. The assembly of claim 11, wherein the probe includes a venturi configured to circulate the gas from the at least one vortex unit in the probe.

13. The assembly of claim 9, wherein the probe includes a thermal transfer head having a first chamber, a second chamber spaced apart from the first chamber, and multiple tubes connecting the first chamber and the second chamber such that the gas from the at least one vortex unit can circulate from the first chamber to the second chamber through the multiple tubes.

14. The assembly of claim 13, wherein the probe includes at least one fin configured to transfer thermal energy between the probe and the precursor material and/or a venturi configured to circulate the gas from the at least one vortex unit in the probe.

15. The assembly of claim 9, wherein the probe includes a pipe defining multiple coils toward an end portion of the pipe thereby defining a thermal transfer head of the probe.

16. The assembly of claim 9, further comprising a sleeve positioned around at least part of the probe and configured to be filled with an inert heat transfer liquid.

17. A temperature control system for use with a precursor delivery assembly to selectively heat or cool precursor material in a container of the precursor delivery assembly, the temperature control system comprising:

at least one vortex unit; and

a probe coupled to the at least one vortex unit;

wherein the probe is configured to be positioned at least partly within the container of the delivery assembly to direct gas from the at least one vortex unit to the container to selectively heat or cool precursor material in the container.

18. The temperature control system of claim 17, wherein the at least one vortex unit includes two vortex units each coupled to the probe.

19. The temperature control system of claim 17, wherein the probe includes a venturi configured to circulate the gas from the at least one vortex unit in the probe.

20. The temperature control system of claim 17, wherein the probe includes at least one fin configured to transfer thermal energy between the probe and the precursor material.

21. The temperature control system of claim 17, wherein the probe includes a thermal transfer head having a first chamber, a second chamber spaced apart from the first chamber, and multiple tubes connecting the first chamber and the second chamber such that the gas from the at least one vortex unit can circulate from the first chamber to the second chamber through the multiple tubes.

22. The temperature control system of claim 21, wherein the probe includes at least one fin configured to transfer thermal energy between the probe and the precursor material and/or a venturi configured to circulate the gas from the at least one vortex unit in the probe.

23. The temperature control system of claim 17, further comprising:
an external thermal transfer unit coupled to the at least one vortex unit;
wherein the external thermal transfer unit is configured to be positioned at least partly along an external portion of the container; and
wherein the probe and the external thermal transfer unit are configured to operate together to selectively heat or cool the precursor material in the container.

24. The temperature control system of claim 23, further comprising a jacket configured to receive the container at least partly therein and to operate with the external thermal transfer unit to selectively heat or cool the precursor material in the container.

25. The temperature control system of any one of claims 17-24, further comprising a sleeve positioned around at least part of the probe and configured to be filled with an inert heat transfer liquid.

26. A precursor delivery assembly comprising the temperature control system of claim 17.

27. A method for monitoring and/or controlling temperature of a precursor material in a delivery assembly, the method comprising:

operating a first vortex unit and/or a second vortex unit to adjust a temperature of a precursor material in a delivery assembly to about a target temperature; and

selectively operating the first vortex unit and the second vortex unit to maintain the temperature of the precursor material in the delivery assembly at about the target temperature.

28. The method of claim 27, wherein the first vortex unit is configured to generate a flow of gas having a temperature greater than the target temperature of the precursor material, and wherein the second vortex unit is configured to generate a flow of gas having a temperature lower than the target temperature of the precursor material.

29. The method of claim 28, wherein the first vortex unit and the second vortex unit are both configured to generate a flow of gas having a temperature within about ten degrees Celsius of the target temperature of the precursor material.

30. The method of claim 27, further comprising measuring the temperature of the precursor material before and/or after adjusting the temperature of the precursor material.

31. The method of claim 27, wherein selectively operating the first vortex unit and the second vortex unit includes operating the first vortex unit alone and then operating the second vortex unit alone to maintain the temperature of the precursor material in the delivery assembly at about the target temperature.

32. The method of claim 27, further comprising maintaining the temperature of the precursor material in the delivery assembly within about 0.3 degrees Celsius of the target temperature after adjusting the temperature of the precursor material in the delivery assembly to the target temperature.

33. The method of claim 32, wherein maintaining comprises maintaining the temperature of the precursor material in the delivery assembly within about 0.1 degrees Celsius of the target temperature after adjusting the temperature of the precursor material in the delivery assembly to the target temperature.

34. The method of any one of claims 27-33, further comprising circulating gas from the first and/or second vortex units through a probe positioned at least partly within the delivery assembly to help adjust the temperature of the precursor material in the delivery assembly to about the target temperature and/or to help maintain the temperature of the precursor material in the delivery assembly at about the target temperature.

35. The method of claim 34, further comprising circulating gas from the first and/or second vortex units to an external thermal transfer unit positioned at least partly along an external portion of the container to help adjust the temperature of the precursor material in the delivery assembly to about the target temperature and/or to

help maintain the temperature of the precursor material in the delivery assembly at about the target temperature.

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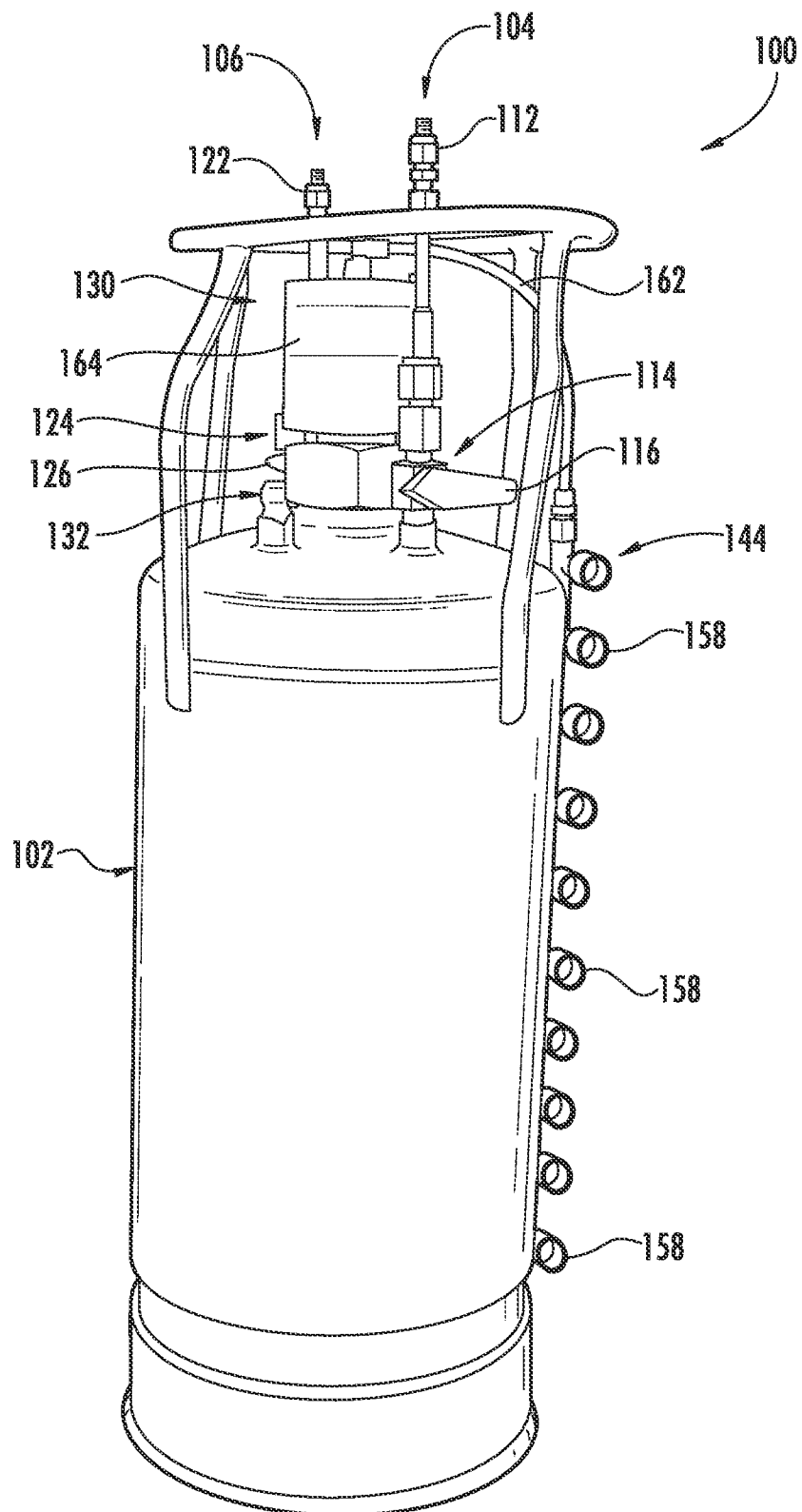


FIG. 1

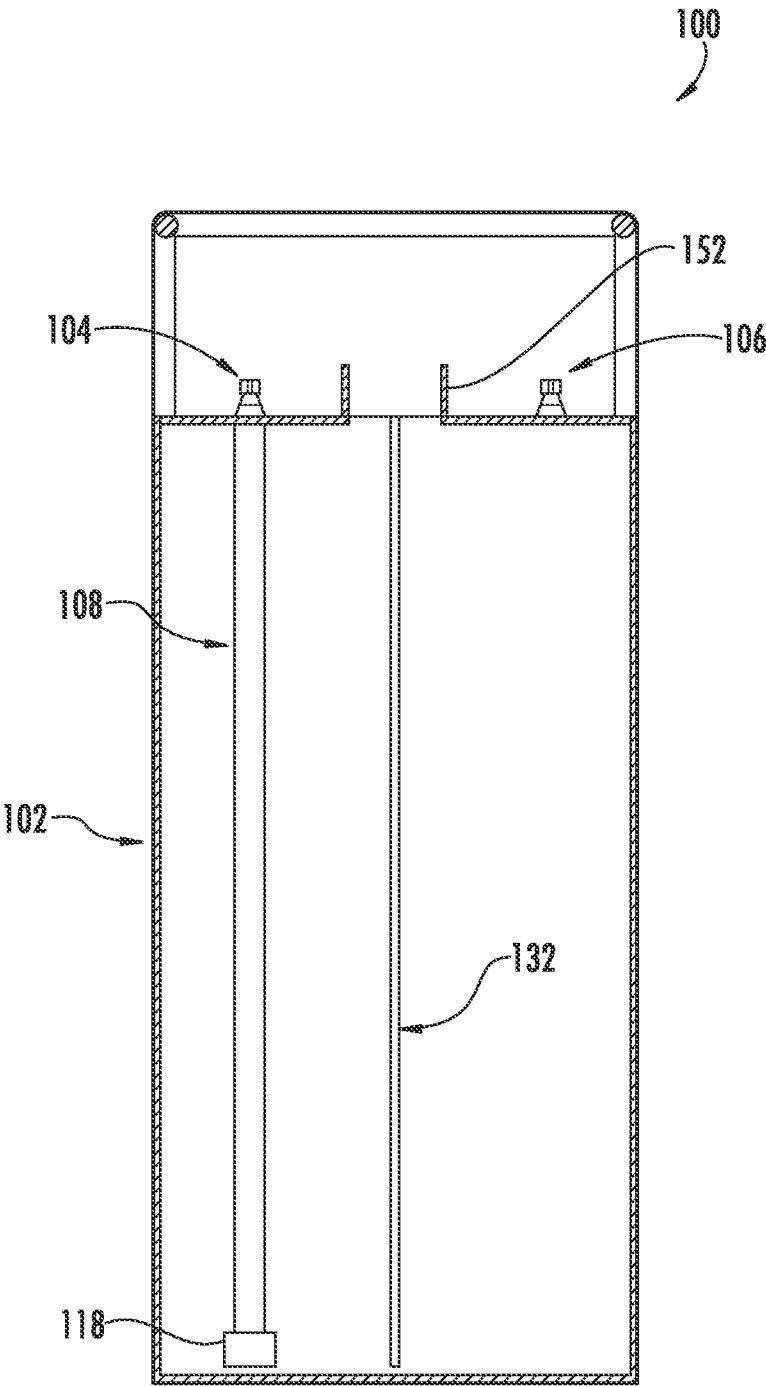
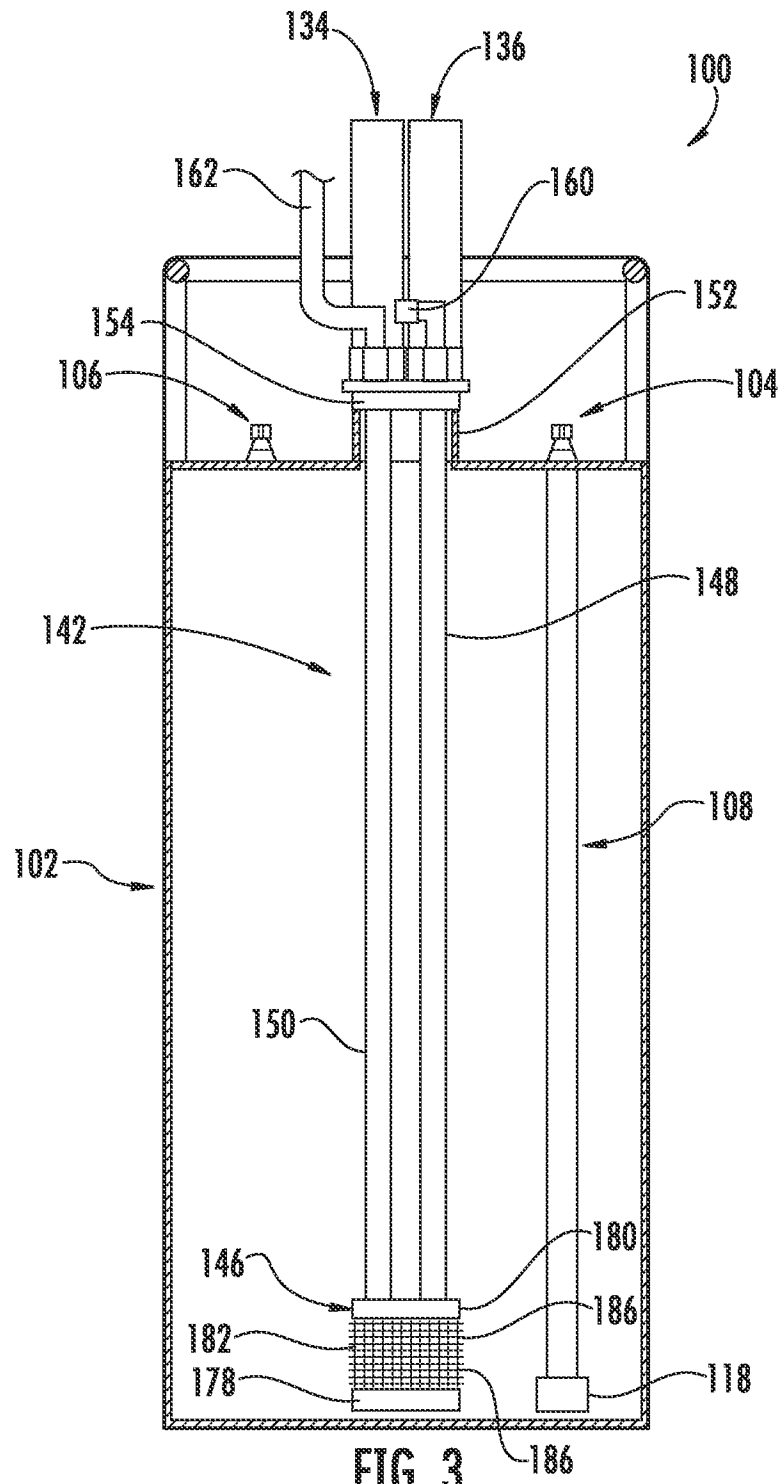


FIG. 2

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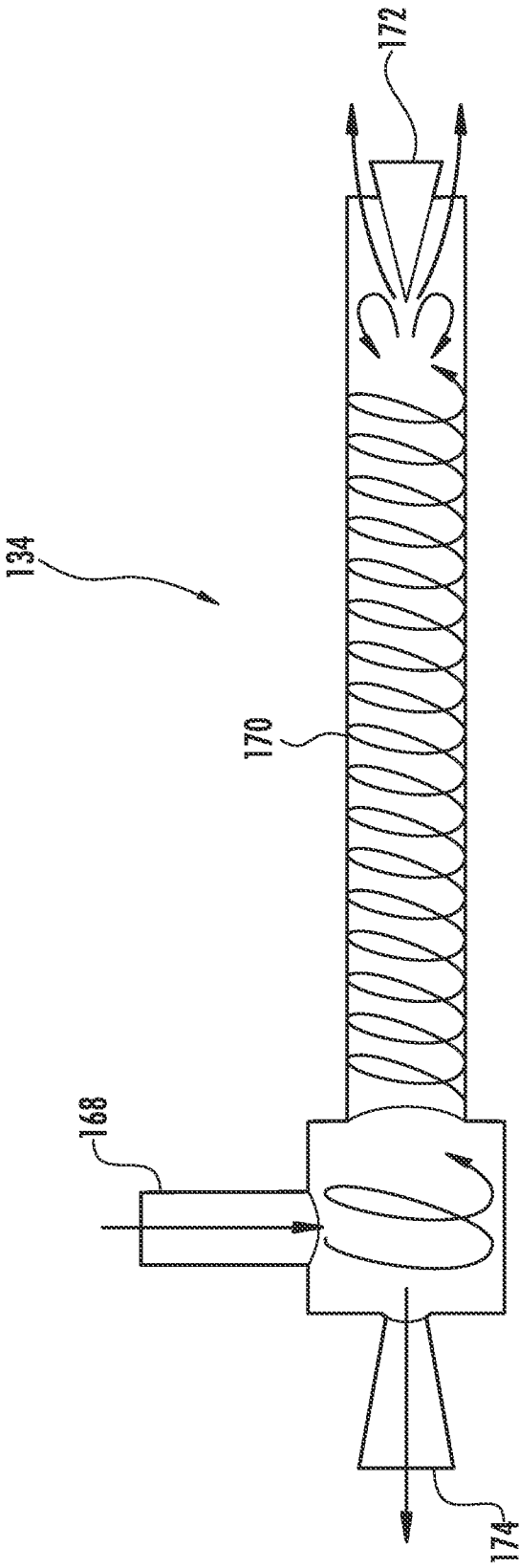


FIG. 4

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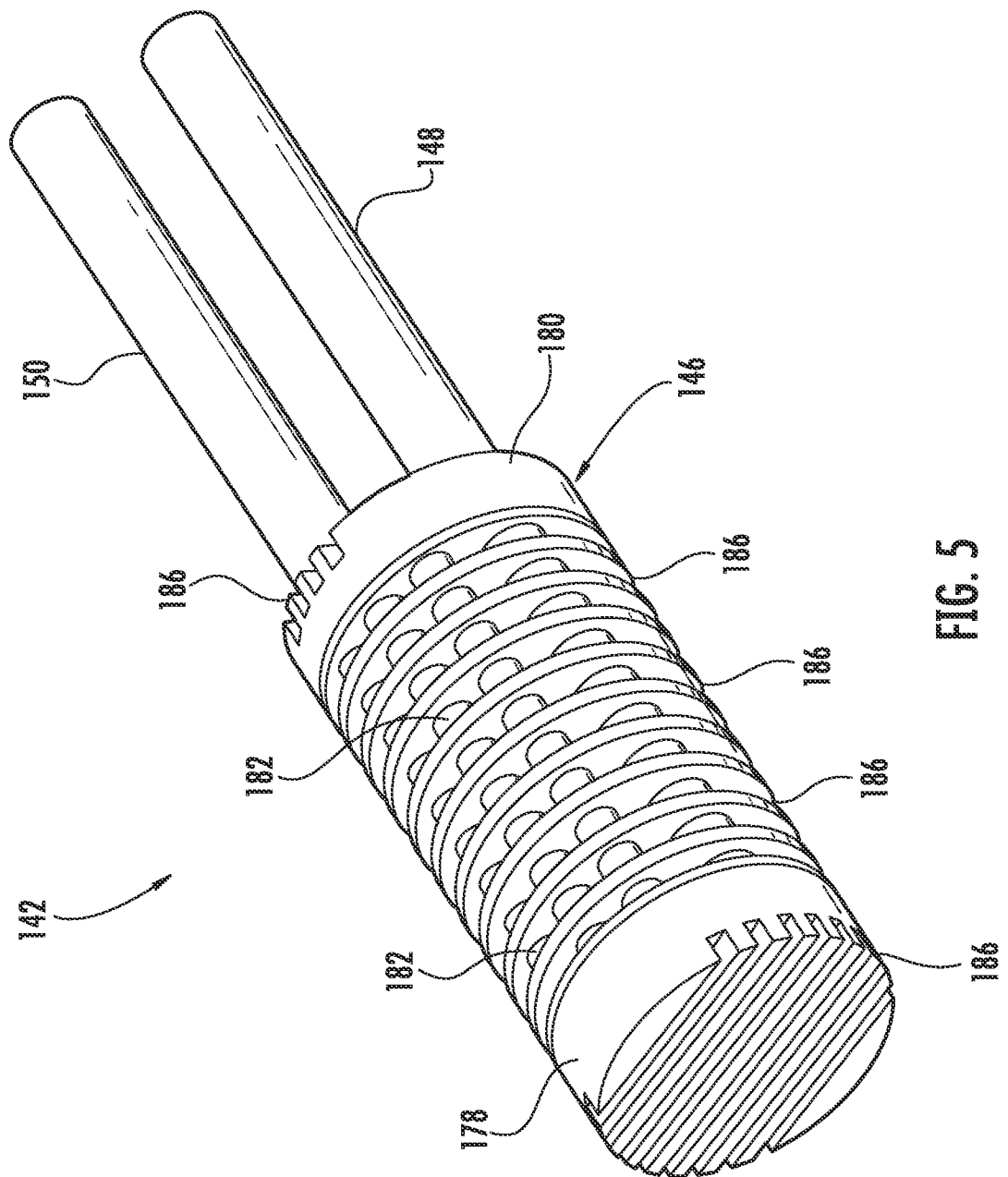
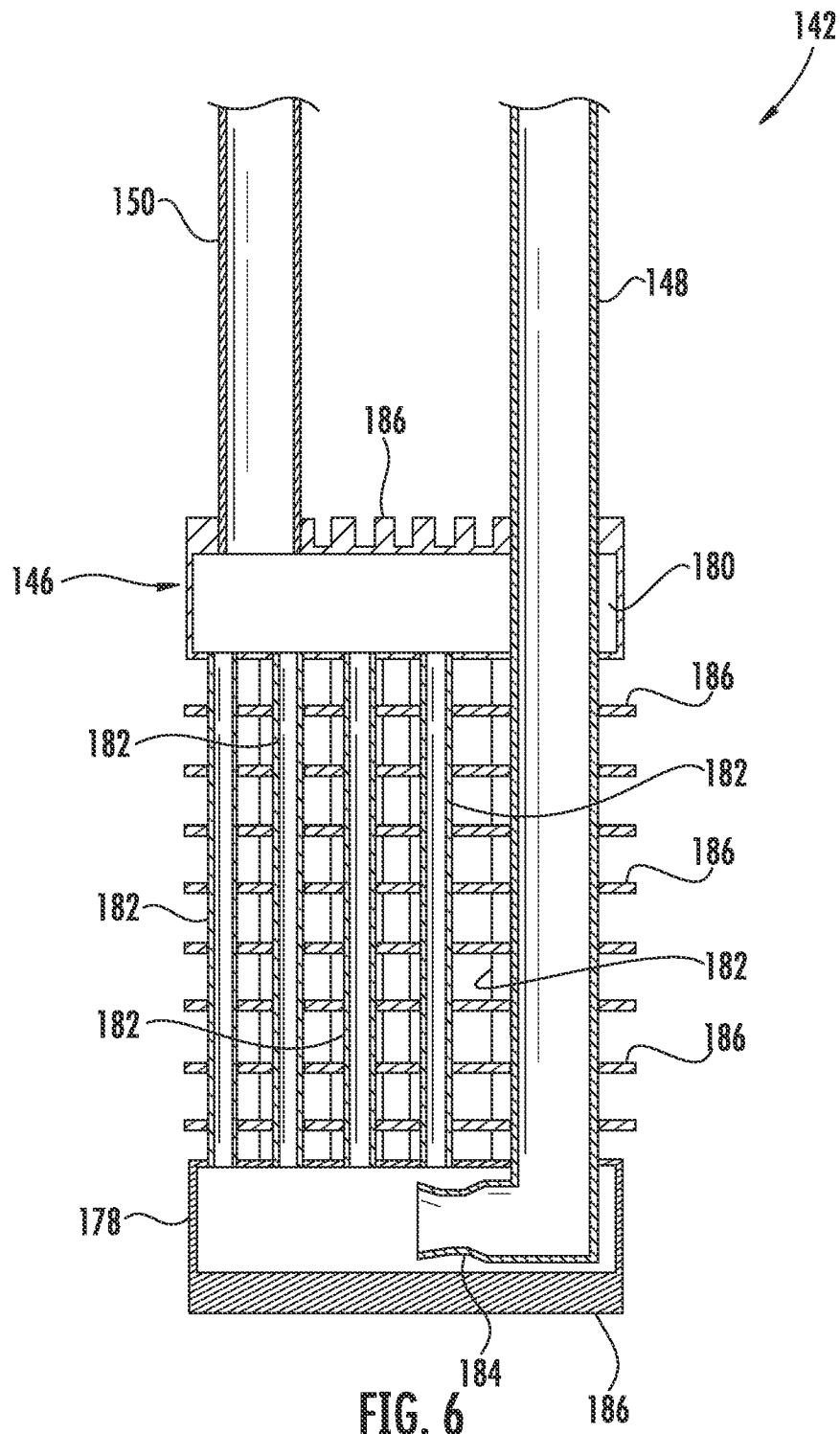


FIG. 5

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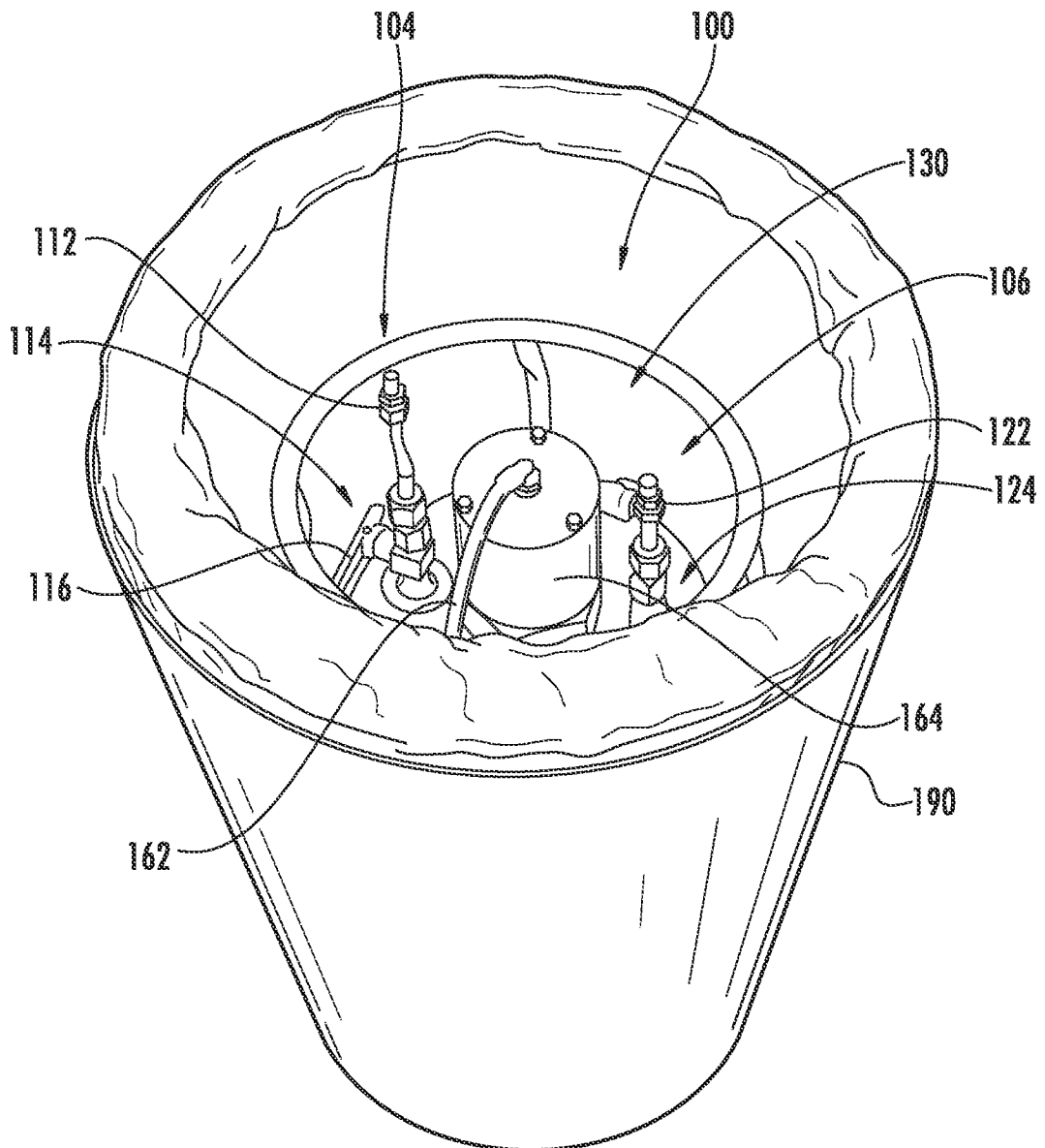


FIG. 7

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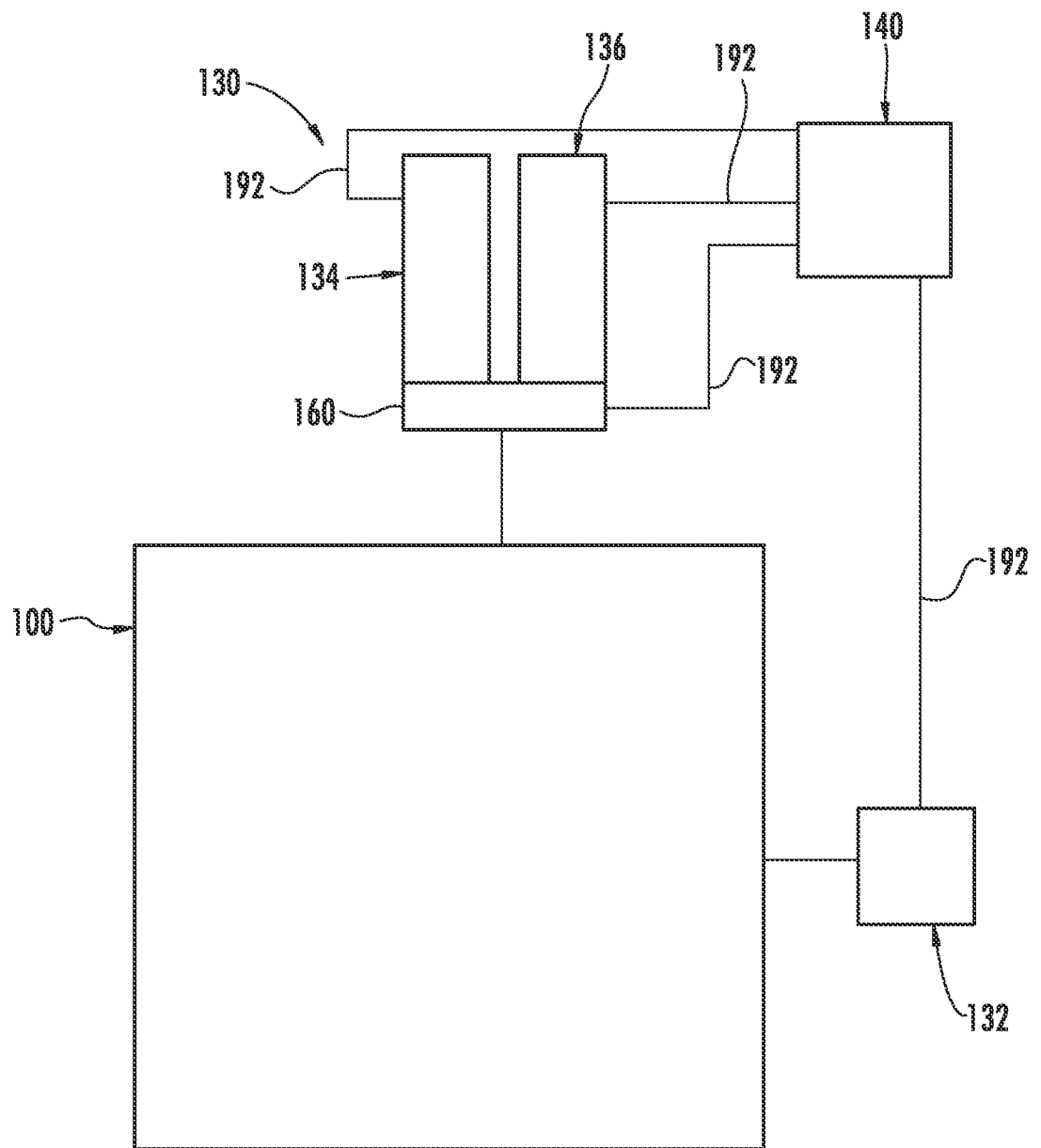


FIG. 8

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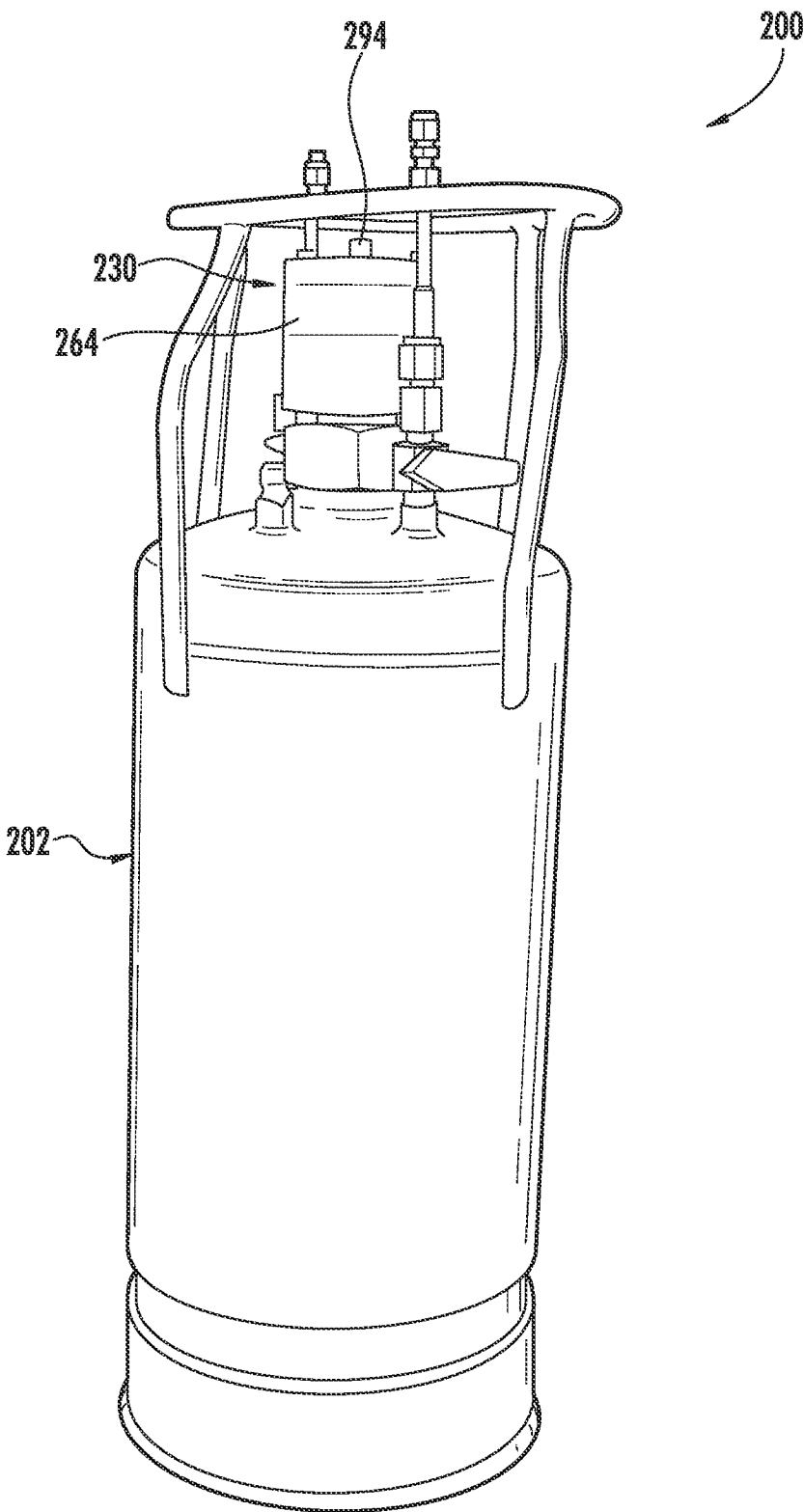


FIG. 9

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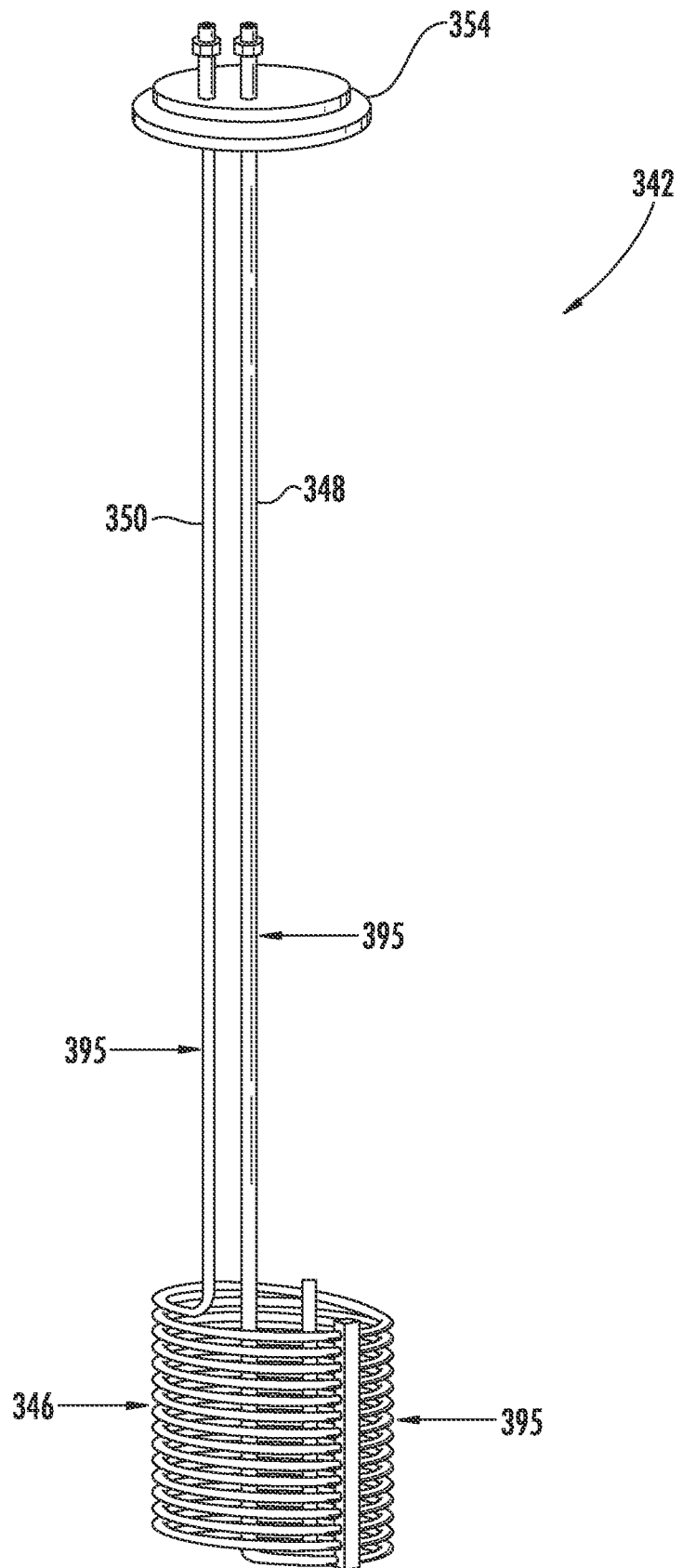
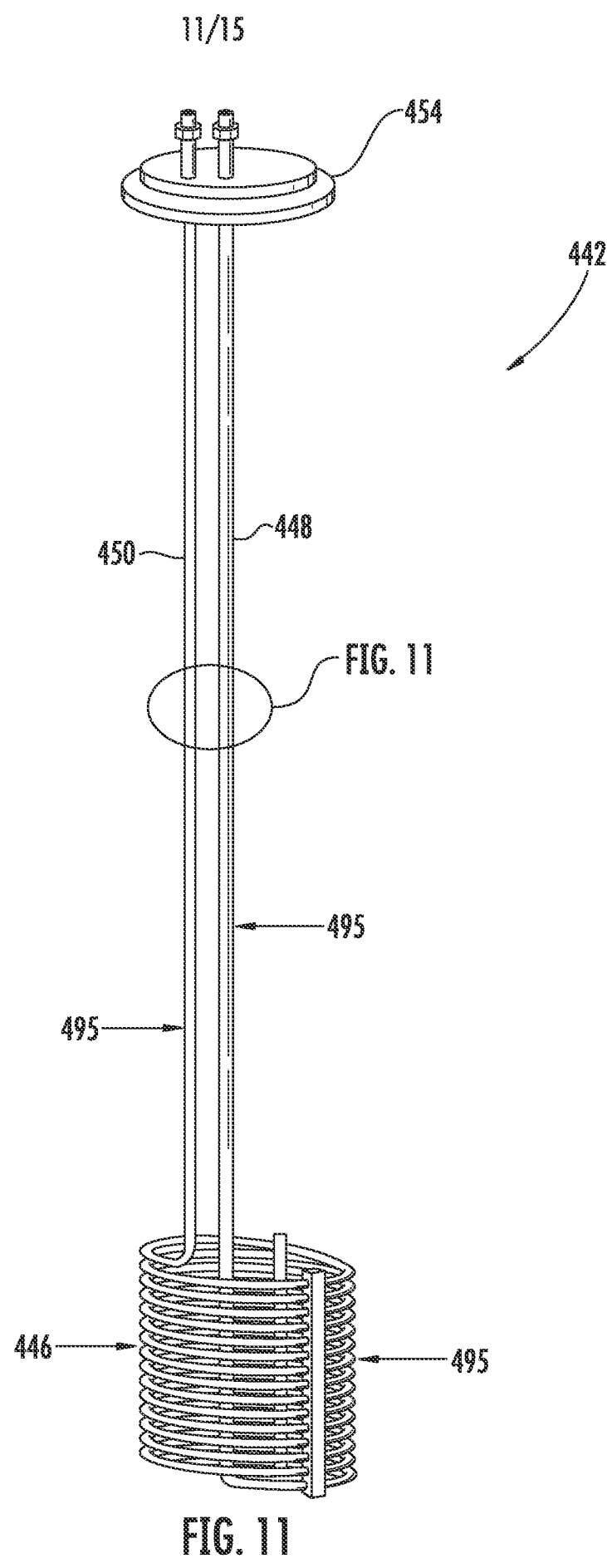


FIG. 10



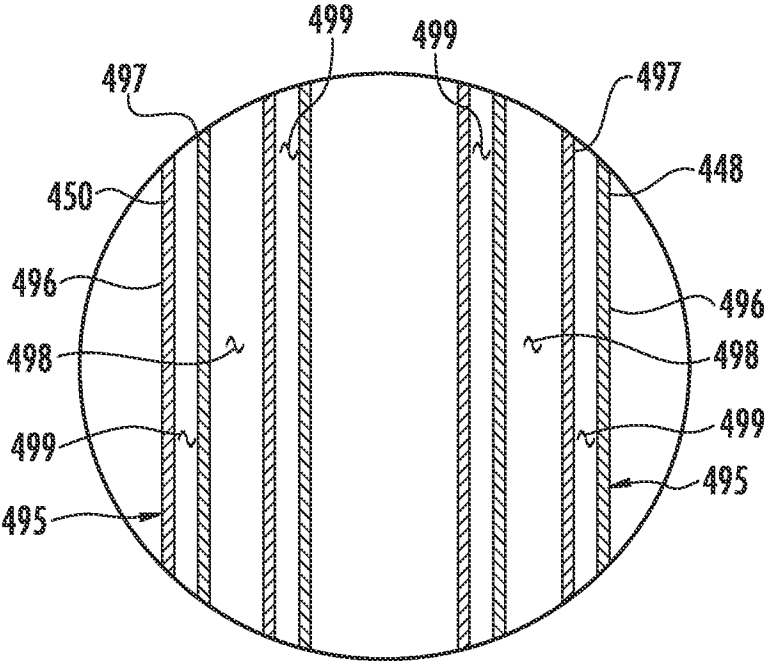


FIG. 12

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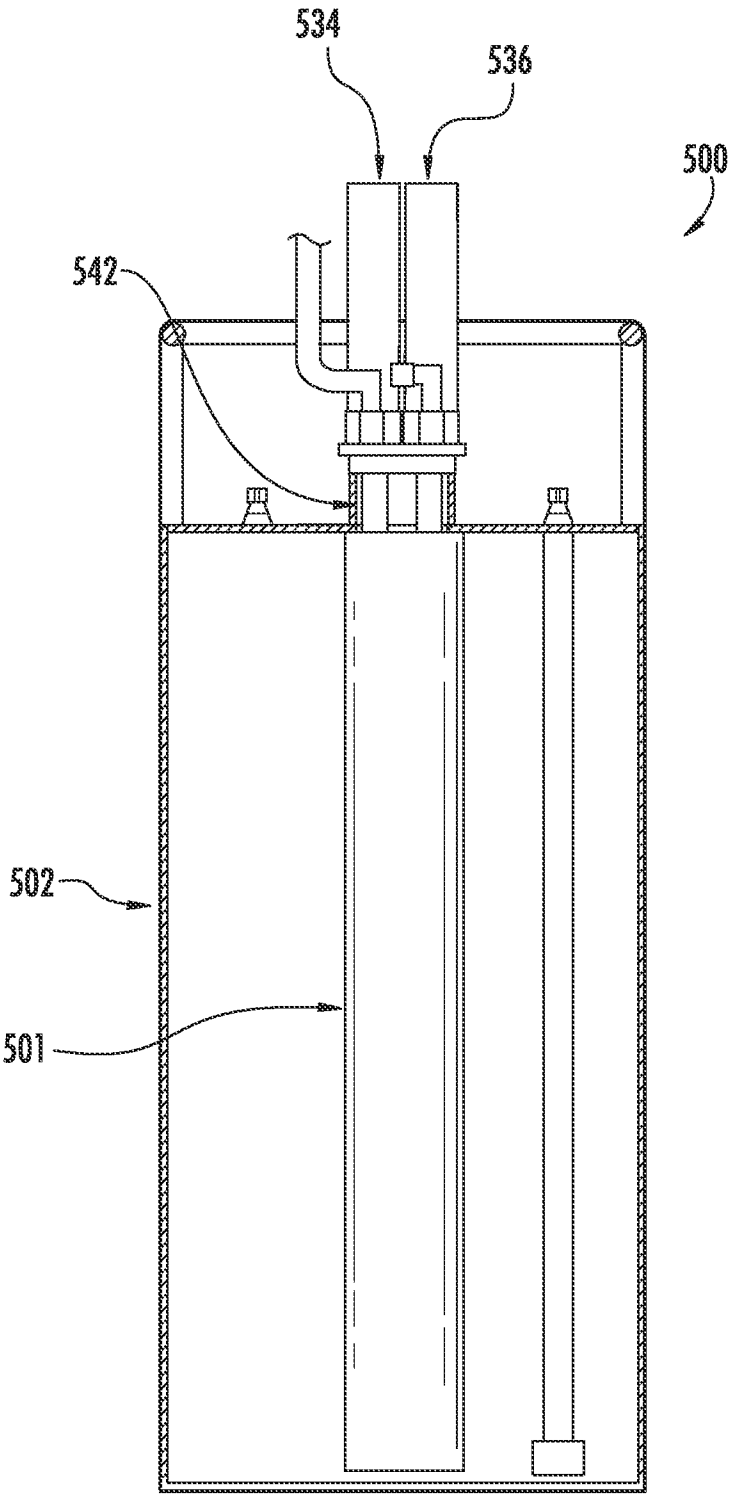


FIG. 13

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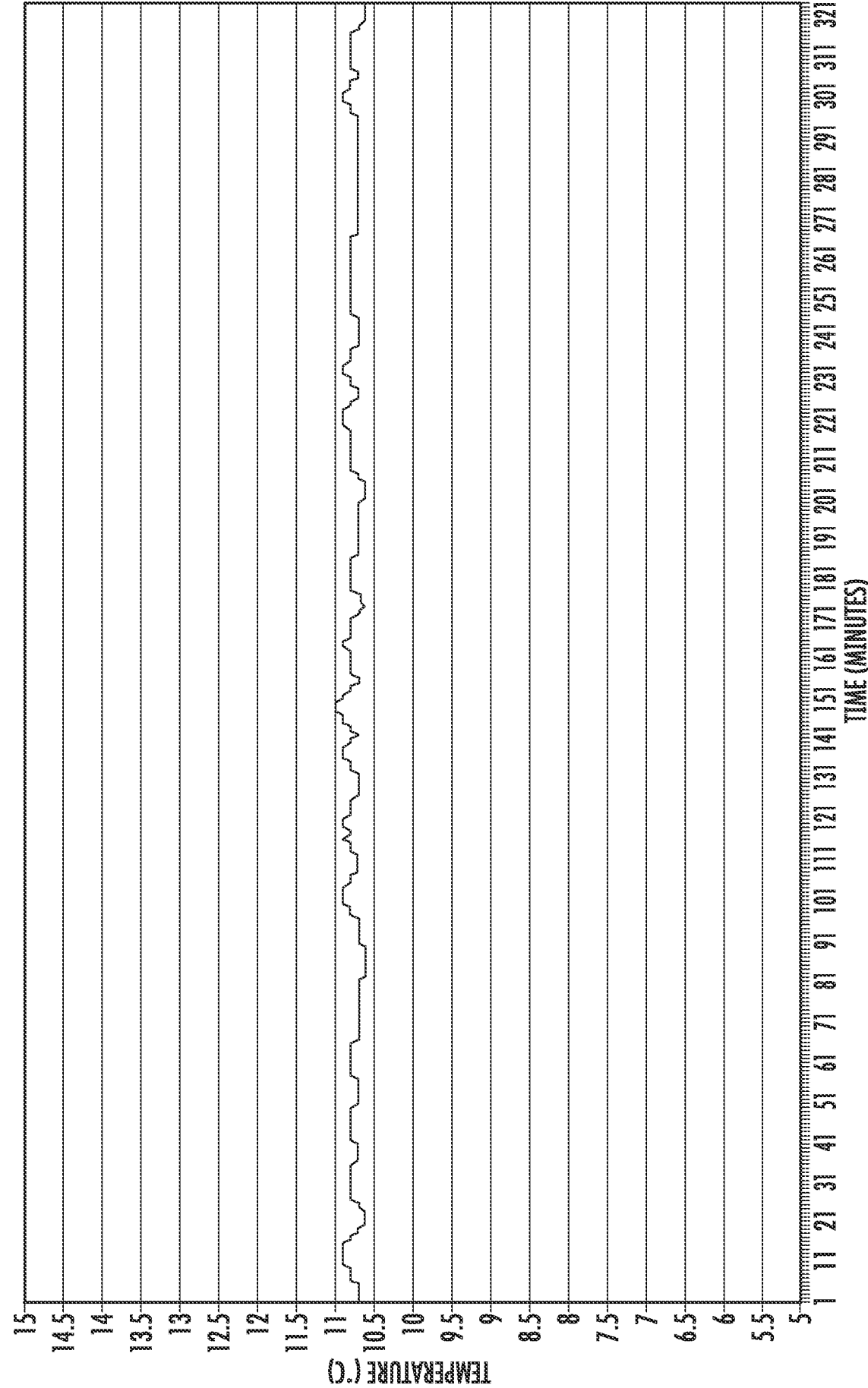


FIG. 14

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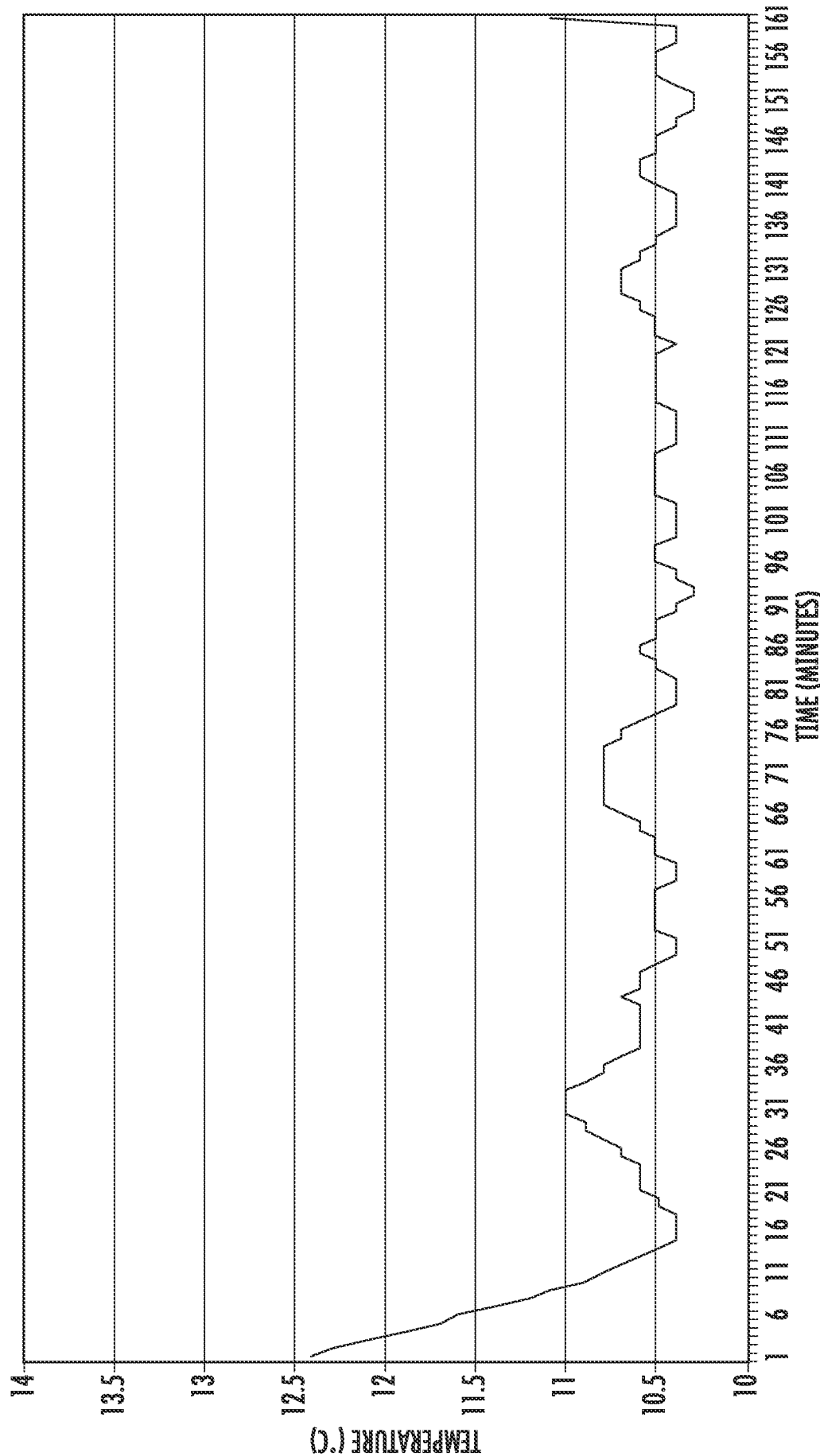


FIG. 15

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2011/026980

A. CLASSIFICATION OF SUBJECT MATTER
INV. C23C16/00 C23C16/448 C23C16/455 C23C16/52
ADD.

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)
C23C

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 practical, search terms used)

EPO-Internal, INSPEC, COMPENDEX

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 01/29491 A1 (MOLINAR LTD [GB]; GEE PETER JOHN [GB]; LOVATT PHILIP JOHN [GB]; PRINCE) 26 April 2001 (2001-04-26)	1,3,5,6
A	page 15, line 15 - line 22; claim 1; figure 7	2,4,7-16
A	----- RU 2 151 970 C1 (ZAO SIGMA GAZ) 27 June 2000 (2000-06-27) abstract; figure 1	1-16
A	----- US 2008/092816 A1 (BIRTCHE CHARLES MICHAEL [US] ET AL) 24 April 2008 (2008-04-24) page 4, paragraph 43 - paragraph 45; claim 1; figure 1	1-16
	----- -/-	



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 document 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

24 May 2011

Date of mailing of the international search report

18/08/2011

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Teppo, Kirsi-Marja

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2011/026980

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2003/010040 A1 (TORRES ROBERT [US] ET AL TORRES JR ROBERT [US] ET AL) 16 January 2003 (2003-01-16) page 6, paragraph 67 - paragraph 68; figures 1, 2 -----	1-16
A	WO 02/33143 A1 (PRIMAXX INC [US]) 25 April 2002 (2002-04-25) claim 1; figures 5,6 -----	1-16

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2011/026980

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

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

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

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

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

see additional sheet

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

1-16 see additional sheet(s)

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

Information on patent family members

International application No

PCT/US2011/026980

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FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-16

These claims are directed to an assembly for use in retrieving vapor product from precursor material, the assembly comprising:
a container configured to retain precursor material;
at least one vortex unit configured to generate flow of gas;
and
a thermal transfer unit coupled to the container and in thermal communication with the at least one vortex unit, the thermal transfer unit configured to direct the gas from the at least one vortex unit to the container to selectively heat or cool the precursor material in the container.

2. claims: 17-26

These claims are directed to a temperature control system for use with a precursor delivery assembly to selectively heat or cool precursor material in a container of the precursor delivery assembly, the temperature control system comprising:
at least one vortex unit; and
a probe coupled to the at least one vortex unit;
wherein the probe is configured to be positioned at least partly within the container of the delivery assembly to direct gas from the at least one vortex unit to the container to selectively heat or cool precursor material in the container.

3. claims: 27-35

These claims are directed to a method for monitoring and/or controlling temperature of a precursor material in a delivery assembly, the method comprising:
operating a first vortex unit and/or a second vortex unit to adjust a temperature of a precursor material in a delivery assembly to about a target temperature; and
selectively operating the first vortex unit and the second vortex unit to maintain the temperature of the precursor material in the delivery assembly at about the target temperature.
