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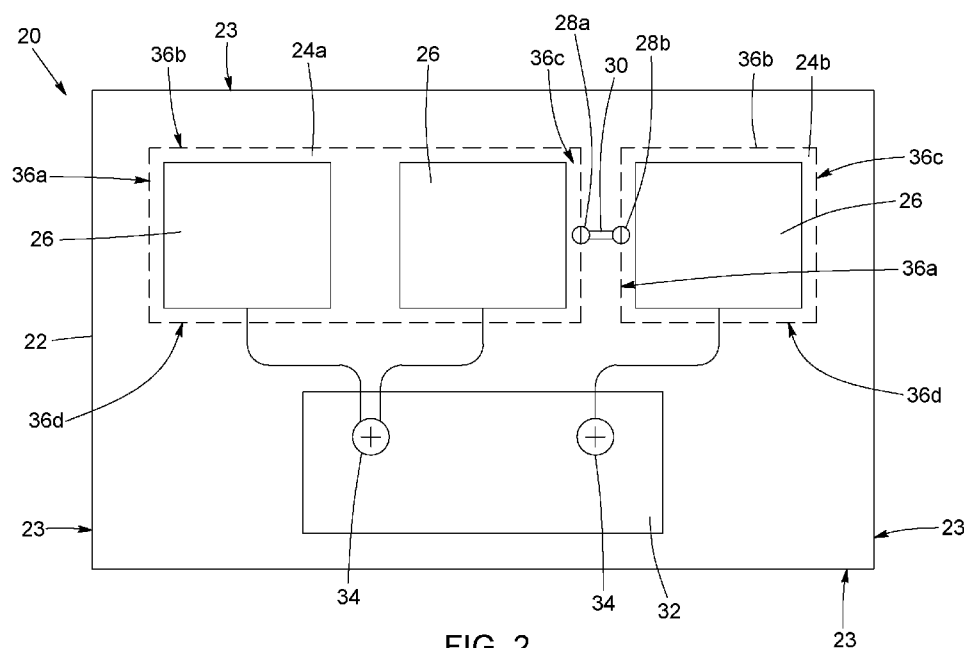


FIG. 2

(57) Abstract: There is provided a gas chromatography modular oven. The modular oven includes a main enclosure, panel(s) and thermal plate(s). The main enclosure includes a backwall and sidewalls defining an internal volume. The sidewalls include a plurality of panel-engaging structures defining multiple panel-mounting positions within the internal volume. The panel(s) are releasably engageable with the panel-engaging structures to divide the main enclosure into individual cells. The thermal plate(s) are releasably engageable with the backwall within an associated one of the individual cells, each thermal plate being operable to set an operation temperature in the associated individual cell, thereby creating temperature-controlled zones within the gas chromatography modular oven. An explosion-proof gas chromatography modular oven is also provided. A gas chromatography column cartridge mountable into a modular oven is also provided.

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GAS CHROMATOGRAPHY MODULAR OVEN

TECHNICAL FIELD

[001] The technical field generally relates to chromatography applications, and more particularly to a gas chromatography oven.

5 **BACKGROUND**

[002] In the field of gas chromatography (GC), laboratory and process gas chromatographs are central in the design of experiments for various analytical chemistry applications. Available gas chromatographs typically share similar characteristics, components and functions. For example, they usually include one
10 large ramping oven on top of which are installed GC components, such as detectors, sample concentrators, valves, columns, and the like.

[003] Despite typically providing enough space for the installation of some custom parts, available gas chromatographs can sometimes be difficult to customize. Indeed, customizing a gas chromatograph can not only require a substantial
15 amount of time to a system integrator, but can also be associated with non-negligible costs. Moreover, designing custom parts, such as, for example, oven boxes for isothermal oven, is in itself time-consuming, and known to be expensive.

[004] There is thus a need for a gas chromatograph architecture that addresses at least some of the challenges presented above.

20 **SUMMARY**

[005] In accordance with one aspect, there is provided a gas chromatography modular oven, including a main enclosure, one or more panel and one or more thermal plate. The main enclosure includes a backwall and sidewalls defining an internal volume, the sidewalls includes a plurality of panel-engaging structures
25 defining multiple panel-mounting positions within the internal volume. The one or more panels are releasably engageable with the panel-engaging structures to divide the main enclosure into individual cells. The one or more thermal plates are

releasably engageable with the backwall within an associated one of the individual cells, each thermal plate being operable to set an operation temperature in the associated individual cell, thereby creating temperature-controlled zones within the gas chromatography modular oven.

- 5 **[006]** In some embodiments, the backwall and sidewalls are made from a respective material stack. The respective material stack includes a thermally insulating layer sandwiched between two thermally conductive layers.

- 10 **[007]** In some embodiments, the one or more panels includes one or more connecting channels extending therethrough and configured to allow a passage of a gas chromatography column.

[008] In some embodiments, the gas chromatography modular oven further includes mechanical fasteners removably engageable with the one or more panels to attach the one or more panels to an associated one of the backwall and sidewalls.

- 15 **[009]** In some embodiments, the panel-engaging structures include slots formed in the sidewalls, the one or more panels being slidably engageable with the slots.

[0010] In some embodiments, the gas chromatography modular oven further includes a first impervious seal extending along at least a portion of the slots.

- 20 **[0011]** In some embodiments, the gas chromatography modular oven further includes a second impervious seal extending along at least a portion of a periphery of the one or more panels.

- 25 **[0012]** In some embodiments, wherein each thermal plate includes: a mounting plate made of a conductive material, a heating element contacting the mounting plate; a temperature sensor contacting the mounting plate; and spacers attachable to the mounting to maintain the mounting plate spaced apart from the backwall.

[0013] In some embodiments, the mounting plate includes a cut provided therethrough.

[0014] In some embodiments, the gas chromatography modular oven further includes a temperature controller operatively connected to the one or more thermal plates, the temperature controller having an associated one of the temperature sensor as an input and an associated one of the heating element as an output.

5 **[0015]** In some embodiments, the temperature controller is a proportional-integral-derivative controller.

[0016] In some embodiments, the one or more thermal plates include one or more corresponding thermoelectric devices.

10 **[0017]** In some embodiments, at least one of the one or more panels, backwall and mounting plate includes one or more mounting holes to receive one or more associated gas chromatography components therethrough.

[0018] In some embodiments, each panel has one or more notches engageable with corresponding one or more notches of another one of the one or more panels.

15 **[0019]** In accordance with another aspect, there is provided a gas chromatography modular oven including a main enclosure, individual cells inside the main enclosure and a chromatography column cartridge. The main enclosure includes a backwall and sidewalls defining an internal volume. The chromatography column cartridge is releasably engageable with the backwall within an associated one of the individual cells. The chromatography column cartridge includes a chamber for
20 receiving at least a portion of a chromatography column therein, opposed ports for allowing a passage of an air flow in the chamber and a heating module provided upstream of the chamber, the heating module being operable for generating, heating and circulating the air flow in the chamber.

25 **[0020]** In some embodiments, the sidewalls include a plurality of panel-engaging structures defining multiple panel-mounting positions within the internal volume.

[0021] In some embodiments, the gas chromatography modular oven further includes one or more panels releasably engageable with the panel-engaging structure to divide the main enclosure into the individual cells.

[0022] In some embodiments, the chamber is donut-shaped.

- 5 **[0023]** In some embodiments, the backwall and sidewalls are made from a respective material stack, the respective material stack including a thermally insulating layer sandwiched between two thermally conductive layers.

- [0024]** In some embodiments, the one or more panels includes one or more connecting channels extending therethrough and configured to allow a passage of
10 a gas chromatography column.

[0025] In some embodiments, the gas chromatography modular oven further includes mechanical fasteners removably engageable with the one or more panels to attach the one or more panels to an associated one of the backwall and sidewalls.

- 15 **[0026]** In some embodiments, the panel-engaging structures include slots formed in the sidewalls, the one or more panels being slidably engageable with the slots.

[0027] In some embodiments, the gas chromatography modular oven further includes a first impervious seal extending along at least a portion of the slots.

- [0028]** In some embodiments, the gas chromatography modular oven further
20 includes a second impervious seal extending along at least a portion of a periphery of the one or more panels.

[0029] In some embodiments, the heating module includes a pipe in fluid communication with the chamber, a heating element contacting the pipe and a temperature sensor contacting the pipe.

- 25 **[0030]** In some embodiments, the heating element is a thermally conductive wire wound around the pipe.

[0031] In some embodiments, the gas chromatography modular oven further includes a temperature controller operatively connected to the heating module, the temperature controller having the temperature sensor as an input and the heating element as an output.

5 **[0032]** In some embodiments, the temperature controller is a proportional-integral-derivative controller.

[0033] In some embodiments, the gas chromatography modular oven further includes one or more thermal plates releasably engageable with the backwall within another associated one of the individual cells, each thermal plate being
10 operable to set an operation temperature in the another associated individual cell.

[0034] In some embodiments, at least one of the one or more panels and the backwall includes one or more mounting holes to receive one or more associated gas chromatography components therethrough.

[0035] In some embodiments, each panel has one or more notches engageable
15 with corresponding one or more notches of another one of the one or more panels.

[0036] In some embodiments, the gas chromatography modular oven further includes a secondary enclosure for receiving the heating module therein, the secondary enclosure being isolated from the chamber.

[0037] In some embodiments, the secondary enclosure includes an inlet port and
20 an outlet port in fluid communication with a respective one of the opposed ports of the chromatography column cartridge.

[0038] In some embodiments, the gas chromatography modular oven further includes a cover pivotally securable to a front portion of the main enclosure.

[0039] In accordance with another aspect, there is provided a gas chromatography
25 modular oven including a main enclosure including a backwall and sidewalls defining an internal volume and one or more open-ended structures releasably engageable with the backwall. Each open-ended structure includes a thermal plate

and one or more panels engaged with the thermal plate to delimit a temperature-controlled zone, the thermal plate being operable to set an operation temperature in the temperature-controlled zone.

5 **[0040]** In some embodiments, the backwall and sidewalls are made from a respective material stack. The respective material stack includes a thermally insulating layer sandwiched between two thermally conductive layers.

[0041] In some embodiments, the one or more panels includes one or more connecting channels extending therethrough and configured to allow a passage of a gas chromatography column.

10 **[0042]** In some embodiments, the thermal plate includes, a mounting plate made of a conductive material, a heating element contacting the mounting plate, a temperature sensor contacting the mounting plate and spacers attachable to the mounting to maintain the mounting plate spaced apart from the backwall.

15 **[0043]** In some embodiments, the mounting plate includes a cut provided therethrough.

[0044] In some embodiments, the gas chromatography modular oven further includes a temperature controller operatively connected to the thermal plate, the temperature controller having a temperature sensor as an input and a heating element as an output.

20 **[0045]** In some embodiments, the temperature controller is a proportional-integral-derivative controller.

[0046] In some embodiments, the thermal plate includes one or more thermoelectric devices.

25 **[0047]** In some embodiments, at least one of the one or more panels, backwall and mounting plate includes one or more mounting holes to receive one or more associated gas chromatography components therethrough.

[0048] In accordance with another aspect, there is a provided a gas chromatography (GC) modular oven for use in analytical chemistry applications. The GC modular oven includes at least one individual temperature cell defining at least one temperature-controlled zone.

- 5 **[0049]** The GC modular oven includes a main enclosure defining an internal volume into which may be mounted different GC parts and components. The GC modular oven may be provided with a door for accessing the internal volume when needed.

- [0050]** In some embodiments, the main enclosure has a rectangular cross-section and has dimensions ranging from approximately 10 to 50 cm x 10 to 50 cm x 5 to 20 cm (height x width x depth).

- [0051]** The main enclosure includes sidewalls defining the internal volume of the GC modular oven. In some embodiments, the main enclosure includes five sidewalls and the door. The sidewalls may be thermally insulated. In some
15 embodiments, the sidewalls are made from a stack of materials. A layer made of an insulating material may be positioned between two layers of thermally conductive material.

- [0052]** In some embodiments, the GC modular oven includes a plurality of individual temperature cells. The GC modular oven may include two, four or six
20 individual temperature cells. The temperature may be maintained at a predetermined temperature and may be controlled using a temperature controller.

- [0053]** Each one of the individual temperature cells is confined within four side panels and a back panel. In some embodiments, at least one of the side panels includes holes for mounting GC accessories and permitting the operational
25 communication between two adjacent cells.

[0054] At least one of the side panels and the back panel includes standard mounting holes compatible with dimensions of conventional chromatographic components.

[0055] The side panels may be provided with thermal insulation. In some embodiments, the thermal insulation is a stack of material made of an insulating material positioned between two thermally conductive layers.

[0056] In some embodiments, the individual temperature cells are defined by partition walls. The partition walls are removably mountable to the main enclosure of the GC modular oven. The main enclosure may include slots provided in its internal surface. The partition walls are slidably engageable with the slots. When the partition walls are engaged with the slots, mechanical fasteners may be used to fix the partition walls in position.

[0057] The GC modular oven includes at least one thermal plate for controlling and adjusting the temperature within the individual temperature cells.

[0058] In some embodiments, the thermal plate is a hot plate. In other embodiments, the thermal plate is a cooling system. The cooling system may be based on a Peltier device.

[0059] In some embodiments, the thermal plate includes a mounting plate. The mounting plate may be a monolithic piece and may be thermally conductive. The thermal plate may include a cut out for accessing one or more rotary valve actuator(s) provided outside of the GC modular oven.

[0060] In some embodiments, the thermal plate includes one or more spacer(s) mechanically affixed to the mounting plate. The spacer(s) may be made of a thermally insulating material. In some embodiments, the spacers are legs provided in each corner of the thermal plate. The legs may include an aperture therethrough to allow a passage of mechanical fastener to fasten the thermal plate to the main enclosure of the GC modular oven.

[0061] In some embodiments, the thermal plate includes a heater and a corresponding temperature sensor. In some embodiments, the heater and the temperature sensor are in thermal connection with the mounting plate. The heater and the temperature sensor may be mounted below the mounting plate.

[0062] In some embodiments, the thermal plates are maintained at isothermal temperature, or ramped at a predetermined rate.

[0063] In some embodiments, the thermal plates are removably mountable and removable into or from the GC modular oven.

5 **[0064]** In some embodiments, the thermal plate includes a thermoelectric device. The thermoelectric device may be a device based on the Seebeck or Peltier effect.

[0065] In some embodiments, the GC modular oven includes a gas inlet and a gas outlet for ensuring the distribution of gas within the GC modular oven.

10 **[0066]** The individual temperature cells may include electronics, mechanical, electromechanical or optical components and/or devices required for the functioning of the GC modular oven.

[0067] In some embodiments, the individual temperature cell is provided with a joint seal and is impervious.

15 **[0068]** The GC modular oven includes a temperature controller operatively connected to the individual temperature cell. The temperature controller is configured to independently control the temperature within each individual temperature cell. In some embodiments, the temperature controller is a proportional-integral-derivative controller (PID) controller. One or more temperature controller(s) may be used.

20 **[0069]** In some embodiments, the temperature controller is operatively connected with the heater (or the cooling system) and the temperature sensor. The temperature controller may have the heater (or the cooling system) as an output and the temperature sensor as an input.

25 **[0070]** The temperature controller includes at least one temperature control. The at least one temperature control may be an adjustable knob or buttons. The at least one temperature control is configured and operable to set the temperature in a corresponding one of the individual temperature cells.

[0071] Each one of the individual temperature cells may be operated under different conditions. In some embodiments, the temperature in each individual temperature cell ranges from approximatively 0 to 400°C.

5 **[0072]** In some embodiments, the GC modular oven includes an electronics architecture for allowing the individual temperature cells to be connected in a network, when a larger volume is needed.

[0073] In accordance with another aspect, a kit including special tools is provided. The special tools may be sized and configured to facilitate the assembly of the GC modular oven, the insertion and/or mounting of the different GC components inside
10 the GC modular oven.

[0074] In accordance with another aspect, there is provided a chromatographic column cartridge and a compact ramping oven.

[0075] The chromatographic column cartridges may be provided with an inlet and outlet port for air circulation.

15 **[0076]** In some embodiments, the cartridge includes a chamber for containing a chromatography column. The chamber may have the shape of a donut, and the chromatography column may be wound within the chamber.

[0077] The compact oven may be provided with a corresponding temperature sensor. In some embodiments, the compact oven includes a heating (or a cooling)
20 element coupled with a blower generating an air flow.

[0078] In some embodiments, the compact oven and the temperature sensor are positioned upstream of the chromatography column of the chromatographic column cartridge.

25 **[0079]** In some embodiments, the temperature is controlled by adjusting an air flow within the compact oven. The air flow may be controlled by controlling the blower rotation speed.

[0080] In some embodiments, the chromatographic column cartridge and the compact oven are mounted in an individual cell of the GC modular.

[0081] In accordance with another aspect, there is provided an explosion-proof compact ramping oven (also simply referred to as “explosion-proof oven”). The explosion-proof oven may include a main enclosure defining an internal volume into which can be mounted different GC components.

[0082] The main enclosure can receive one or more chromatographic column cartridge(s). In some embodiments, the main enclosure includes two chromatographic column cartridges. The chromatographic column cartridges may each include respective inlet/outlet ports for allowing passage of air therein. The chromatographic column cartridges can also be insulated by providing an insulating material on the outer surface of the chromatographic column cartridges. Each one of the chromatographic column cartridges is configured to receive a corresponding chromatography column.

[0083] In some embodiments, the chromatographic column cartridges have a donut shape, or a substantially annular cross-section defining an empty space therein (also referred to as a “compartment”). Different GC components can be mounted in the compartment.

[0084] In some embodiments, the compartment can be divided in multiple zones into which can be mounted and assembled various GC components. The GC components mounted in the multiple zones of the compartment can be the same, or different.

[0085] In some embodiments, the explosion-proof oven includes a secondary enclosure mounted and operatively to the main enclosure. The secondary enclosure is configured to receive the compact oven as well as its associated blowers. The blowers blow the heated (or cooled) air from the compact oven towards a respective one of the chromatographic column cartridges through corresponding inlet port.

[0086] In some embodiments, the explosion-proof oven includes a cover. The cover can include a male and/or female threaded portion for attachment to a front portion of the main enclosure. The cover can be provided with a seal or an insulating material to ensure proper sealing of the explosion-proof oven.

- 5 **[0087]** Other features and advantages of the present description will become more apparent upon reading of the following non-restrictive description of specific embodiments thereof, given by way of example only with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

- 10 **[0088]** Figure 1 is a GC lab chromatograph from prior art.

[0089] Figure 2 illustrates a gas chromatography modular oven, in accordance with one embodiment.

[0090] Figure 3 illustrates a gas chromatography modular oven, in accordance with another embodiment.

- 15 **[0091]** Figure 4 is a cross-sectional view of a thermal plate, in accordance with one embodiment.

[0092] Figure 5 is a top view of the thermal plate illustrated in Figure 4.

[0093] Figure 6 shows a schematic representation of a gas chromatography oven, in accordance with another embodiment.

- 20 **[0094]** Figure 7 shows a schematic representation of a gas chromatography oven, in accordance with another embodiment.

[0095] Figure 8 shows a schematic representation of a gas chromatography oven, in accordance with another embodiment.

- 25 **[0096]** Figure 9 shows a schematic representation of a gas chromatography oven, in accordance with another embodiment.

[0097] Figure 10 is a GC lab chromatograph oven from prior art.

[0098] Figures 11A-B illustrate a chromatographic column cartridge coupled with a compact oven, in accordance with one embodiment.

5 [0099] Figures 12A-F show different configurations of the GC modular oven, in accordance with some embodiments.

[00100] Figure 13 is an explosion-proof GC lab chromatograph oven from prior art.

[00101] Figures 14A-C show different configurations of an explosion-proof compact ramping oven, in accordance with some embodiments.

DETAILED DESCRIPTION

10 In the following description, similar features in the drawings have been given similar reference numerals, and, to not unduly encumber the figures, some elements may not be indicated on some figures if they were already identified in one or more preceding figures. It should also be understood herein that the elements of the drawings are not necessarily depicted to scale, since emphasis is
15 placed upon clearly illustrating the elements and structures of the present embodiments.

Gas chromatography oven: context and applications

[00102] Gas chromatography (GC) is a technical field where constituents of a gas sample are separated in order to be individually analysed. Typically, a sample gas
20 is injected at an injection port into a chromatography column and carried by a carrier gas towards a detector to be analysed. The sample gas can include one or more analytes (also referred to as “impurities” or “species”) to be detected, carried by the carrier gas along the chromatography column. The different species are outputted at different moments in time at the detector and are associated with an
25 elution peak. The detector is typically operatively connected to an analysis system and a computer, so as the elution peak can be processed by a third-party software.

[00103] The chromatography column is typically kept in a temperature-controlled oven positioned downstream of the injection port and upstream of the detector, which allows to maintain the chromatography column at a predetermined temperature or ramping the temperature of the chromatography column at a given rate, depending on the targeted applications. An example of a GC oven according to the prior art is illustrated in Figure 1.

[00104] The chromatography column can be wound into a spiral within the GC oven, hence accommodating different length of columns within the oven, depending on the analytes under investigation and their associated elution time.

[00105] GC ovens can be suitable for use in conjunction with chromatography systems using all types of chromatography columns, such as but not limited to capillary column, pack column, micro pack column, or any other types of column generally used in the gas chromatography field.

Gas chromatography modular oven

[00106] In accordance with embodiments, there is provided a gas chromatography (GC) modular oven for use, for example, in analytical chemistry applications, for instance for analyzing the constituents of a gas. Embodiments described herein below permit the design and the fabrication of a compact and modular GC oven. The modular GC oven is configurable by the user and is based on a “building block approach”. The GC modular oven can be quickly and easily reconfigured to accommodate new needs and/or applications.

[00107] Broadly described, the gas chromatography modular oven includes a main enclosure, one or more panels (referred to as “the panel(s)”) and one or more thermal plates (referred to as “the thermal plate(s)”). The main enclosure includes a backwall (sometimes referred to as “back panel”) and sidewalls (sometimes referred to as “side panels”) defining an internal volume. The sidewalls include a plurality of panel-engaging structures defining multiple panel-mounting positions within the internal volume. The panel(s) can be releasably engageable with the

panel-engaging structures to divide the main enclosure into individual cells. The thermal plate(s) are releasably engageable with the backwall within an associated one of the individual cells and are operable to set an operation temperature in the associated individual cell, thereby creating temperature-controlled zones within the gas chromatography modular oven.

[00108] It is to be noted that, in the present application, the term “thermal plate” will be used as referring to an operable unit or module, and more particularly to a unit or module allowing to adjust and set the operation temperature in the associated individual cell. In this context, the GC modular oven will be referred to as a structure including one or more individual temperature cell(s), each one of the temperature cell(s) including one or more thermal plate(s), which may be grouped together or separated using panels (sometimes referred to as “partition walls”) to form an individual temperature cell. Each one of the thermal plates can have one or more GC component(s) (e.g., valves, chromatography column, pack column, capillary columns, fittings, traps, and/or the like) mounted thereon.

[00109] The use of multiple individual temperature cells can advantageously enable the possibility of integrating multiple independently operable individual cells within the same GC oven, while allowing to maintain each one of the individual temperature cells at a predetermined and isolated temperature from one another.

[00110] Now that the gas chromatography has been broadly presented, different embodiments will be described in greater detail.

[00111] With reference to Figures 2 and 3, embodiments of a GC modular oven 20 are shown.

[00112] The GC modular oven 20 includes a main enclosure 22. The main enclosure 22 defines an internal volume into which can be mounted individual cells 24, which will be described in greater detail later. Each individual cell 24 can include associate GC parts, components and accessories. The main enclosure 22 generally includes a door (not shown in Figure 2) for accessing the internal volume

(i.e., the content) of the modular oven 20 when required (e.g., for preparing or setting up the GC modular oven 20 prior to and/or after an experiment).

[00113] As illustrated, the main enclosure 22 has a substantially rectangular cross-section. In one implementation, the main enclosure has dimensions ranging from approximately 10 to 50 cm x 10 to 50 cm x 5 to 20 cm (height x width x depth). It will however be understood that the geometrical configuration, as well as the dimensions of the main enclosure 22 could vary, and that the main enclosure 22 can be embodied by any structure or components assembled together defining a spaced admitting the insertion of the required GC components.

[00114] As previously mentioned, the main enclosure 22 includes sidewalls 23 and a backwall 38 defining the internal volume of the GC modular oven 20. In some embodiments, the main enclosure 22 includes four sidewalls joined and a backwall 38 at respective corners of the main enclosure 22 (e.g., in the situation in which the main enclosure 22 has the shape of a parallelepiped) and a front opening which can be selectively open/closed with the door (not illustrated). In other embodiments, the number of sidewalls 23 and the overall shape of the GC modular oven 20 could vary.

[00115] The sidewalls 23 and the backwall 38 can be configured to provide thermal insulation to the GC oven 20. In the context of thermally-insulating sidewalls 23 and backwall 38, the sidewalls 23 and the backwall 38 can be made from a stack of different materials, for example a layer of an insulating material positioned between (i.e., "sandwiched") two layers of thermally conductive material. The thermally conductive material can be, for example and without being limitative, aluminum, stainless steel, steel alloys, or other materials, while the insulating material can be mineral wool, flexible alumina fibers, solid porous ceramic, or other materials having insulating properties.

[00116] An external surface of the sidewalls 23 and the backwall 38 of the main enclosure 22 (i.e., the surface of the sidewalls 23 visible from outside the GC

modular oven 20) can be covered with a coating, a layer or painting to provide a finished look to the GC modular oven 20.

[00117] The GC modular oven 20 includes individual temperature cells 24 (also sometimes referred to as the “individual cells 24”). The individual cells 24 define a temperature-controlled zone within the GC modular oven 20, *i.e.*, a zone within the main enclosure 22 in which the temperature can be controlled, *i.e.*, maintained, ramped up or ramped down. In some scenarios, the temperature can be maintained at a predetermined constant value. In these implementations, the temperature is said to be “isothermally controlled” or to be an “isothermal temperature”. In other scenarios, the temperature can be ramped at a given rate, so as to obtain, for example, a specific gradient of temperature in the individual cells 24, depending on the analytical applications. It is to be noted that the number of individual cells may vary, and that, in such circumstances, the individual cells are numbered 24a, 24b, 24c, and so on, depending on the number of individual cells provided in the GC modular oven 20.

[00118] Now referring to Figures 2 to 4, the structure of the individual cells 24 will now be described.

[00119] As illustrated, each individual cell 24 is confined within four panels 36a-d and a portion of the backwall 38, and further has a front opening. It will readily be understood that the front opening of the individual cells 24 is generally aligned with the front opening of the GC modular oven 20, so as the content of each individual cell 24 is accessible from outside the GC modular oven 20 when the user opens the door. It is to be noted that at least some of the four panels 36a-d could be the sidewalls 23 of the main enclosure 22, and, so the terms “panel” and “sidewall” could be in some circumstances used interchangeably, for example when one of the four panels 36a-d is a sidewall 23.

[00120] The four panels 36a-d can be fixed to each other and/or to a thermal plate to define an open-ended O-shaped structure (sometimes referred to as the “open-ended structures”). In one embodiment, the panels can be engaged, fixed and/or

attached to a thermal plate, so as to form “integrated” individual cells 24 that can be releasably engaged, *i.e.*, mounted to and/or unmounted from the backwall 38. In this embodiment, the “integrated” individual cells 24 define individual releasably mountable cubicles. One or more individual releasably mountable cubicles can be
5 mounted in the internal volume of the main enclosure 22 of the gas chromatography modular oven. The backwall 38 is configured to close one end of the open-ended O-shaped structure.

[00121] The side panels 36a-d can comprise hole(s) (sometimes referred to as “mounting holes”) and/or slot(s) for GC components or accessories. Such GC
10 components include, but are not limited to tubes for gas connection, and allow the operational communication (*i.e.*, fluid, electrical, optical and/or mechanical communication) from one individual cell 24a to another adjacent and/or neighbouring individual cell 24b, and more particularly between some of the GC components 50a-c.

[00122] For example, now referring to Figure 2, the side panel 36c of the first individual cell 24a can comprise a hole 28a and the side panel 36a of the second individual cell 24b can comprise a corresponding hole 28b, hence admitting a
15 passage of a connecting element 30 (for example a gas chromatography column, a tube, or other components) from the first one to the second one of the individual cells 24a,b (respectively).
20

[00123] In some embodiments, the side panels 36a-d have standard mounting holes provided therein. The expression “standard holes” herein refers to holes that are compatible with dimensions specified by chromatographic components manufacturers, and so can be useful for easily and quickly installing standard
25 chromatographic components, such as, and without being limitative valve, manifold, “T” and/or “X” connector(s). Such a feature can be useful for facilitating the configuration and the customization of the GC modular oven 20, as well as optimising the space use so as to achieve a more compact design, based on the targeted GC application(s). Typically, those types of connectors (*i.e.*, the valve,

manifold, “T” and “X” connectors) are installed on the GC base plate (*i.e.*, the back sidewall of the main enclosure of the GC oven), and can occupy, consume and/or waste a lot of space. This feature of the GC modular oven 20 described herein can notably be advantageous when used in conjunction with the standard mounting
5 holes and/or slots that can be provided in the side panels 36a-d, which can allow gas tube(s) (or other GC component(s)) to go from one individual cell 24 to another adjacent and/or neighbouring individual cell, as well as ensuring a fluid communication between the individual cells 24 and potentially reducing the presence of cold spots, as the tube(s) is typically not submitted to an ambient
10 temperature region due to the close proximity of the different individual cells. It will be understood that the exposition of the tube(s) to the ambient temperature and its potential effect(s) can be minimized or mitigated by the abovementioned configuration.

[00124] Quite similarly to the sidewalls 23 of the main enclosure 22, the panels
15 36a-d of the individual cells 24 (*i.e.* the side panels 36a-d and the backwall 38) are provided with thermal insulation. For example, and without being limitative, the panels 36a-d can also comprise an insulating material, such as the ones which have been previously introduced, the insulating material being provided between two layers (*i.e.*, “sandwiched”) of a thermally conductive material, such as
20 aluminium or any other thermally conductive material listed above. The thermally conductive material is used to uniformly distribute the heat within the individual temperature cells 24, while the insulating material is provided to ensure the maintenance of the temperature within the temperature cells 24, despite being in contact with other temperature cells 24 being maintained at different (*i.e.* higher or
25 lower) temperatures.

[00125] When two individual cells 24a,b are placed one next to the other, two of their corresponding panels can be put in contact in a common region, *i.e.*, along their respective outer surface. Alternatively, two adjacent individual cells 24a,b could share a common panel.

[00126] In the context of Figure 2, for example, the side panel 36c of the first individual cell 24a is put in contact with the side panel 36a of the second individual cell 24b. In order to maintain an appropriate temperature in each individual cell 24a,b, the panels 36a-e can all be thermally isolated from one another, but
5 also from the main enclosure 22 (*i.e.*, the sidewalls 23 of the main enclosure 22), which can help reducing the heat transfer from one individual cell 24a to the other individual cell 24b and/or from outside the GC modular oven 20. In some embodiments, for example when the first and second individual cells 24a,b are contiguous, each individual cell 24a,b is insulated from one another by separating
10 the panels 36a-d of the first individual cell 24a from the panels 36a-d of the second individual cell 24b. Such a separation may be made by using an insulating standoff (*e.g.*, a leg protruding from on the panels 36a-d of at least one of the two adjacent individual cell 24a,b). The insulating standoff is herein understood as a spacer and may be made from, for example and without being limitative, ceramic or any other
15 insulating material.

[00127] It will be readily understood that different materials could be used for forming the side panels 36a-d, as well as their insulating and thermally conductive components, and that various dimensions could be used in the design and fabrication of the individual cells 24, according to the user's needs.

20 **[00128]** Now turning to Figures 12A-F, various embodiments of a GC modular oven 20 are shown.

[00129] The main enclosure 22 includes a plurality of panel-engaging structures defining multiple panel-mounting position within the internal volume. In the illustrated embodiments, the panel-engaging structures include a plurality of
25 slots 37 provided in the internal surface of the main enclosure 22. The slots 37 generally extend from the front portion towards the back portion of the main enclosure 22 along at least a portion of the depth of the main enclosure 22.

[00130] In the depicted embodiments, the panels 36a-d forming the individual cells include notches 39. The panels 36a-d with notches 39 (illustrated for example in

Figure 12F) are similar to the panels 36a-d in terms of structure, composition and function.

[00131] The embodiments of Figures 12A-F illustrate the modular aspect of the gas chromatography oven in that the panels 36a-d may be removably mounted to the main enclosure 22. More particularly, the panels 36a-d are slidably engageable with corresponding slots 39 to define individual cells 24a,b (see for example Figure 12B), four individual cells 24a-d (see for example Figure 12C), six individual cells (see Figures 12D-E), or any other number of individual cell(s). It will be readily understood that such panels 36a-d may be advantageous, because they allow the user to selectively design the configuration of the internal volume of the GC modular oven 20, and rearrange the size, as well as the number of individual cells within the main enclosure 22 of the GC modular oven 20. As such, the user can revisit and reconfigure the individual cells of the GC modular oven 20, based on requirements that may be dictated, for example, by a targeted analytical application.

[00132] In some embodiments, the notch 39 is sized and configured to receive a portion of another panels. More particularly, the notch 39 formed in a panel is engageable with the notch 39 of another panel so as they are matingly engaged when abutting each other.

[00133] When the panels 36a-d are engaged and mounted in the mounting structures of the main enclosure 22, mechanical fasteners may be used to fix the panels 36a-d in position within the main enclosure 22, so that they remain in place when performing experiments. Such mechanical fasteners may be removed to permit the reconfiguration of the panels 36a-d within the main enclosure 22.

[00134] As it has been previously introduced, the individual cells 24 can include one or more thermal plate(s). In some embodiments, the thermal plate(s) are mounted to the backwall 38.

[00135] In the embodiment illustrated in Figure 2, the GC modular oven includes two individual cells 24a,b: the first individual cell 24a includes two thermal plates 26 while the second individual cell 24b includes one thermal plate 30. In an alternate embodiment, such as the one depicted in Figure 3, the GC modular oven 20 includes three individual cells 24a,b,c, each one including a respective thermal plate 26.

[00136] In some embodiments, the thermal plate 26 is a hotplate. In other embodiments, the thermal plate 26 can include a cooling device based, for example on Peltier effect, for example to adjust the temperature.

[00137] Now turning to Figure 4, a cross-sectional view of a thermal plate (e.g., the hot plate 26) is shown. The thermal plate 26 is configured to be removably mountable to the backwall 38 of the main enclosure 22 (directly or indirectly). As illustrated, the thermal plate 26 can be mounted in one individual cell 24 and depending on the volume of the individual cell 24, one or more (e.g. two, three, four or more) thermal plates 26 can be mounted in the individual cells. Multiple thermal plates 26 can be mounted in a larger individual cell 24 to either maintain the whole internal volume at a uniform predetermined temperature or to heat some zones of the individual cell 24 at different temperature.

[00138] In some embodiments, the thermal plate 26 can define a portion of the back portion of an individual cell 24.

[00139] In the depicted embodiment, the thermal plate 26 includes a mounting plate 40. The mounting plate 40 can be made as a monolithic piece made, for example, from aluminum, or any thermally conductive material which has been previously listed. The mounting plate 40 is notably used to distribute the heat uniformly in the individual cell 24 or at least a portion thereof (e.g., in a limited region or zone of the individual cell 24). More generally, the mounting plate 40 acts as a heating surface, and so can be seen as a local heat source in each individual cell 24. Dimensions (width, length and/or thickness) of the mounting plate 40 can

vary according to the required dimensions of the individual cells 24, and can depend, among others, on the targeted application.

[00140] As illustrated, the mounting plate 40 includes a cut out 45 (illustrated as two facing letters "C"). The cut out 45 may be useful, for example, for accessing one or more rotary valve actuator(s), which are generally located outside the GC modular oven 20. It will be readily understood that the dimensions and overall shape of the cut out 45 may vary, depending on the dimensions of the actuator(s).

[00141] The thermal plate 26 includes one or more spacer(s) 42. The mounting plate 40 is mechanically affixed to the spacer 42.

[00142] In some embodiments, the spacer 42 extends along a perimeter of the mounting plate 40 and below the mounting plate 40. When the mounting plate 40 is mounted to the backwall 38 of the main enclosure 22, the spacer 42 is in direct contact with the backwall 38, and a gap (*i.e.*, a space) is formed between the mounting plate 40 and the backwall 38 of the main enclosure 22. Such a gap is typically filled with an insulating material 48, similar to the ones which have been previously described. In some embodiments, the mounting plate 40 and the spacer 42 are formed as one piece.

[00143] In some variants, such as the one illustrated in Figures 4 and 5, the spacer 42 can be embodied by four legs 43 extending below the mounting plate 40 (towards the backwall 38), and each leg 43 can be provided in a respective corner of the mounting plate 40.

[00144] In some variants, the spacers 42 are made of a thermally insulated material to provide the mounting plate 40 with thermal insulation.

[00145] Once the spacer 42 is put in contact with the backwall 38, the thermal plate 26 can be fixed thereto by inserting, for example, at least one mechanical fasteners through the mounting plate 40. The mechanical fasteners can be, for example and without being limitative, nails, clips, snap, or any other fasteners already known by one skilled in the art that allow removably mounting the thermal

plate 26 to the backwall 38 of the main enclosure 22. The mechanical fasteners are typically insertable through each corners of the thermal plate 26 but could alternatively be insertable elsewhere on the thermal plate 26 (e.g., in its central portion). In some embodiments, the legs 43 provided in each corner of the thermal plate 26 (and below the mounting plate 40) comprise an aperture defined therethrough, into which the mechanical fastener(s) can be inserted.

[00146] In the illustrated variant, the thermal plates 26 each include a corresponding heating element 44 (sometimes referred to as the “heater”) and a corresponding temperature sensor 46, both contacting the mounting plate 40. The heater 44 and the temperature sensor 46 are in thermal connection with the mounting plate 40 of their respective thermal plate 26. The heating element 44 can be in direct contact with the mounting plate 44.

[00147] The heating element 44 is operable to heat the mounting plate 40 at a predetermined temperature which can be selected (and changed, if needed) by the user, hence heating the individual cell 24 or a portion thereof at a predetermined temperature. As illustrated in Figure 4, the heating element 44 and the temperature sensor 46 are provided below the mounting plate 40, *i.e.*, in the gap formed between the mounting plate 40 and the backwall 38. In such a configuration, the heating element 44 and the temperature sensor 46 are in direct thermal connection with the mounting plate 40. In an alternate configuration, the heating element 44 and the temperature sensor 46 could be in indirect thermal connection with the mounting plate 40, *i.e.*, some intermediate(s) could be provided for ensuring an efficient heat transfer between the heating element 44, the sensor 46 and/or the mounting plate 40.

[00148] In an alternate configuration, a cooling system such as a Peltier cell could also be provided to cool down the mounting plate 40, when needed. It will be understood that the heating and/or cooling systems can include different thermoelectric devices and/or components based, for example on the Seebeck and/or Peltier effect.

[00149] When the thermal plate 26 is mounted to the backwall 38 of the main enclosure 22, the heating element 44 and the temperature sensor 46 are typically positioned between the mounting plate 40 and the backwall 38. As such, the heating element 44 and the temperature sensor 46 are generally positioned near or in the back portion of the GC modular oven 20 (*i.e.*, near the backwall 38 of the main enclosure 22).

[00150] The abovementioned configuration of the heating element 44 and the temperature sensor 46 can be useful, for example, because their positioning does not interfere with the positioning of the chromatography components included in the individual cells 24. On this aspect, each individual cell 24 can include one or more GC components (numbered 50a, 50b, 50c, and so on, depending on the number of GC components).

[00151] In some embodiments, the GC components are mounted on the top of the mounting plate 40 (*i.e.*, on the top of the thermal plates 26), as it will be described below, and so project within the internal volume of the main enclosure 22. The GC component can be embodied, for example and without being limitative, valves, chromatography column, pack column, capillary columns, and/or the like.

[00152] With reference to Figure 5, the structure of the mounting plate 40 will now be described in more detail.

[00153] The mounting plate 40 can comprise mounting holes 41. As illustrated, the mounting holes 41 are embodied by an array of standard holes across the mounting plate 40. In some embodiments, the mounting holes 41 are evenly distributed so as to form a regular array. In the illustrated embodiment, the mounting plate 40 includes twelve circular mounting holes 41 regularly spaced apart across the surface of the mounting plate 40. As it will be readily understood, the mounting holes 41 can have identical or different diameter. Their general shape, geometrical features and/or dimensions could of course vary, depending on the targeted application. Such mounting holes 41 are however generally

provided to further facilitate the integration of the GC components within the GC modular oven 20 by allowing to mount standard chromatographic components.

[00154] The mounting plate 40 hence allows designing standard GC components and associated pieces that can be used in the individual cells 24, which in turn permits developing standard chromatographic methods, and so can potentially reduce design and assembly time, as well as the costs associated to these steps.

[00155] In some embodiments, the GC modular oven 20 can also include one or more gas inlets and outlets, positioned at locations compatible with the “building block” approach previously introduced, for ensuring the distribution of the gas within the GC modular oven 20. The building block approach allows the user to use standard tubes and fitting assembly, which may facilitate assembly of the GC modular oven 20 and may reduce configuration and integration time. For example, and without being limitative, the gas inlet and outlet can be provided in the back of the GC modular oven 20.

[00156] In order to facilitate the assembly of the GC modular oven 20, and keep the design as compact as possible, a kit including special tools can be provided. The tool can be, for example and without being limitative, special spanner(s) and/or screw driver(s) to facilitate the assembly of the GC modular oven 20, the insertion and mounting of different GC components inside the GC modular oven 20. In some implementations, the tools are designed such that they provide easy access to GC components and/or the inside of the GC modular oven 20. The kit can be useful, for example, for connecting various GC components (e.g. a chromatographic column with a valve). In some embodiments, the kit can be used to easily connect and tighten the GC components to one another.

[00157] In some implementations, one or more GC component(s) can be mounted to or into the sidewalls 23 of the GC modular oven 20 and/or to the side panels 36a-d, prior to their installation into the GC modular oven 20. More particularly, some GC components can be mounted to the side panels 36a-d of the GC modular oven 20, and then the side panels 36a-d may be mounted in the GC modular oven 20.

[00158] Each individual cell 24 can further include electronics, mechanical, electromechanical or optical components and/or devices required for the functioning of the GC modular oven 20. Such components can include, for example and without being limitative, electrical circuits, batteries, resistors, inductors, capacitors, switches, current and/or voltage sources, resistances, inductances, capacitances, tube, capillary, pump, connectors, fans, optical fibers, lenses, mirrors, filters, gratings, prisms, windows, combinations thereof, or any other components typically included in gas chromatographs.

[00159] The individual cell 24 as described above may be, in some implementations, impervious, for example by providing a first and/or second joint seals in extending along the mounting structures (e.g., the slots 37) or at least some portions of the side panels 36a-d (e.g., along at least a periphery of the panels 36a-d). Such a characteristic may be useful, for example, if a targeted application requires to purge the internal volume of the individual cell 24. Nitrogen, argon or other gases may be used as purge gases, which could be useful if a hazardous gas is used in the GC modular oven 20. In such implementations, a detector may be provided with the GC modular oven 20. The detector may be placed in fluidic communication with the purge gas (i.e. protrude in the individual cell 24), in order to measure contaminations level in the gas and/or in the individual cell 24.

[00160] The GC modular oven 20 includes a temperature controller 32 operatively connected to the individual cells 24. As its name entails, the temperature controller 32 is a component used to control the temperature of the individual cells 24 to which it is connected. In the context of the current description, the temperature controller 32 is configured to control the temperature (i.e. select and monitor the temperature) in each individual cell 24. The temperature controller 32 can be provided with a user interface such as adjustable knobs or buttons or computer-implemented interface for selecting a temperature value within a predetermined range. Of course, this range depends on the characteristics of the heater 44 (or the cooling system), and is not a limitation of the controller 78 itself.

The temperature controller 32 can also be provided with a display for indicating the selected temperatures.

[00161] As it will be readily understood, the temperature controller 32 can be embodied by any type of temperature controllers, such as, and without being
5 limitative, on-off controllers, proportional controllers, fuzzy logic controllers and proportional-integral-derivative controller (PID) controllers.

[00162] The heating element 44 and the temperature sensor 46 can be operatively connected to the temperature controller(s) 32, according to the configuration which has been described. More particularly, the temperature controller(s) 32 can have
10 the heating element 44 as an output and the temperature sensor 46 as an input, and upon a selection of the predetermined temperature by the user (for example using the individual control 34), the heating element 44 is set at this predetermined temperature, and the associated individual cell 24 is heated or cooled at the predetermined temperature. By its positioning with respect to the heating element
15 44, the temperature sensor 46 is in thermal connection with the heating element 44 and can measure the actual temperature at the mounting plate 40, which can be useful for tracking the temperature and/or temperature deviations within the individual cells 24 and for making appropriate adjustments when required. In some embodiment, the temperature controller 32 can be provided with an automated
20 feedback loop so as to track the temperature at the mounting plate 40 and automatically adjusting it if diverging from the predetermined temperature value by a given threshold value.

[00163] In the embodiment illustrated in Figure 2, the GC modular oven 20 includes two individual cells 24. The first individual cell 24a can be maintained at
25 a temperature T_1 , while the second cell 24b can be maintained at a temperature T_2 . The temperature controller 32 is operable to set the values T_1 and T_2 . The temperature can range, for example from 0 to 400°C (*i.e.*, below, approximately equal to or above the ambient temperature when used in combination with an appropriate heater and/or cooling system). More particularly, in this context, the

temperature controller 32 is operatively connected to the temperature sensor 46 of each thermal plate 26. More specifically, the temperature controller 32 can receive the temperature sensor 46 as an input, display the temperature as measured in the individual cells 24, compare this value to the set values T_1 and T_2 , and, in some
5 embodiments, adjust the temperature.

[00164] In some embodiments, such as the one illustrated in Figure 2, only one temperature controller 32 is used to control the temperature in the two individual cells 24a,b. More specifically, the temperature controller 32 is connected to each thermal plate 26: two of the thermal plates 26 are maintained at a first
10 predetermined temperature, while the other one of the thermal plates 26 is maintained at a second predetermined temperature. Similarly, the embodiment illustrated in Figure 3 shows one temperature controller 32 associated with three individual cells 24 and connected to the three thermal plates 26, each being maintained at a different predetermined temperature. In an alternate embodiment,
15 one temperature controller 32 per individual cell 24 could be used. It is hence understood that the number of temperature controller(s) 32 used in the GC modular oven 20 could be equal or smaller than the number of individual cells 24 provided. For example, if a GC modular oven 20 includes n individual cells 24, the modular oven 20 could include n , $n-1$, $n-2$, ..., 1 temperature controller(s) 32.

[00165] The temperature controller 32 includes at least one individual control. While the ratio of temperature controllers 32 to the individual cells 24 can vary according to the embodiments, it will be readily understood that each individual cell 24 is associated with a corresponding individual control 34. Such an individual control 34 can be embodied, for example, by the adjustable knobs or buttons which
25 have been described above. The individual control 34 is configured and operable to set the temperature in the corresponding one of the individual cells 24. More particularly, the individual control 34 can be used to independently adjust the temperature in each one of the thermal plates 26. In the context of the embodiment illustrated in Figure 2, while the GC modular oven 20 includes one temperature
30 controller 32, the temperature controller 32 includes two individual controls 34,

each one being operatively connected to a respective thermal plate. Generally, if a GC modular oven 20 includes m thermal plate(s), the GC modular oven 20 includes m individual control(s). More particularly, the ratio of thermal plate(s) to the individual control(s) 34 is typically 1:1.

5 **[00166]** While the control of the individual cells 24 and thermal plates 26 can be useful to operate the individual cells 24 under different conditions, it is also feasible, using the GC modular oven presented in the current description, to combine the individual cells 24 and/or the thermal plates 26 to create a larger cell (also referred to as a “combined cell”). The combined cell can be obtained by placing into
10 electrical and/or mechanical connection the thermal plates provided in each individual cell 24, or by setting different thermal plates provided within the same individual cell 24 at the same predetermined temperature. The combined cell can be useful, for example, when a larger cell (i.e. a larger volume) is needed for a targeted chromatographic application.

15 **[00167]** It is to be noted that such a combination of the individual cells 24 or thermal plates 26 is reflected in the software used for operating the GC modular oven. The software is designed such that thermal plates can be combined to create larger cells through an interface. As such, the software is configured so that the user can control, combine and operate the GC modular oven 20 or components
20 thereof.

[00168] In some implementations, the GC modular oven 20 is provided with a scalable electronics architecture allowing for multiple individual cells 24 to be connected in a network when the chromatographic application requires more space. The electronics architecture may be built around a communication network
25 which allows data to be shared and remotely accessible from the cloud to remotely control and data storage. The accumulated data can be used by the user for advanced data analytics, for example using a third-party software.

[00169] The electronics architecture may also permit multiple independent GC modular ovens 20 to be connected. Such a configuration can be useful, for

example, when one modular oven 20 is not sufficient to fit all the required GC components, or when the chromatographic application requires physical separation between some of the GC components. Such a requirement can be influenced by safety hazard, or by the context of the targeted application, e.g. when performing impurity analysis in hydrogen and oxygen.

[00170] The GC modular oven 20 can be operatively connected to different modules. The modules can be embodied but are not limited to a digital signal process (DSP), a sequencer, a flow controller, a valves controller, a gas detector, digital I/O, analog I/O and/or the like. Such modules are useful for operating the GC modular oven 20 and/or the analysis system and associated computer.

[00171] When used in conjunction with the embodiments of the GC modular oven 20 as described above, the modules can also facilitate the system integration, by allowing to install the standard electronic modules that are generally needed to control the GC components. For example, in some implementations, the modules can be used to control the GC modular oven 20 control valves and the electronics for gas detection. All those modules can be installed, for example, on brackets using snaps or similar fasteners, such as snap-lock or buttons. It is to be noted that the modules, such as digital IOs and analog IOs can also be included in the GC modular configuration. Such modules can be provided as external modules, and so may be mounted outside the GC modular oven 20.

[00172] It will be understood that the modules can be provided inside or outside the GC modular oven 20. For example, the modules can be mounted on the top and/or at the back of the GC modular oven 20, or elsewhere near the GC modular oven 20. In some implementations, for example, the modules are mounted behind the back panel 38.

[00173] In some embodiments, the modules can be connected to form a network. More particularly, it is to be noted that the network somehow reflects the design of the GC modular oven 20, *i.e.*, the arrangement of the individual cells 24. For example, the network can be configured to ensure a proper communication

between the individual cells, the different elements provided on and/or with the GC modular oven 20, and/or the modules. In some variants, for example when multiple individual temperature cells are combined, there may be mapping between the individual temperature cells and the different modules.

5 **[00174]** The network can be used to remotely access the modules, share and/or store data. As such, the network allows operating the modules, which in turn may be used to operate the individual cells 24 or at least some components of the GC modular oven 20 (e.g., the temperature controller 32).

10 **[00175]** In some embodiments, the thermal plates 26 and/or the mounting plate 40 can be removably mounted or removed into or from the GC modular oven 20, depending on the required configuration of the GC modular oven 20. As such, the thermal plates 26 can be rearranged within the individual cell 24, as and when needed. This feature of the GC modular oven 20 presented in the current description provides modularity and allows to define multiple zones in which the
15 temperature is independently controlled. This feature of the GC modular oven 20 can hence reduce the time and the costs associated with the integration of a GC oven for a specific application and provide more flexibility to the GC system integrator.

20 **[00176]** It is to be noted that other components, such as detectors (chromatography detectors, as well as gas detectors, e.g. H₂ detector) may be provided with the GC modular oven 20. Such components are typically provided outside of the GC modular oven 20 and may be mounted on top or on a back portion of the GC modular oven 20. As such, the GC modular oven 20 may comprise holes in its main enclosure 22 to allow connection to such components
25 (e.g. a detector) with the components (e.g. a column) provided inside of the GC modular oven 20.

Examples of implementation

[00177] With reference to Figures 6 to 9, different implementations of a GC modular oven will now be described.

[00178] In Figure 6, an embodiment of a GC modular oven 120 is shown. The features of the GC modular oven 120 are numbered with reference numerals in the 100 series which correspond to the reference numeral of the previous embodiment. The GC modular oven 120 includes, in the illustrated embodiment, five individual cells 124a-e. Four of the five individual cells include one thermal plate, while the remaining one includes three thermal plates. Each one of the thermal plates can have one or more GC component(s) (noted 150a-g) mounted and/or attached thereon, as well as electrical, mechanical, electromechanical and optical components and/or devices. For example, and without being limitative, the GC component(s) can be embodied by sampler, connection, chromatography valve(s), valve selector(s), flow control valve(s), chromatography column(s), impurities trap(s), and/or the like. Four of the five individual cells 124a-e are approximately of the same size and each occupies a volume V_1 , while the remaining one is bigger than the four others and occupies a volume V_2 . In the illustrated embodiment, V_1 is approximately equal to the half of V_2 .

[00179] Another embodiment of a GC modular oven 220 is illustrated in Figure 7. The features of the GC modular oven 220 are numbered with reference numerals in the 200 series which correspond to the reference numeral of the previous embodiment. The GC modular oven 220 includes three individual cells 224a-c, each including one thermal plate having one GC component noted 250a-d mounted and/or attached thereon, which can be, for example, similar to the ones which have been previously listed. In this example, one of the three individual cells 224a includes a chromatography column, while the two other 224b and 224c includes one GC component (e.g., valves). Two of the three individual cells 224 are approximately of the same size and each occupies a volume V_3 , while the

remaining one is bigger than the two others and occupies a volume V_4 . In the illustrated embodiment, V_3 is approximately equal to the quarter of V_3 .

[00180] Now turning to Figure 8, an embodiment of a GC modular oven 320 is illustrated. The features of the GC modular oven 320 are numbered with reference numerals in the 300 series which correspond to the reference numeral of the previous embodiment. The GC modular oven 320 includes four individual cells 324a-d, one including three thermal plates each having a corresponding GC component (numbered 350a-c) thereon, and the three others each including one thermal plate having one GC component (350d-f) mounted and/or attached thereon. The GC components 350a-f can be, for example, similar to the ones which have been previously listed. Three of the four individual cells 324a-d are approximately of the same size and each occupies a volume V_5 , while the remaining one is bigger than the three others and occupies a volume V_6 . In the illustrated embodiment, V_6 is approximately equal to the third of V_6 .

[00181] With reference to Figure 9, another embodiment of a GC modular oven 420 is shown. The features of the GC modular oven 420 are numbered with reference numerals in the 400 series which correspond to the reference numeral of the previous embodiment. The GC modular oven 420 includes three individual cells 424a-c, one including four thermal plates, each having one GC component (noted 450a-d) mounted and/or attached thereon, and the two others each including one thermal plate, each including one GC component (noted 450 e-f) mounted thereon. In this embodiment, the GC components 450 a-f can be, for example, similar to the ones which have been previously listed. Two of the three individual cells 424a,c are approximately of the same size and each occupies a volume V_7 , while the remaining one 424b is bigger than the two others, and occupies a volume V_8 . In the illustrated embodiment, V_6 is approximately equal to the quarter of V_8 .

[00182] Once the mechanical assembly done, the software is configured to reflect the mechanical assembly of the GC modular oven 20.

Chromatographic column cartridges

[00183] In accordance with some embodiments, and as it will be explained in greater detail below, the GC modular oven can comprise one or more chromatography column cartridge(s). In such embodiments, the chromatography column cartridges can be connected with a heating module. Such chromatography column cartridge can be mounted into one of the individual cells of the GC modular oven. Such chromatography column cartridges will now be described

[00184] Traditional GC oven, such as the one illustrated in Figure 10, usually includes one ramping oven provided in their back portion. Such a ramping oven typically includes a convection fan and a circular heating element located in front of the fan, so that the heat generated by the heating element is blown in the GC oven chamber when in operation. As such, the temperature in the whole GC oven is the same. Such a traditional GC oven also contain an ambient air inlet and vent, which can be operated, *i.e.*, selectively open or closed, so that the GC oven can cool down when needed. One major drawback of the traditional GC ovens is that they are large in internal volume. In some applications, for instance when the chromatography column is a small capillary (compared to the volume of the GC oven chamber) the GC oven and its corresponding large volume (with respect to the size of the small capillary) is uselessly heated. As such, traditional GC ovens could benefit from a better energetical efficiency.

[00185] Now referring to Figures 11a and 11b, an embodiment of a chromatography column cartridge 52 (also referred to as "the cartridge 52") is shown. The chromatography column 52 is compatible with a gas chromatography modular oven. Such a modular oven generally includes a main enclosure including a backwall and sidewalls defining an internal volume and individual cells inside the main enclosure. The chromatography column cartridge 52 is releasably engageable with the backwall within an associated one of the individual cells.

[00186] Broadly described, the chromatography column cartridge 52 includes a chamber for receiving at least a portion of a chromatography column therein, opposed ports for allowing a passage of an air flow in the chamber; and a heating module provided upstream of the chamber, the heating module being operable for generating, heating and circulating the air flow in the chamber.

[00187] More specifically, and as illustrated in Figures 11A-B, the cartridge 52 includes a chromatography column 54, and is provided with opposed ports 58a,b for air circulation.

[00188] In some embodiments, the cartridge 52 includes a chamber 60 for containing the chromatography column 54. As illustrated, the chamber 60 has the shape of a donut, so that the chromatography column 54 can be wound within (*i.e.*, inside) the chamber 60. Such a chamber 60 can be useful, for example, for maintaining the chromatography column 54 in place, but also for ensuring a more efficient heat transfer between the chromatography column 54 and its environment.

[00189] More particularly, an external portion of the chamber 60 can contain thermal insulation, so that the chromatography column 54 is surrounded by a thermal insulating material which results in a much smaller air volume around the chromatography column 54 within the chamber 60. Moreover, the shape of the chamber 60 can be useful to reduce the overall GC modular oven internal volume. It will be readily understood that the general shape of the chamber 60 could vary according to the available space in the oven and could be adapted according to a specific application.

[00190] Still referring to Figures 11A and 11b, a heating module 62 (sometimes referred to as a “compact module”) and a temperature sensor 56 operatively connected to the cartridge 52 are shown. The temperature sensor 56 is operatively connected (*i.e.*, coupled) to the heating module 62, for example at its output, so as to monitor the temperature.

[00191] As illustrated, the heating module 62 is positioned upstream of the chromatography column 54 and is used to heat the chromatography column 54. As such, the heating module 62 is in thermal connection with the chromatography column 54 and/or the chamber 60.

5 **[00192]** In some embodiments, the heating module 62 includes a heating element 64 and a blower 66. The heating element 64 is a component or a device that converts electricity into heat (*i.e.*, thermal energy). Such conversion can be achieved through resistive or Joule heating, for example. As illustrated, the heating module 62 is thermally connected to the chromatography column 54 through a
10 pipe 63. The pipe 63 is provided downstream of the blower 66, but upstream of the chromatography column 54. The compact oven 62 forms a close circuit, and an air flow circulates therein, using the blower 66 and appropriate tubes, pipes (e.g. the pipe 63), and other GC components. The air flow is generated by the blower 66.

[00193] The heating module 62 can be connected to the cartridge 52 with couplers,
15 such as quick-connect couplers. Other similar mechanical components could be used.

[00194] The heating element 64 can be, for example, and without being limitative, a circular heater, an annular heater, a wire or similar device(s) wound or coiled around the pipe 63. One will readily understand that, in this context, the pipe 63
20 can be made of a thermal conductive material, so as to conduct the heat from the heating element to an internal portion of the pipe 63.

[00195] In an alternate configuration, the heating element 64 could be replaced by a cooling system such as a Peltier cell to cool the chromatography column 54. In such a configuration, the cooling system is in thermal connection with the pipe 63.
25 Such a cooling system could be used, for example, to control or adjust the temperature set by the heating module 62

[00196] The temperature of the heating module 62 is controlled by controlling the heat generated by the heating element, for example by adjusting the power of the

heating element 64 or an air flow at the output of the heating module 62, e.g., by adjusting the blower 66 rotation speed. In some embodiments, control of the power of the heating element 64 is achieved by varying the current flowing through the heating element 64.

- 5 **[00197]** In some embodiments, the temperature is controlled by adjusting the air flow by controlling the blower 66 rotation speed. The blower 66 rotation speed may also be controlled depending on the operation mode. In some implementations, when a temperature set point is reached (*i.e.*, a predetermined temperature), the blower 66 speed may be reduced in order to reduce the noise. When heating
10 module 62 is operated at a lower temperature (*i.e.*, cooled down), the blower 66 speed may be adjusted to evacuate the hot air from the heating module 62.

[00198] The heating module 62 can be maintained at isothermal temperature, or ramped at a predetermined rate, according to the targeted application. The inlet and outlet 58 can be used to vent heated air from the cartridge 52.

- 15 **[00199]** As it has been previously mentioned, the GC modular oven 20 can contain one or more cartridge(s) 52. For example, as better illustrated in Figure 11B, the GC modular oven can be provided with two cartridges 52a,b. It is to be noted that the cartridges 52a,b could be, but are not necessary, in the same individual cell 24.

- [00200]** It will be understood that the cartridges 52a and 52b can be provided with
20 corresponding inlet/outlet ports 58a,b (sometimes referred to as “opposed ports”), heating elements 64a,b, pipes 63a,b, and blowers 66a,b. In some embodiments, for example when multiple cartridges (e.g. cartridges 52a,b) are provided, each one of the multiple cartridges (e.g. cartridges 52a,b) can have respective independent inlet and outlet, or a respective common inlet and outlet.

- 25 **[00201]** In order to keep the design of the GC modular oven 20 as compact as possible, the heating module 62 can be provided with a motor 68 operatively connected to the blower 66. More particularly, in the illustrated variant, only one motor 68 is provided to impart movement to the blowers 66a and 66b through a

common shaft 70. The common shaft 70 extends from the motor 68 and is in mechanical connections with the two blowers 66a and 66b. In this variant, two cartridges 52a, 52b are superimposed within the same individual cell (not illustrated).

5 **[00202]** The chromatographic column cartridge 52 and the heating module 62 can be mounted in an individual cell 24 of the GC modular oven 20 which has been previously described. In such scenarios, the individual cell 24 does not include a thermal plate, and the temperature within the corresponding individual cell 24 is adjusted by adjusting the power of the heating element 64 of the heating module 62
10 or the blower 66 rotational speed. In one embodiment, the temperature is controlled by recirculating the air inside the cartridge 52. It will readily be understood that, in these embodiments, the heating module 62 is operatively connected to the temperature controller 32, in a similar manner of what has been previously described.

15 ***Explosion-proof gas chromatography modular oven***

[00203] Traditional explosion-proof ramping ovens, as the ones from prior art, usually include a large enclosure with a circular cover mountable to a front portion of the oven. An example of such a traditional explosion-proof compact ramping oven is illustrated in Figure 13.

20 **[00204]** Now referring to Figures 14a to 14c, an embodiment of an explosion-proof gas chromatography modular oven 500, which is sometimes referred to as the “compact ramping oven”, or, alternatively, the “explosion-proof oven”, is shown. Broadly described, the explosion-proof gas chromatography modular oven 500 includes a main enclosure, individual cells inside the main enclosure, a gas
25 chromatography column cartridge and a secondary enclosure. The main enclosure includes a backwall and sidewalls defining an internal volume. The chromatography column cartridge is releasably engageable with the backwall within an associated one of the individual cells. The chromatography column cartridge includes a chamber for receiving at least a portion of a chromatography

column therein and opposed ports for allowing a passage of an air flow in the chamber. The secondary enclosure is generally stackable with the main enclosure and is isolable therefrom. The secondary enclosure includes an inlet port and an outlet port in fluid communication with a respective one of the opposed ports of the chromatography column cartridge and a heating module operable for generating, heating and circulating the air flow in the chamber. It is to be noted that the explosion-proof gas chromatography oven 500 may share common characteristics with the embodiments of the gas chromatography modular oven which have been previously described.

10 **[00205]** Now turning specifically to Figures 14A-C, the explosion-proof gas chromatography modular oven 500 includes a main enclosure 522 defining an internal volume into which can be mounted different GC components.

[00206] The main enclosure 522 can receive one or more chromatographic column cartridges similar to the ones which have been previously described in terms of design, shape and other characteristics. As better illustrated in the embodiment depicted in Figures 14B-C, the main enclosure 522 includes two chromatographic column cartridges 552a,b and are configured to receive a corresponding chromatography column 554. The chromatographic column cartridges 552a,b could each include respective opposed ports 558a,b for allowing passage of air therein. The chromatographic column cartridges 552a,b can also be insulated with an insulating material provided on the outer surface of the chromatographic column cartridges 552a,b.

[00207] In the illustrated embodiments of Figures 14A-C, the chromatographic column cartridges 552a,b include a chamber having a donut shape, *i.e.*, have a substantially annular cross-section defining an empty space therein. The chamber is sized and configured to receive at least a portion of the gas chromatography column therein. The empty space defined by the inner periphery of the donut-shaped chamber could sometimes be referred to as a compartment 553. It is to be noted that different GC components can be mounted in the compartment 553. In

this sense, the compartment 553 is similar to the individual temperature cells which have been previously with respect to the other embodiments of the gas chromatography modular oven, and so could have or share similar functions. Of course, one would readily that the shape and/or geometrical configuration of the chromatographic column cartridges 552a,b and/or the chamber could vary.

[00208] In some embodiments, the compartment 553 can be divided in multiple zones into which can be mounted and assembled various GC components, such as depicted in the nonlimitative embodiment of Figure 14A, in which different zones are illustrated (*i.e.*, zone 1, zone 2 and zone 3). The GC components mounted in the multiple zones of the compartment 553 can be the same, or different, depending on the targeted application.

[00209] Now referring to Figure 14B, the explosion-proof gas chromatography modular oven 500 includes a secondary enclosure 521 isolable from the chamber. The secondary enclosure can be mounted and operatively connected to the main enclosure 522. In the illustrated embodiment, the secondary enclosure 521 is stacked with the main enclosure 522. The secondary enclosure 521 is sized and configured to receive the heating module (not illustrated in Figure 14B) as well as its associated blowers 556a,b. The blowers 556a,b generate and circulate (*i.e.*, “blow”) the heated (or cooled) air from the compact oven towards a respective one of the chromatographic column cartridges 552a,b through corresponding inlet port 558a,b.

[00210] The explosion-proof gas chromatography oven 500 includes a cover 559. The cover 559 can include a male and/or female threaded portion for attachment to a front portion of the main enclosure 522. More particularly, the cover 559 is pivotally mountable to the front portion of the main enclosure 522 (also corresponding to a front portion of the explosion proof gas chromatography oven 500). The cover 559 can be provided with a seal or an insulating material to ensure proper sealing of the explosion-proof oven 500 once the cover 559 is pivotally mounted to the front portion of the main enclosure 522.

[00211] Several alternative embodiments and examples have been described and illustrated herein. The embodiments described above are intended to be exemplary only. A person skilled in the art would appreciate the features of the individual embodiments, and the possible combinations and variations of the components. A person skilled in the art would further appreciate that any of the embodiments could be provided in any combination with the other embodiments disclosed herein. The present examples and embodiments, therefore, are to be considered in all respects as illustrative and not restrictive. Accordingly, while specific embodiments have been illustrated and described, numerous modifications come to mind without significantly departing from the scope defined in the appended claims.

CLAIMS

1. A gas chromatography modular oven, comprising:

a main enclosure comprising a backwall and sidewalls defining an internal volume, said sidewalls comprising a plurality of panel-engaging structures defining multiple panel-mounting positions within the internal volume;

one or more panels releasably engageable with said panel-engaging structures to divide the main enclosure into individual cells; and

one or more thermal plates releasably engageable with said backwall within an associated one of said individual cells, each thermal plate being operable to set an operation temperature in the associated individual cell, thereby creating temperature-controlled zones within the gas chromatography modular oven.

2. The gas chromatography modular oven of claim 1, wherein the backwall and sidewalls are made from a respective material stack, said respective material stack comprising a thermally insulating layer sandwiched between two thermally conductive layers.

3. The gas chromatography modular oven of claim 1 or 2, wherein said one or more panels comprises one or more connecting channels extending therethrough and configured to allow a passage of a gas chromatography column.

4. The gas chromatography modular oven of any one of claims 1 to 3, further comprising mechanical fasteners removably engageable with said one or more panels to attach said one or more panels to an associated one of said backwall and sidewalls.

5. The gas chromatography modular oven of any one of claims 1 to 4, wherein said panel-engaging structures comprise slots formed in the sidewalls, said one or more panels being slidably engageable with the slots.

6. The gas chromatography modular oven of claim 5, further comprising a first impervious seal extending along at least a portion of said slots.

7. The gas chromatography modular oven of claim 5 or 6, further comprising a second impervious seal extending along at least a portion of a periphery of said one or more panels.

8. The gas chromatography modular oven of any one of claims 1 to 7, wherein each thermal plate comprises:

a mounting plate made of a conductive material;

a heating element contacting the mounting plate;

a temperature sensor contacting the mounting plate; and

spacers attachable to the mounting to maintain the mounting plate spaced apart from said backwall.

9. The gas chromatography modular oven of claim 8, wherein the mounting plate comprises a cut provided therethrough.

10. The gas chromatography modular oven of claim 8 or 9, further comprising a temperature controller operatively connected to said one or more thermal plates, the temperature controller having an associated one of the temperature sensor as an input and an associated one of the heating element as an output.

11. The gas chromatography modular oven of claim 10, wherein the temperature controller is a proportional-integral-derivative controller.

12. The gas chromatography modular oven of any one of claims 8 to 11, wherein said one or more thermal plates comprise one or more corresponding thermoelectric devices.

13. The gas chromatography modular oven of any one of claims 8 to 12, wherein at least one of said one or more panels, said backwall and said mounting plate comprises one or more mounting holes to receive one or more associated gas chromatography components therethrough.

14. The gas chromatography modular oven of any one of claims 1 to 13, wherein each panel has one or more notches engageable with corresponding one or more notches of another one of said one or more panels.

15. A gas chromatography modular oven, comprising:

5 a main enclosure comprising a backwall and sidewalls defining an internal volume;

 individual cells inside the main enclosure; and

 a chromatography column cartridge releasably engageable with said backwall within an associated one of the individual cells, the
10 chromatography column cartridge comprising:

 a chamber for receiving at least a portion of a chromatography column therein;

 opposed ports for allowing a passage of an air flow in the chamber;
 and

15 a heating module provided upstream of the chamber, the heating module being operable for generating, heating and circulating the air flow in the chamber.

16. The gas chromatography modular oven of claim 15, wherein said sidewalls
20 comprise a plurality of panel-engaging structures defining multiple panel-mounting positions within the internal volume.

17. The gas chromatography modular oven of claim 16, further comprising one or more panels releasably engageable with said panel-engaging structure to divide the main enclosure into said individual cells.

18. The gas chromatography modular oven of any one of claims 15 to 18, wherein
25 the chamber is donut-shaped.

19. The gas chromatography modular oven of any one of claims 15 to 18, wherein the backwall and sidewalls are made from a respective material stack, said respective material stack comprising a thermally insulating layer sandwiched between two thermally conductive layers.

5 20. The gas chromatography modular oven of any one of claims 17 to 19, wherein said one or more panels comprises one or more connecting channels extending therethrough and configured to allow a passage of a gas chromatography column.

21. The gas chromatography modular oven of any one of claims 17 to 20, further comprising mechanical fasteners removably engageable with said one or more
10 panels to attach said one or more panels to an associated one of said backwall and sidewalls.

22. The gas chromatography modular oven of any one of claims 17 to 21, wherein said panel-engaging structures comprise slots formed in the sidewalls, said one or more panels being slidably engageable with the slots.

15 23. The gas chromatography modular oven of claim 22, further comprising a first impervious seal extending along at least a portion of said slots.

24. The gas chromatography modular oven of claim 22 or 23, further comprising a second impervious seal extending along at least a portion of a periphery of said one or more panels.

20 25. The gas chromatography modular oven of any one of claims 15 to 24, wherein said heating module comprises:

a pipe in fluid communication with the chamber;

a heating element contacting the pipe; and

a temperature sensor contacting the pipe.

25 26. The gas chromatography modular oven of claim 25, wherein the heating element is a thermally conductive wire wound around the pipe.

27. The gas chromatography modular oven of claim 25 or 26, further comprising a temperature controller operatively connected to said heating module, the

temperature controller having the temperature sensor as an input and the heating element as an output.

28. The gas chromatography modular oven of claim 27, wherein the temperature controller is a proportional-integral-derivative controller.

5 29. The gas chromatography modular oven of any one of claims 15 to 28, further comprising one or more thermal plates releasably engageable with said backwall within another associated one of said individual cells, each thermal plate being operable to set an operation temperature in said another associated individual cell.

10 30. The gas chromatography modular oven of any one of claims 17 to 29, wherein at least one of said one or more panels and said backwall comprises one or more mounting holes to receive one or more associated gas chromatography components therethrough.

15 31. The gas chromatography modular oven of any one of claims 17 to 30, wherein each panel has one or more notches engageable with corresponding one or more notches of another one of said one or more panels.

32. The gas chromatography modular oven of any one of claims 15 to 31, further comprising a secondary enclosure for receiving the heating module therein, the secondary enclosure being isolated from the chamber.

20 33. The gas chromatography modular oven of claim 32, wherein the secondary enclosure comprises an inlet port and an outlet port in fluid communication with a respective one of the opposed ports of the chromatography column cartridge.

34. The gas chromatography modular oven of claim 32 or 33, further comprising a cover pivotally securable to a front portion of the main enclosure.

35. A gas chromatography modular oven, comprising:

25 a main enclosure comprising a backwall and sidewalls defining an internal volume; and

one or more open-ended structures releasably engageable with said backwall, each open-ended structure comprising:

a thermal plate and one or more panels engaged with said thermal plate to delimit a temperature-controlled zone, the thermal plate being operable to set an operation temperature in said temperature-controlled zone.

5 36. The gas chromatography modular oven of claim 35, wherein the backwall and sidewalls are made from a respective material stack, said respective material stack comprising a thermally insulating layer sandwiched between two thermally conductive layers.

37. The gas chromatography modular oven of claim 35 or 36, wherein said one or
10 more panels comprises one or more connecting channels extending therethrough and configured to allow a passage of a gas chromatography column.

38. The gas chromatography modular oven of any one of claims 35 to 37, wherein said thermal plate comprises:

a mounting plate made of a conductive material;
15 a heating element contacting the mounting plate;
a temperature sensor contacting the mounting plate; and
spacers attachable to the mounting to maintain the mounting plate spaced apart from said backwall.

39. The gas chromatography modular oven of claim 38, wherein the mounting
20 plate comprises a cut provided therethrough.

40. The gas chromatography modular oven of claim 38 or 39, further comprising a temperature controller operatively connected to said thermal plate, the temperature controller having a temperature sensor as an input and a heating element as an output.

25 41. The gas chromatography modular oven of claim 40, wherein the temperature controller is a proportional-integral-derivative controller.

42. The gas chromatography modular oven of any one of claims 35 to 41, wherein said thermal plate comprises one or more thermoelectric devices.

43. The gas chromatography modular oven of any one of claims 38 to 42, wherein at least one of said one or more panels, said backwall and said mounting plate comprises one or more mounting holes to receive one or more associated gas chromatography components therethrough.

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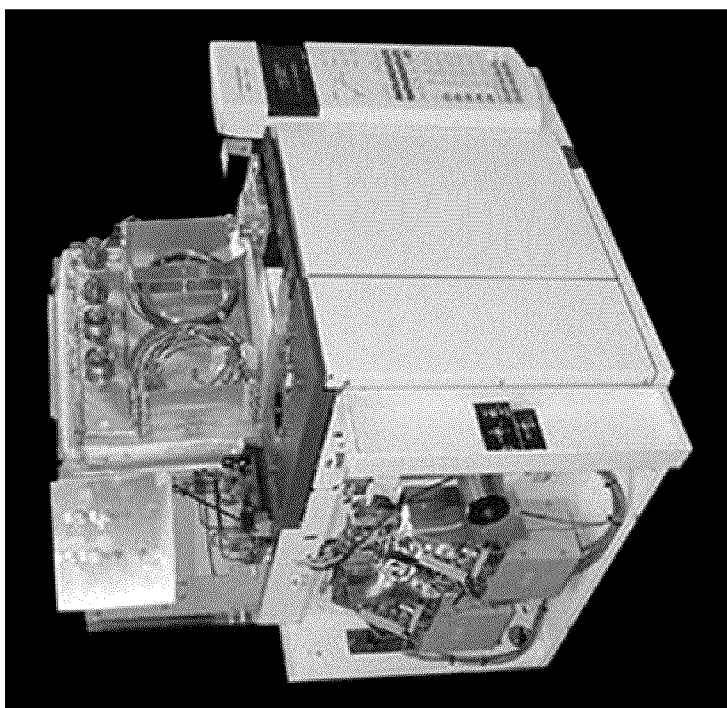
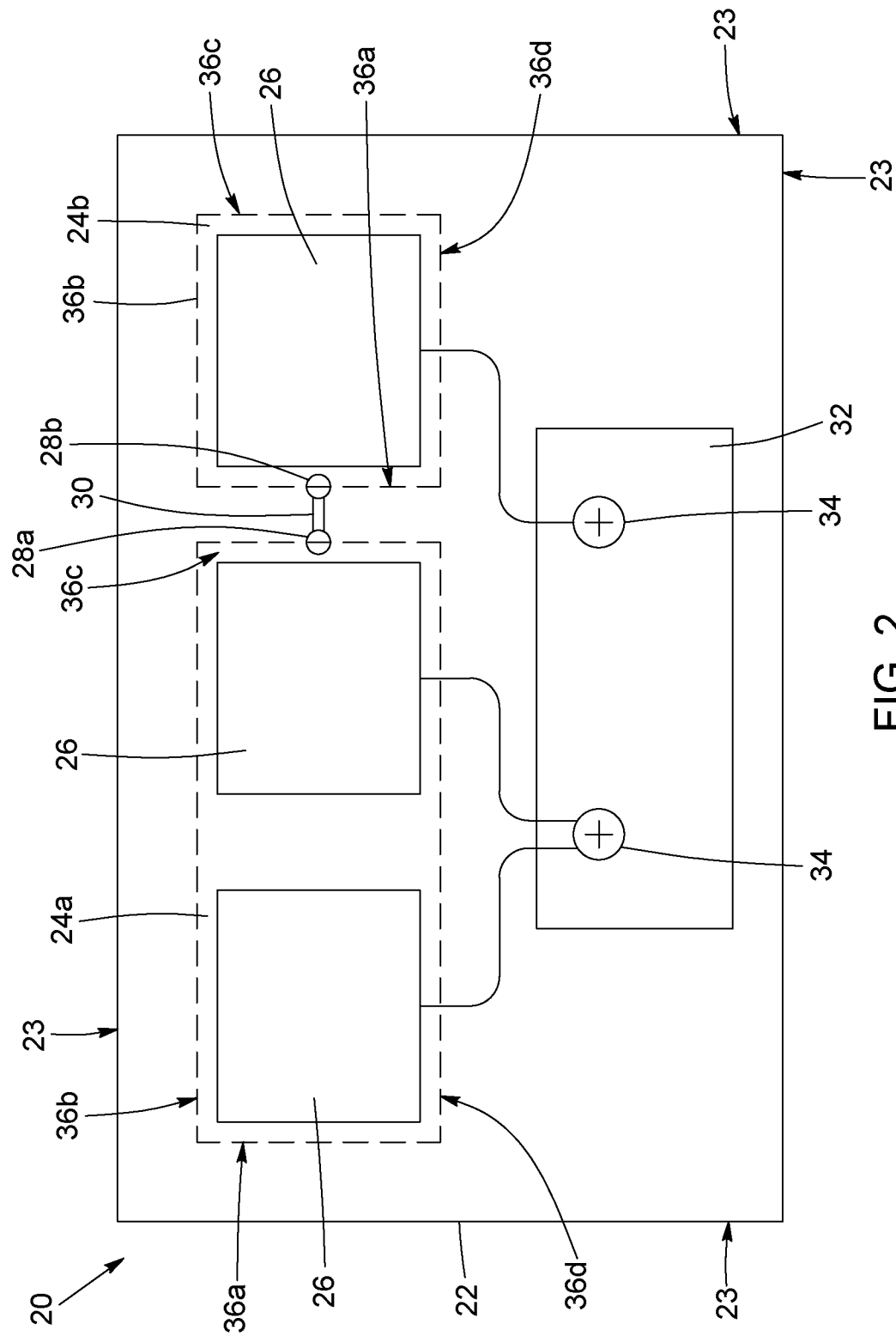


FIG. 1
(PRIOR ART)



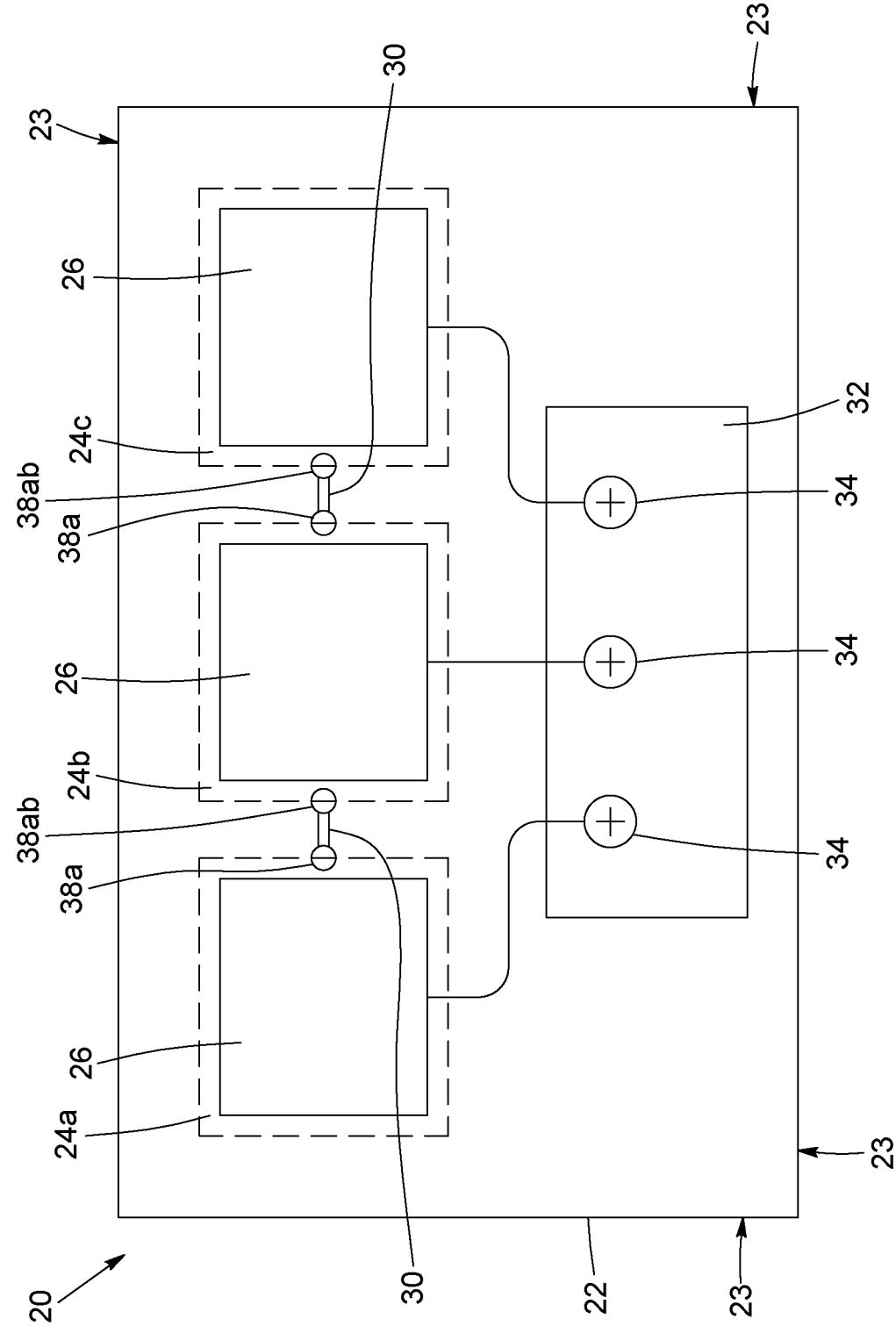


FIG. 3

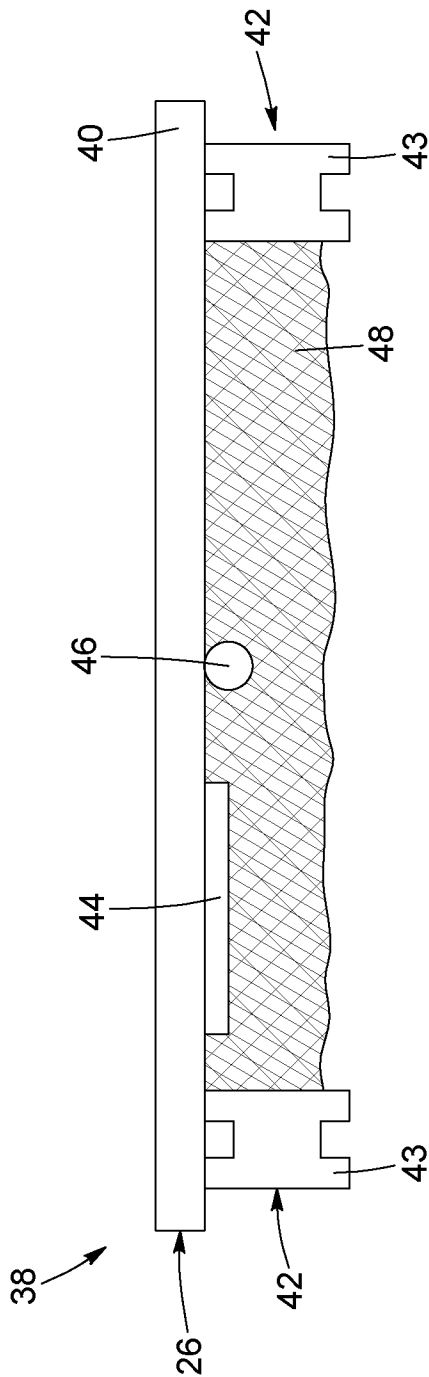


FIG. 4

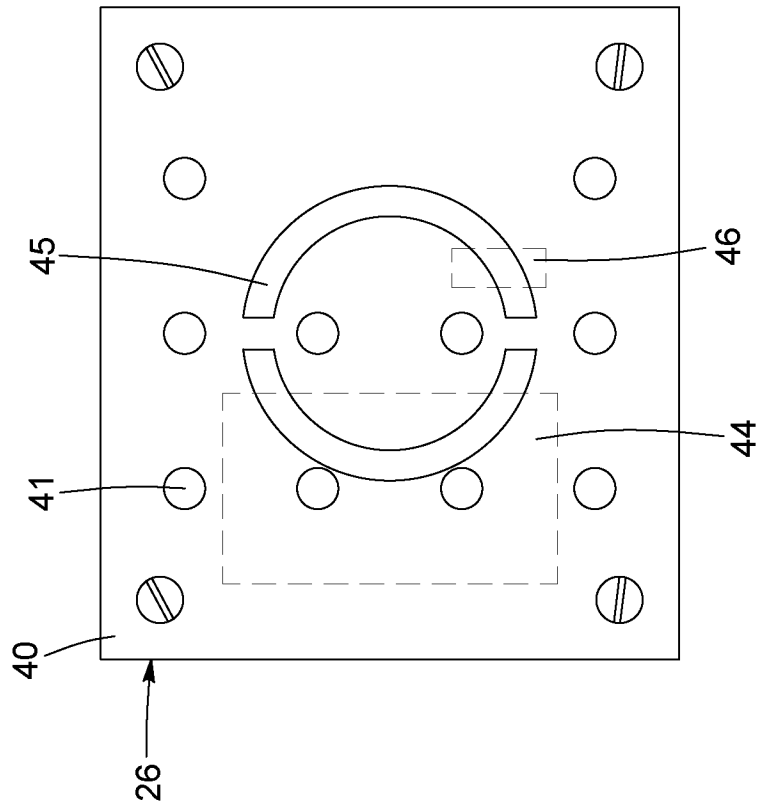


FIG. 5

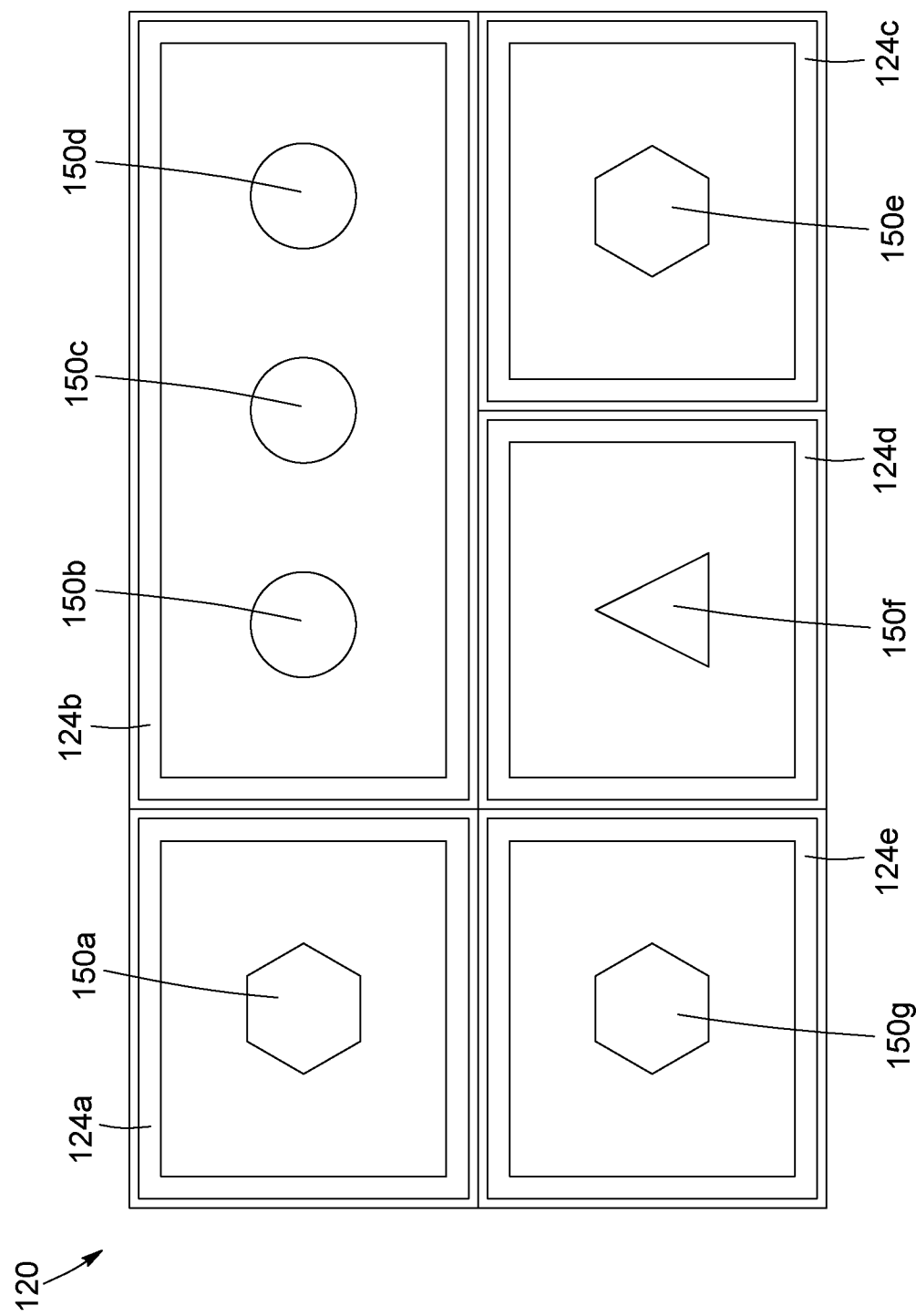


FIG. 6

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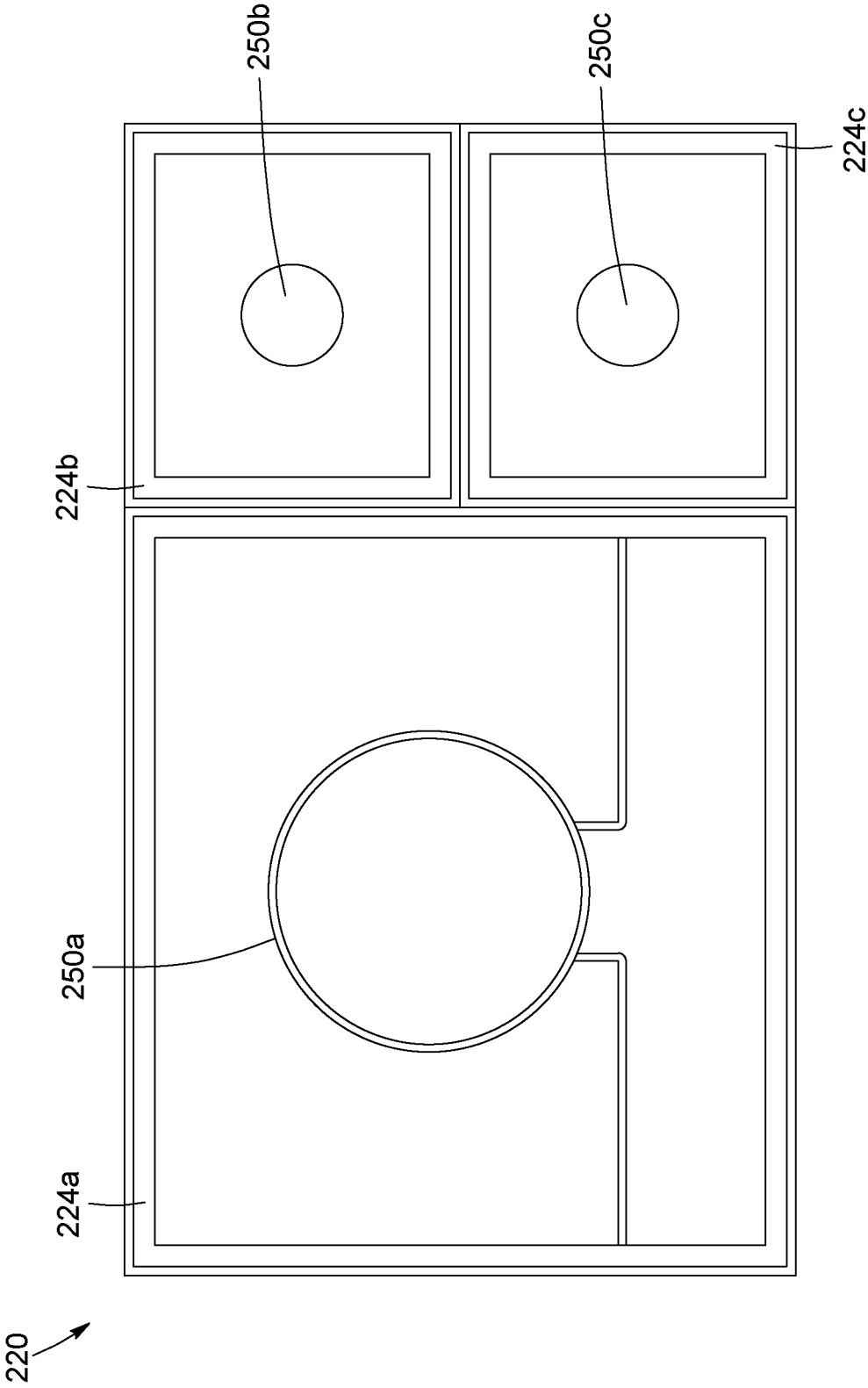


FIG. 7

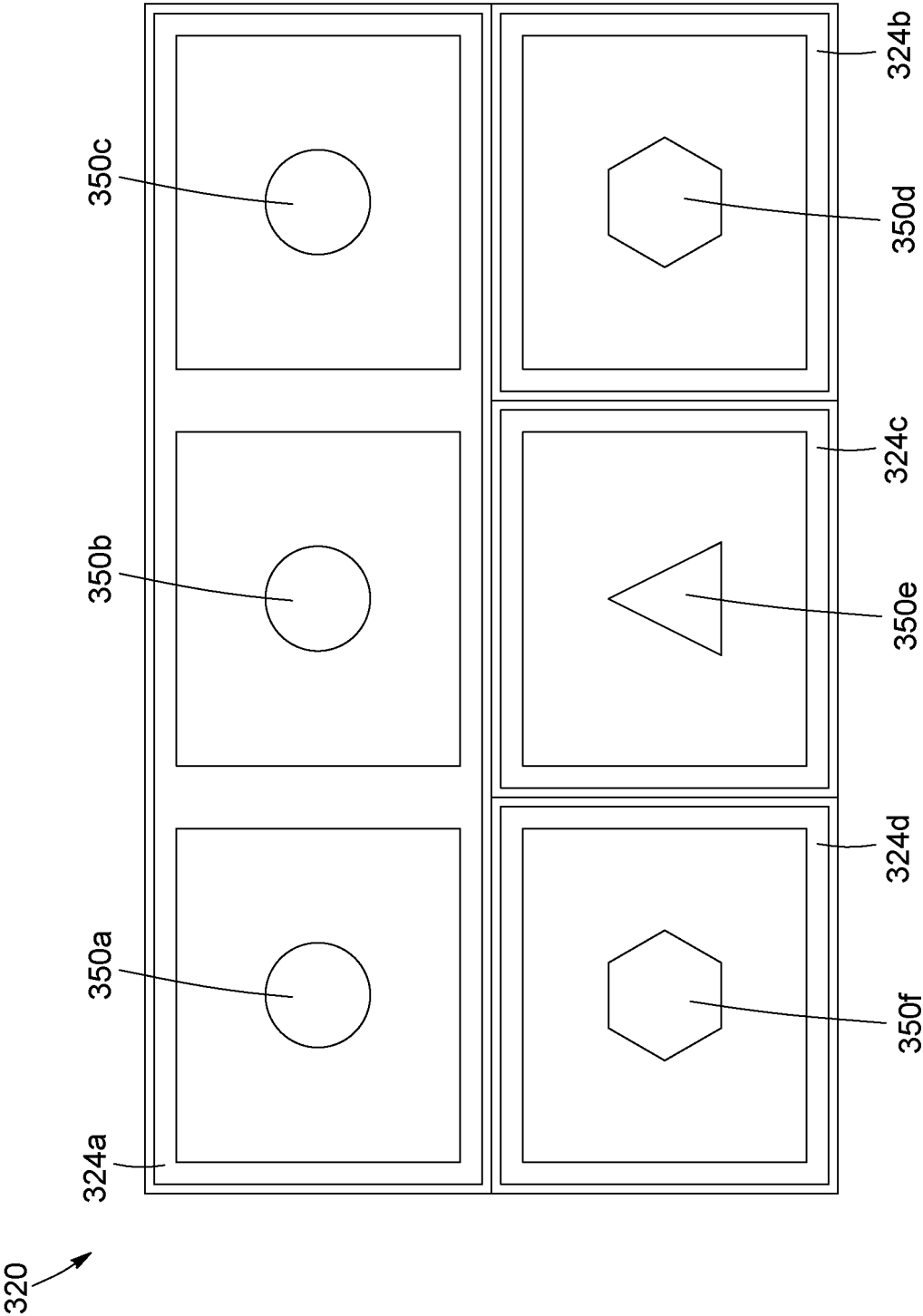


FIG. 8

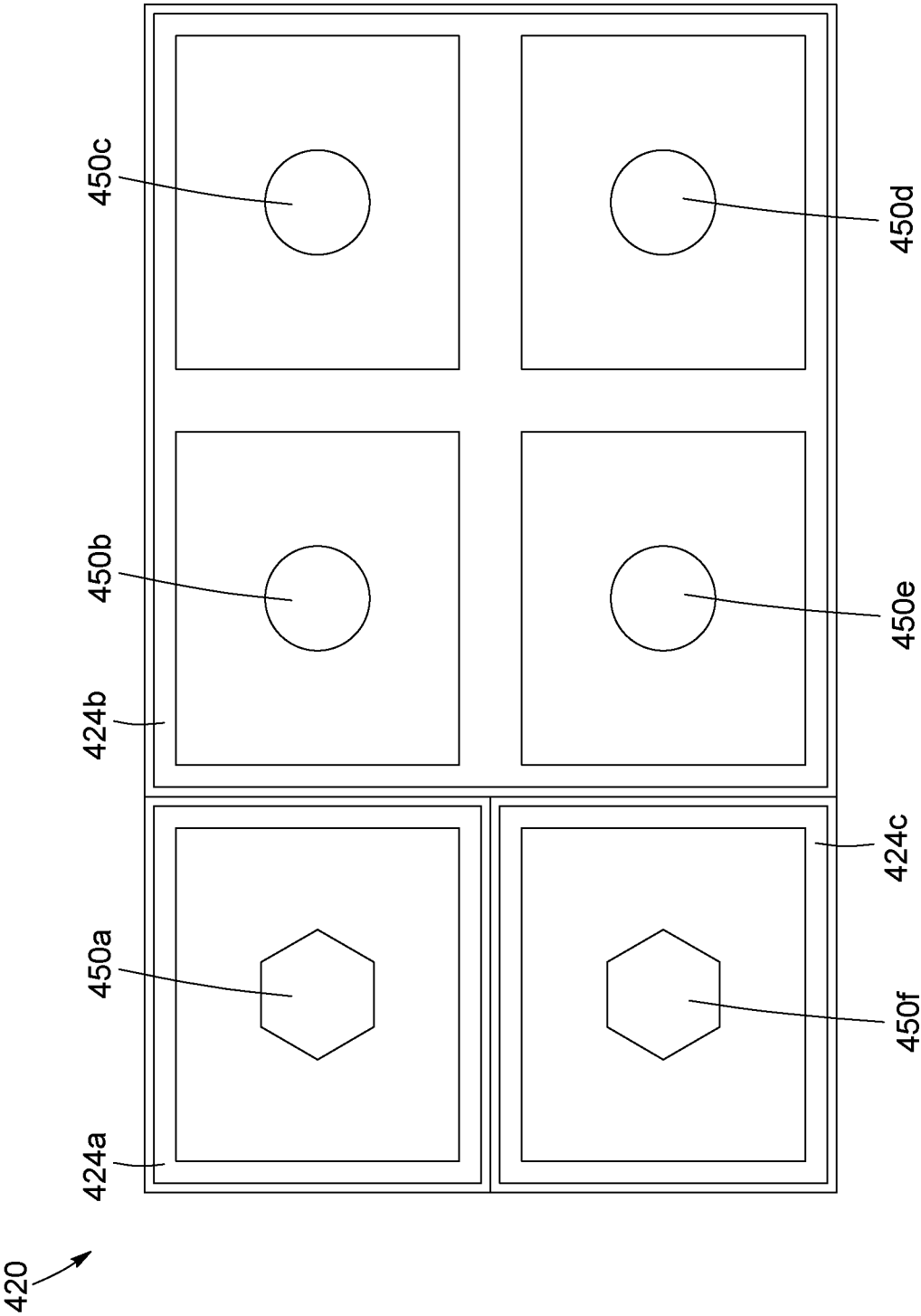


FIG. 9

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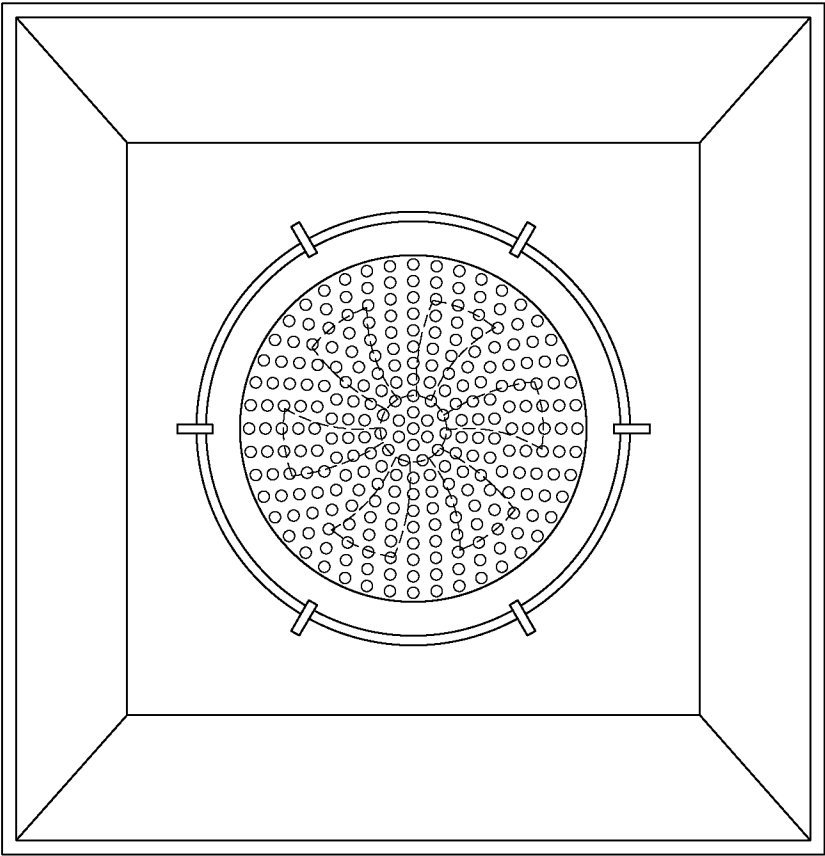
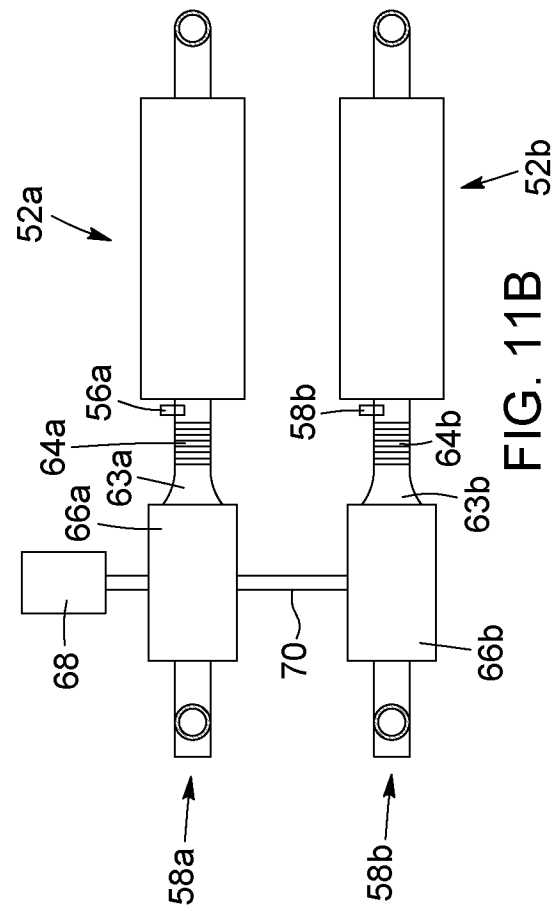
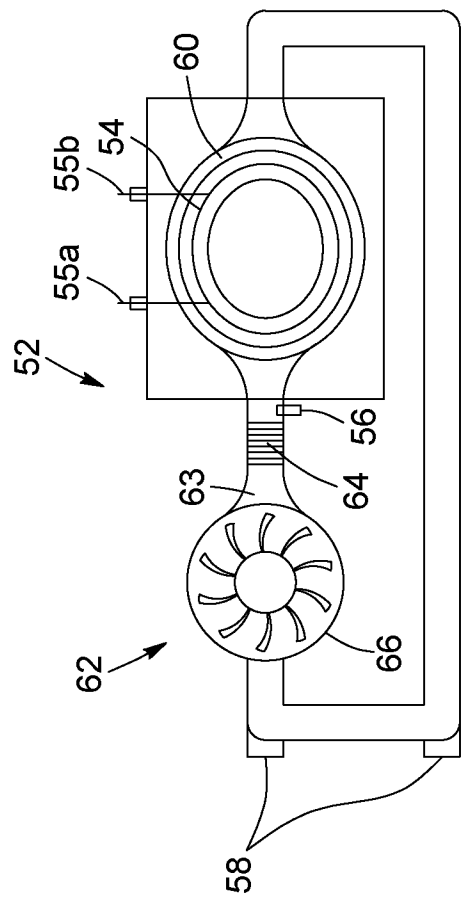


FIG. 10
(PRIOR ART)



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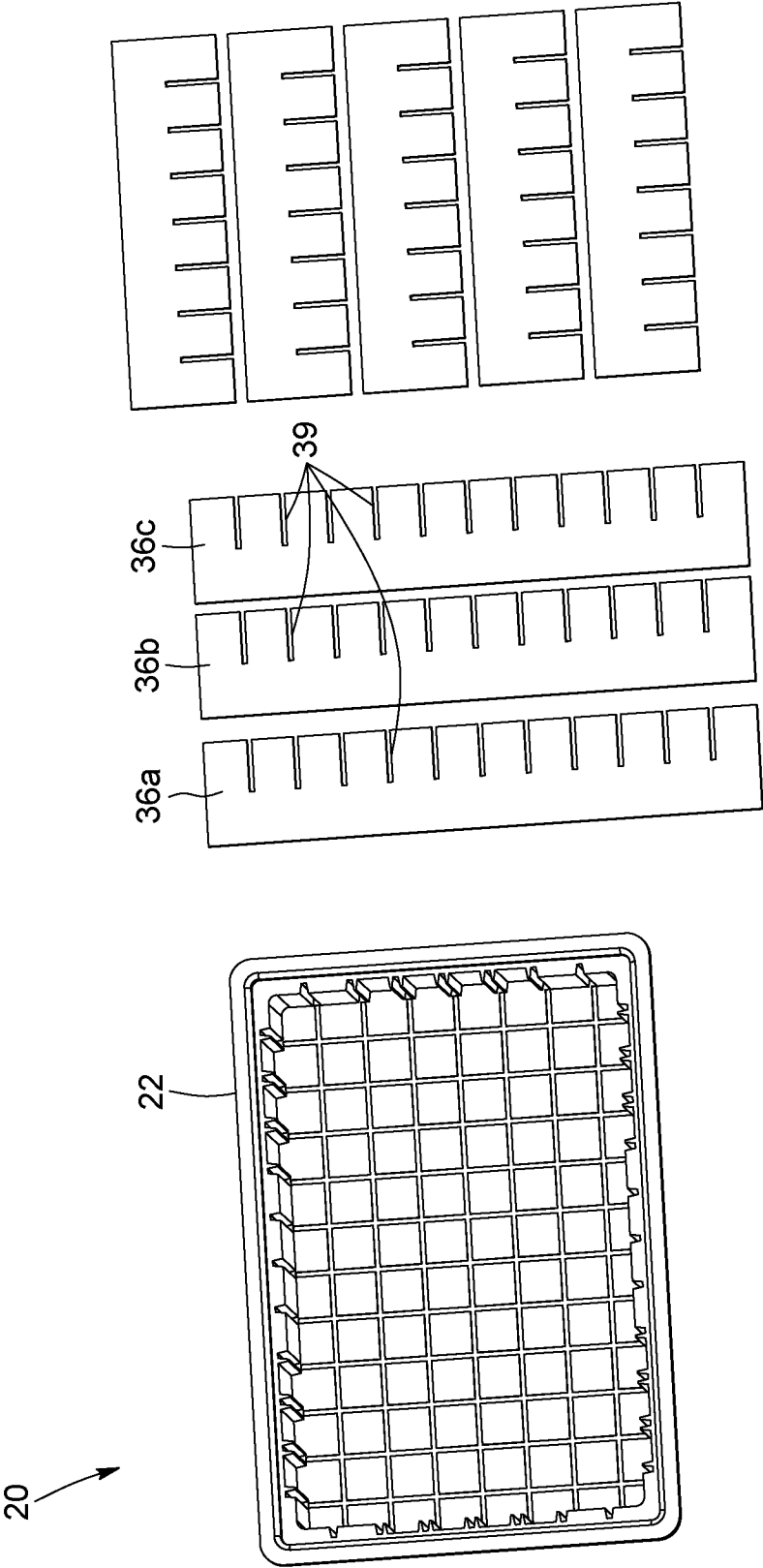


FIG. 12A

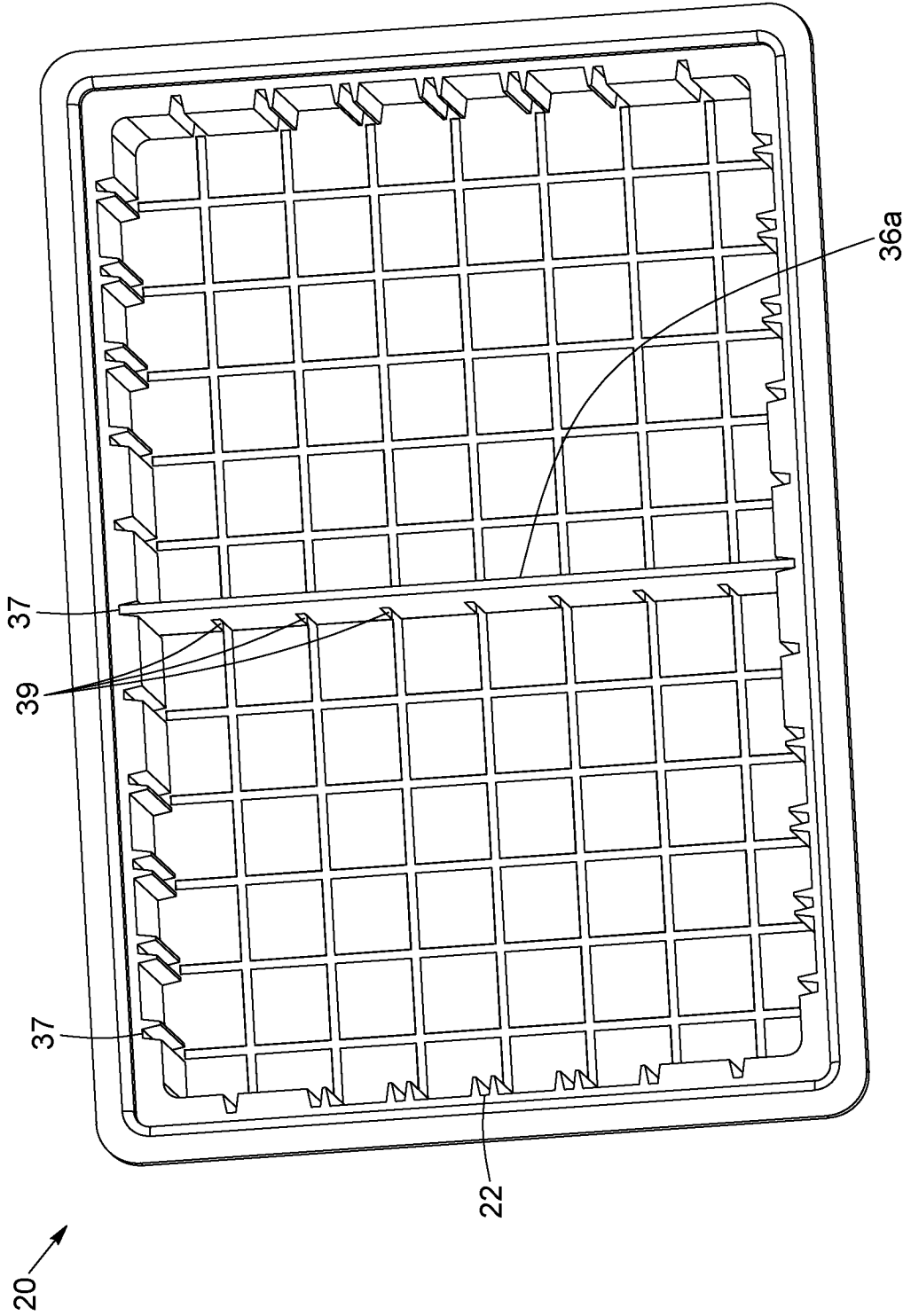


FIG. 12B

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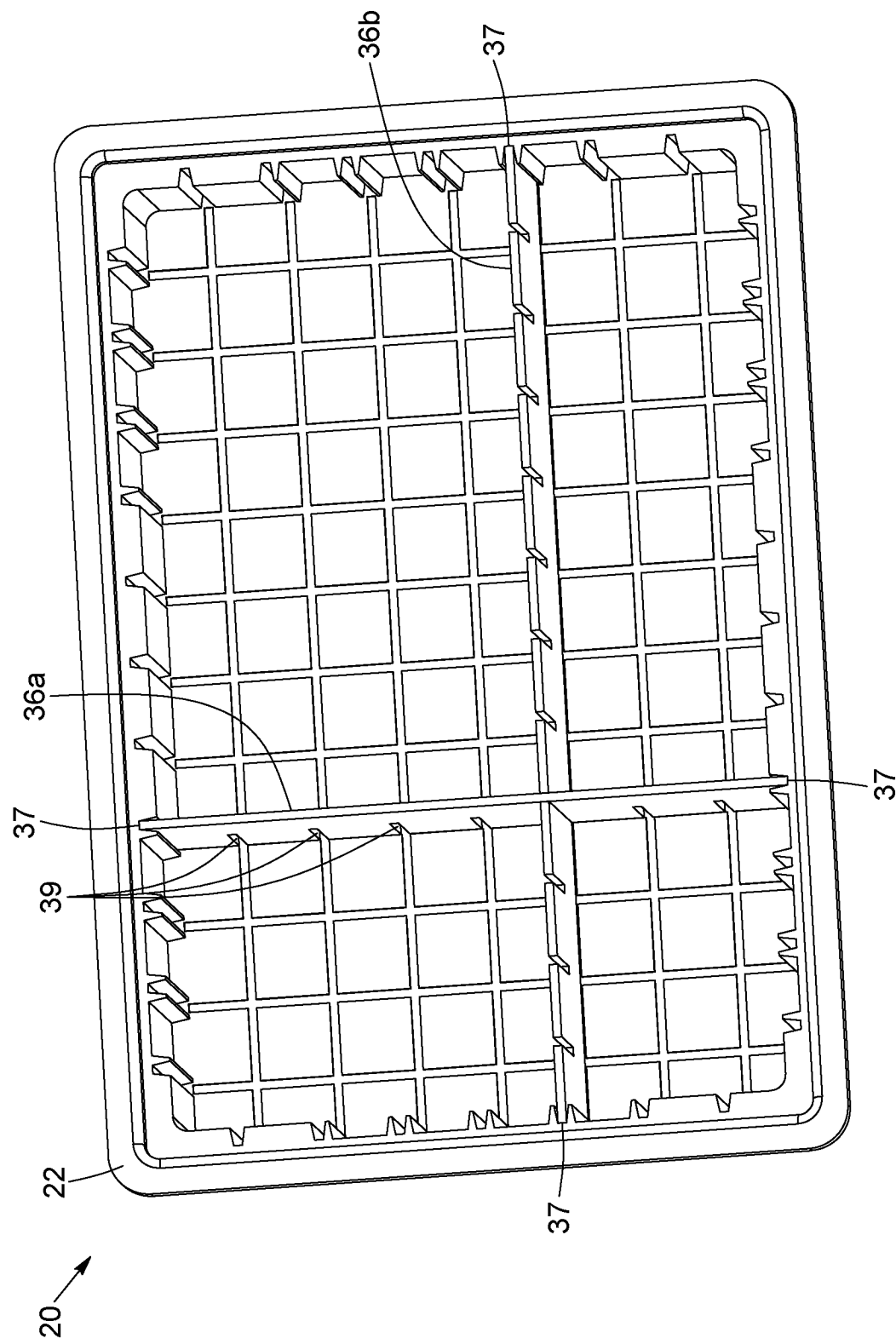


FIG. 12C

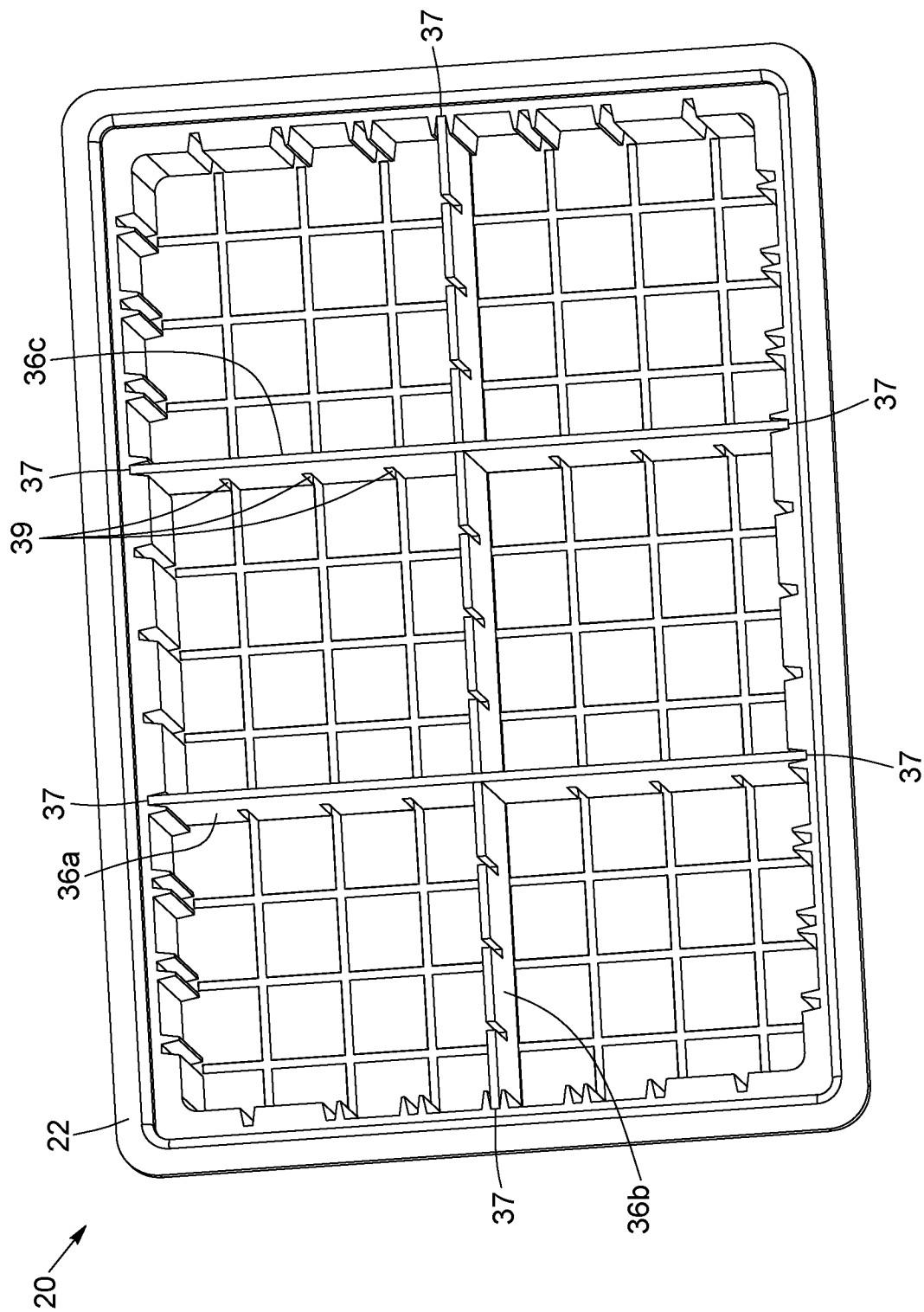


FIG. 12D

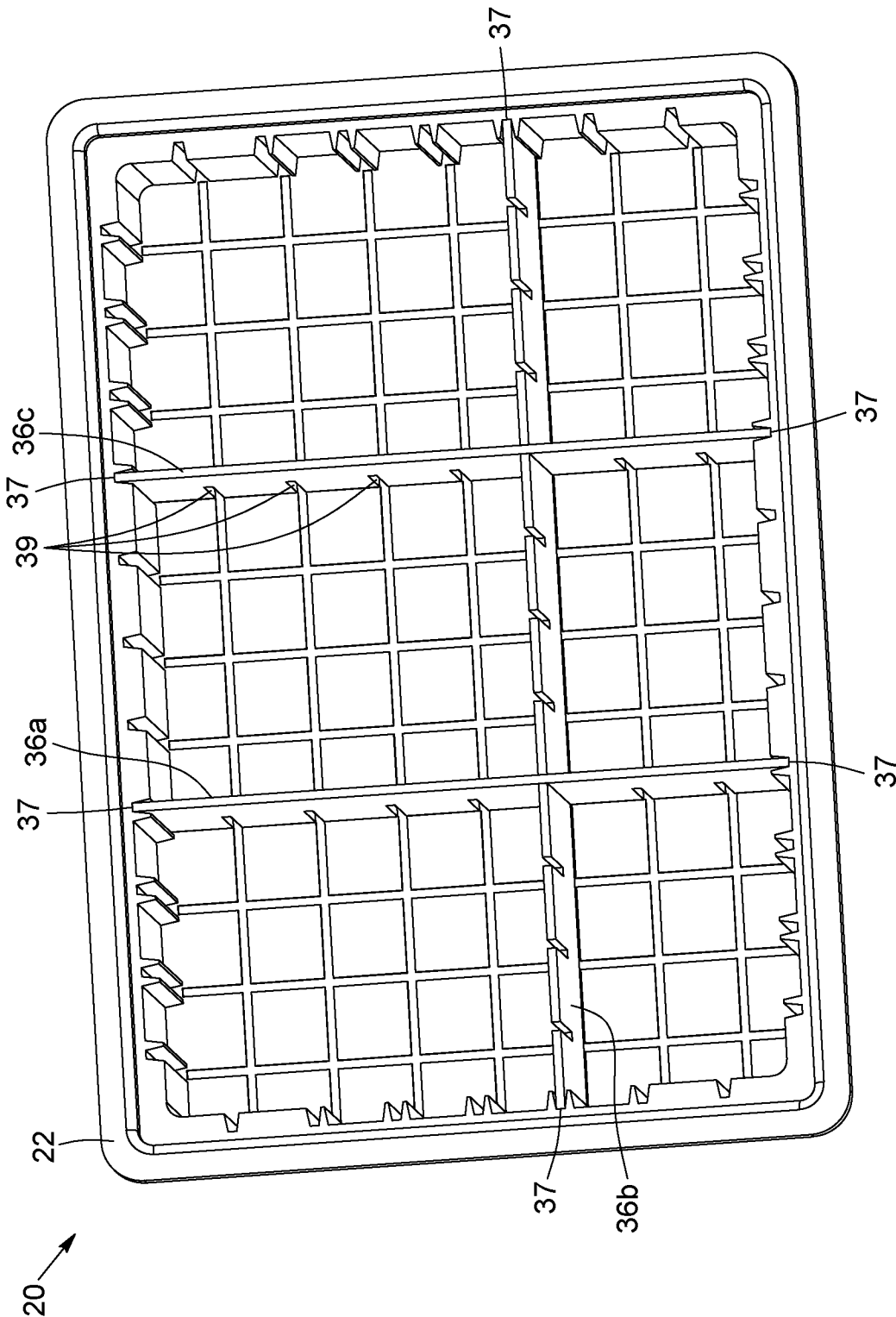


FIG. 12E

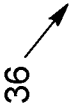
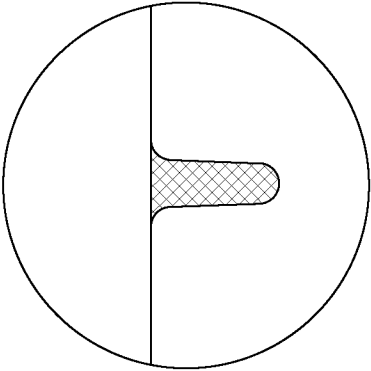
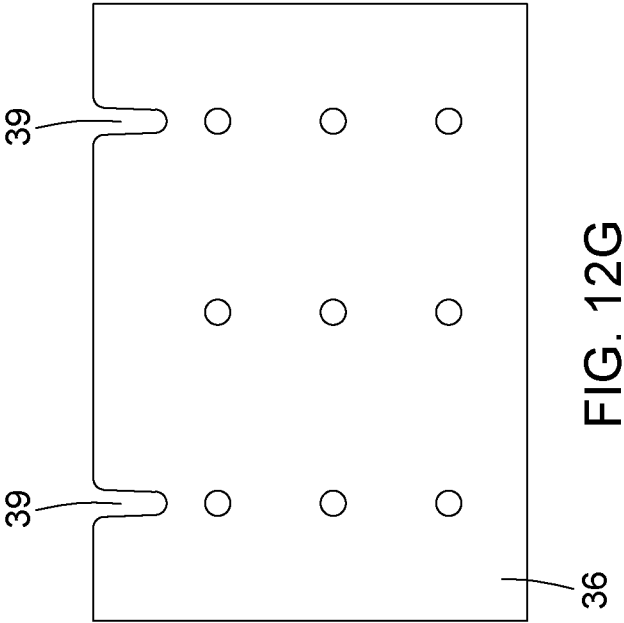


FIG. 12F

FIG. 12G

FIG. 12H

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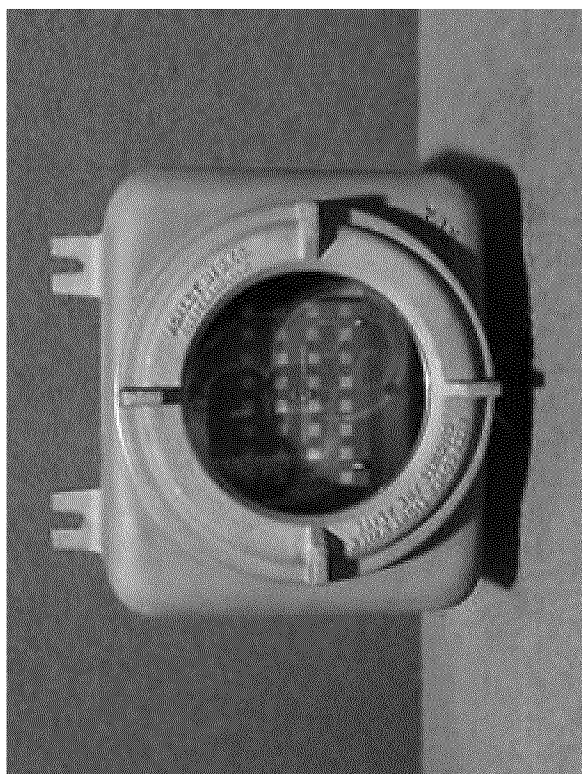


FIG. 13
(PRIOR ART)

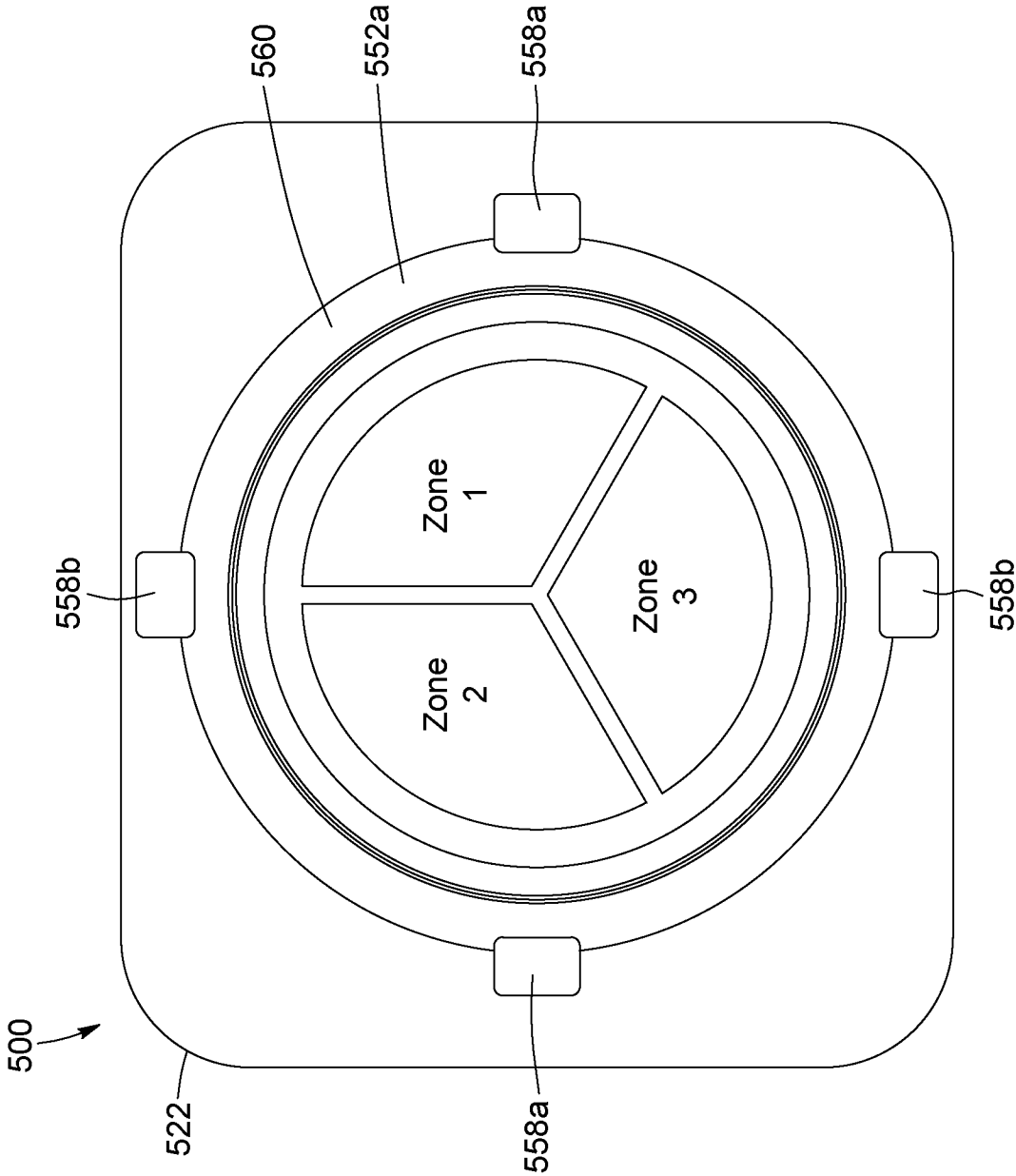


FIG. 14A

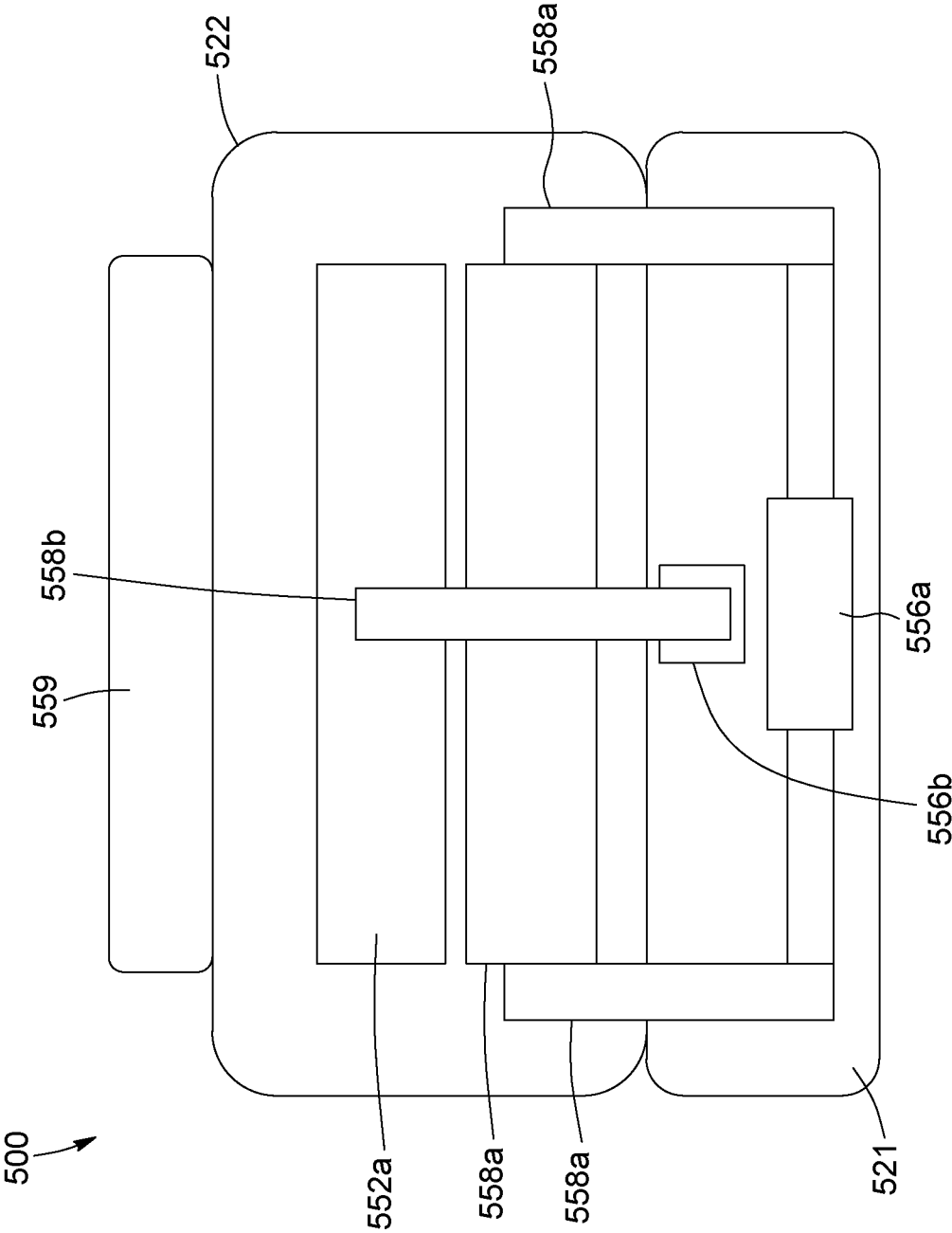


FIG. 14B

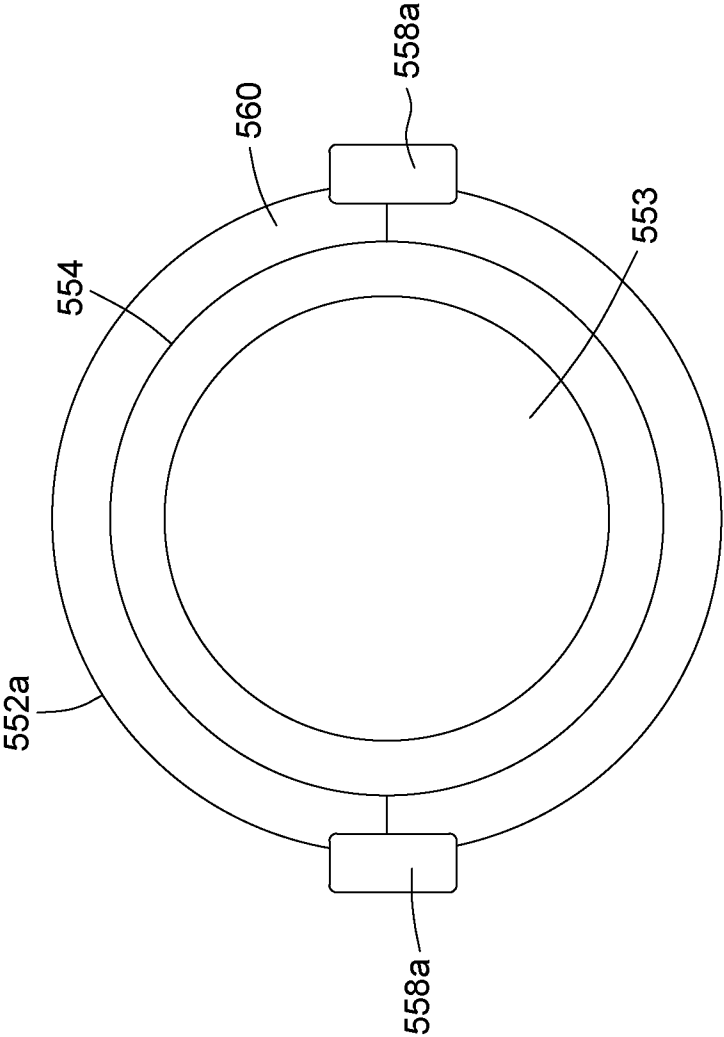


FIG. 14C

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CA2018/051556

A. CLASSIFICATION OF SUBJECT MATTER

IPC: **F27B 17/02** (2006.01), **B01D 15/10** (2006.01), **F27D 1/00** (2006.01)

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: **F27B 17/02** (2006.01)

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

Electronic database(s) consulted during the international search (name of database(s) and, where practicable, search terms used)

- See Extra Sheet

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CA2837364 (ECKERT) 19 June 2015 (19-06-2015)	1, 35
A	US8336366 (ROQUES et al.) 25 December 2012 (25-12-2012)	15

☐ Further documents are listed in the continuation of Box C.☒ See patent family annex.

* "A" "E" "L" "O" "P"	Special categories of cited documents: document defining the general state of the art which is not considered to be of particular relevance earlier application or patent but published on or after the international filing date 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) document referring to an oral disclosure, use, exhibition or other means document published prior to the international filing date but later than the priority date claimed	"T" "X" "Y" "&"	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 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 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
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Date of the actual completion of the international search
25 February 2019 (25-02-2019)Date of mailing of the international search report
28 February 2019 (28-02-2019)Name and mailing address of the ISA/CA
Canadian Intellectual Property Office
Place du Portage I, C114 - 1st Floor, Box PCT
50 Victoria Street
Gatineau, Quebec K1A 0C9
Facsimile No.: 819-953-2476

Authorized officer

Simon Webster (819) 956-6135

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CA2018/051556**Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of the 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. ☐ Claim Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claim 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. ☐ Claim 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:

Group A - Claims 1-14 and 35-43 are directed to a gas chromatography modular oven featuring one or more thermal plates releasably engageable with said backwall within an associated one of said individual cells, each thermal plate being operable to set an operation temperature in the associated individual cell, thereby creating temperature-controlled zones within the gas chromatography modular oven; and

Group B - Claims 15-34 are directed to a gas chromatography modular oven featuring chromatography column cartridge comprising: a chamber for receiving at least a portion of a chromatography column therein; opposed ports for allowing a passage of an air flow in the chamber; and a heating module provided upstream of the chamber, the heating module being operable for generating, heating and circulating the air flow in the chamber.

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 claim 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 claim 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

Information on patent family members

International application No.

PCT/CA2018/051556

Patent Document Cited in Search Report	Publication Date	Patent Family Member(s)	Publication Date
CA2837364A1	19 June 2015 (19-06-2015)	None	
US8336366B2	25 December 2012 (25-12-2012)	US2010256922A1 US8414832B1 WO2010028398A2 WO2010028398A3	07 October 2010 (07-10-2010) 09 April 2013 (09-04-2013) 11 March 2010 (11-03-2010) 27 January 2011 (27-01-2011)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CA2018/051556

Continuation of : Electronic database(s) consulted during the international search (name of database(s) and, where practicable, search terms used)

Questel/Orbit

- ((gas chromatograph+)/TI/AB/IW/CLMS/DESC/ODES/OBJ/ADB/ICLM/KEYW/TX AND (oven)/TI/AB/IW/CLMS/DESC/ODES/OBJ/ADB/ICLM/KEYW/TX AND (modular)/TI/AB/IW/DESC/ODES/OBJ/ADB/ICLM)
- (gas chromatograph+)/TI/AB/IW/CLMS/DESC/ODES/OBJ/ADB/ICLM/KEYW/TX AND (f27b+)/IPC/CPC
- (compartment+)/TI/AB/IW/CLMS/DESC/ODES/OBJ/ADB/ICLM/KEYW/TX AND (f27b+)/IPC/CPC