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(54) Cooking oven with vapor treatment system

(57) An oven **(100)** comprising an oven chamber **(105)** for the cooking of foods, heating means **(125)** for heating the oven chamber, and a vapor exhaust system **(155)** for treating vapors produced in the oven chamber during a food cooking process. The vapor exhaust system comprises: a first region **(405)** in fluid communication **(160,165,170)** with the oven chamber so as to receive vapors exiting the oven chamber and wherein the vapors are de-moisturized and cooled down; and a second region **(410)** downstream the first region and wherein the de-moisturized and cooled down vapors exiting the first region are mixed to hot dry air **(140)** before being exhausted to the outside ambient.

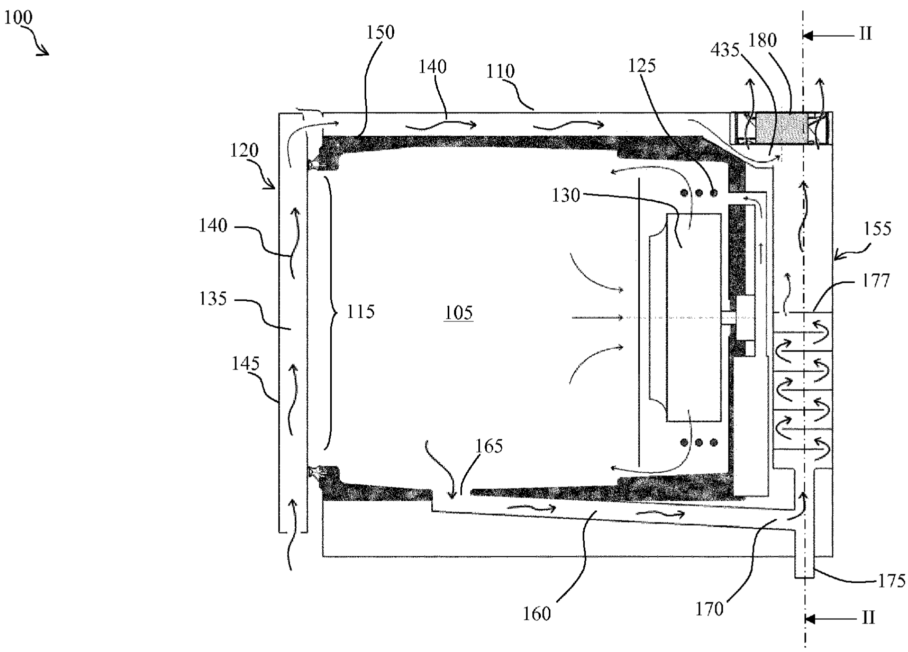

FIG. 1

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Description

Background of the invention

Field of the invention

[0001] The present invention relates to cooking apparatuses for cooking or baking foods, of the type having a cooking chamber, like cooking ovens, both for domestic and for professional use. Within this general scope, the present invention relates to improvements in respect of the treatment of vapors produced in the cooking chamber while cooking food. In the rest of the description, with "cooking" it will be intended any kind of preparation of foods by heat, including baking.

Overview of the relevant known art related to the invention

[0002] Cooking apparatuses comprise a cooking chamber in which food is cooked. During the cooking process, vapors forms in the cooking chamber of the cooking apparatus. Vapors are predominantly in the form of steam and consist of water vapor for the most part; in addition, they also contain oils and fats, which are present in the form of aerosols or else in liquid form. Other components may also be contained therein.

[0003] Vapors are created during the cooking process through the vaporization of water that is naturally contained in the foods being cooked; in addition, however, vapor that is deliberately fed into the cooking chamber of the apparatus (either by way of an external steam generator or else by direct vaporization of water inside of the hot cooking chamber) for some types of cooking also contributes to the creation of vapors. This water vapor is intentional and is important for certain aspects of the cooking process.

[0004] When fat-containing foods or fat-containing cooking products are cooked at high temperatures, the aforementioned oil and fat aerosols are additionally created.

[0005] Vapors in excess must be exhausted to the outside, otherwise an undesired vapor pressure would build up within the cooking chamber. Some conventional cooking apparatuses have an exhaust air opening from which steam or vapors can escape into the room air, but this can lead to a strong accumulation of moisture and heat in the room air in the surroundings of the cooking apparatus and in the entire kitchen premises; moreover, the room is also dirtied by the oil and fat aerosols contained in the escaped vapors. All this is totally unsatisfying.

[0006] US 2011/072983 discloses a cooking apparatus having a cooking chamber, wherein the vapors created in the cooking chamber are removed with a vapor outlet channel. A vapor condensation device brings the vapors into contact with a cooling liquid. The vapor condensation device has a container, in which a liquid bath is located. The vapor outlet channel carries the vapors out of the cooking chamber into the container of the vapor condensation device. There, the vapors are brought into contact with the liquid from the liquid bath and thereby partially condensed. Furthermore, a device drain is provided. The container of the vapor condensation device has a vapor guide element, that guides the vapors through one or more channels in the container; the vapor guide element is configured such that one wall of the wall surfaces of the channel or channels is formed by the surface of the liquid bath in the container.

[0007] EP 691513 discloses an oven having a cooking interior enclosed by a door and casing. There is a heater and floor drain removing condensate. Above the oven, an extraction hood removes water vapor, via a fan. Preferably, a suction duct connects the extraction hood to drain. A hood intake is immediately above the door opening and leads to a condenser integral with the hood; this has vertical baffle surfaces defining a steam channel. The base surfaces slant toward the extraction duct connection.

Summary of the invention

[0008] The Applicant has tackled the problem of devising a solution for providing an oven with an improved treatment of vapors produced in the cooking chamber while cooking or baking food.

[0009] According to an aspect of the present invention, there is provided an oven comprising an oven chamber for the cooking of foods, heating means for heating the oven chamber, and a vapor exhaust system for treating vapors produced in the oven chamber during a food cooking process.

[0010] The vapor exhaust system comprises:

- a first region in fluid communication with the oven chamber so as to receive vapors exiting the oven chamber and wherein the vapors are de-moisturized and cooled down; and
- a second region downstream the first region and wherein the de-moisturized and cooled down vapors exiting the first region are mixed to hot dry air before being exhausted to the outside ambient.

[0011] Therefore, the oven has, associated with the first region, means for demoisturize and cool down vapors received from the oven chamber, and, associated with the second region, means for mixing hot dry air to the vapors exiting the first region.

[0012] Preferably, said first region extends vertically.

[0013] Advantageously, in the first region a tortuous path for the vapors is formed. Said tortuous path may be a duct comprising a plurality of baffles.

[0014] In an embodiment, at least one of said baffles is hollow and is run through a heat-exchange fluid.

[0015] Advantageously, a coolant liquid feeding device may be associated with said first region, arranged for feeding a coolant liquid into the first region for cooling down the vapors.

[0016] Said coolant liquid feeding device may comprise at least one liquid feeding nozzle adapted to spray coolant liquid into said first region in a nebulized form.

[0017] Said coolant liquid feeding device may for example be arranged to cause the coolant liquid to enter into the first region proximate to a top side thereof.

[0018] Said coolant liquid feeding device is preferably connected to an activator adapted to selectively activate said coolant liquid feeding device for selectively feeding the coolant liquid.

[0019] Preferably, at least a temperature sensor is associated with the first region, arranged for sensing the temperature of the vapors entering into the vapors exhaust system.

[0020] Said coolant liquid feeding device may be selectively activated based on a sensed temperature of the vapors sensed by said temperature sensor.

[0021] The oven may comprise at least an air propeller associated with said vapor exhaust system and configured for promoting the exit of vapors from the oven chamber and their flow through the vapor exhaust system.

[0022] Said air propeller may comprise an axial or radial fan arranged at the exit of the second region.

[0023] Said air propeller may be selectively activatable.

[0024] Advantageously, said hot dry air comprises air exploited to cool down at least one among a door of the oven and/or air exploited to cool down internal oven parts subjected to heat up during the oven operation.

Brief description of the drawings

[0025] The following detailed description of exemplary and non-limitative embodiments of the present invention will help to render the above as well as other features and advantages of the present invention clearer. For its better intelligibility, the following description should be read while referring to the attached drawings, wherein:

- **FIG. 1** schematically shows an oven according to an embodiment of the present invention, in cross-section according to a vertical plane orthogonal to a front of the oven;
- **FIG. 2** schematically shows the oven of **FIG. 1** in cross section according to a plane parallel to the front of the oven, indicated in **FIG. 1** as **II-II;**
- **FIG. 3** schematically shows the oven of **FIG. 1** and **FIG. 2** in cross section according to a horizontal plane, indicated in **FIG. 2** as **III-III;**
- **Fig. 4** is a schematization of a vapor exhaust tower of the oven of **FIG. 1** to **FIG. 3,** with indicated different vapor control regions;
- **FIG. 5** is a schematization similar to **FIG. 4,** with notations used in a mathematical analysis of the different vapor control regions;
- **FIG. 6** is a simplified Carrier diagram or psychrometric chart (specific humidity in ordinate *versus* temperature in abscissa), of the humid air for a first control region of the vapor exhaust tower;
- **FIG. 7** is a complete Carrier diagram of the humid air for a first control region of the vapor exhaust tower;
- **FIG. 8** is a complete Carrier diagram of the humid air for a second control region of the vapor exhaust tower;
- **FIG. 9** is a schematic flowchart of an exemplary way of operation of the oven according to an embodiment of the present invention, and
- **FIG. 10** shows, in a schematical view similar to that of **FIG. 5,** a vapor exhaust tower according to another embodiment of the present invention.

Description of exemplary embodiments of the invention

[0026] Referring to **FIG. 1, FIG. 2** and **FIG. 3,** an oven according to an embodiment of the present invention is schematically depicted, in three cross-sectional views (as explained in the Brief description of the drawings).

[0027] The oven, denoted as a whole **100,** comprises an oven chamber **105** (cooking chamber) wherein the foods to be cooked/backed are to be introduced for being cooked.

[0028] The oven chamber **105** is a delimited region of space within an oven cabinet **110** having a front opening **115** for inserting/removing the foods, which is selectively closable by an oven door **120,** hinged to the oven cabinet **110** so as to be movable by an oven user between a closed position (the one depicted in **FIG. 1)** adapted to close the front opening **115,** and an open position (not depicted in the drawings) in which the oven chamber **105** is accessible through the front opening **115.**

[0029] Inside the oven chamber **105,** heating elements **125,** for example one or more resistive heaters, are provided, energizable for heating up the oven chamber environment.

[0030] Preferably, an air propeller **130** is also provided inside the oven chamber **105,** operable (possibly in a selective way, depending on a food cooking program selected by the oven user) to cause air circulation within the oven chamber **105** so as to better distribute the air heated up by the heating elements **125** and achieve a more uniform temperature inside the oven chamber **105.**

[0031] It is pointed out that although in **FIG. 1** the heating elements **125** are depicted as arranged at the periphery of the air propeller **130,** this is merely an example; the heating elements might be arranged in different locations, and/or additional heating elements might be arranged in different locations of the oven chamber **105,** *e.g.* at the top and/or at the bottom thereof.

[0032] The oven door **120** is designed so to have an air gap **135** formed therein, for the passage of cooling air **140** having the function of cooling the external panel **145** (usually of glass or other transparent material) of the oven door **120,** in order to keep such external panel at a temperature sufficiently low not to be harmful for the oven user. The oven door cooling air **140** is for example taken in from the outside ambient, *e.g.* through an opening formed at the bottom of the door **120.**

[0033] In a space formed between the oven chamber **105** and the walls of the oven cabinet **110,** thermally-insulating material **150** is preferably provided, in order to avoid heat dissipation from inside the oven chamber **105** to the outside ambient, and at the same time reducing the temperature of the cabinet walls when the oven **100** is operating.

[0034] Albeit not shown, it is intended that the oven **100** may comprise several other components, like for example a steam and/or microwaves generator(s) to be supplied to the oven chamber **105** for performing some particular kinds of cooking processes.

[0035] According to the present invention, the oven **100** is equipped with a system for exhausting vapors that are produced within the oven chamber 105 when foods are cooked. Advantageously, the vapor exhaust system is integrated, embedded in the structure of the oven **100.**

[0036] In the exemplary embodiment of the present invention here presented, the vapor exhaust system comprises a vapor exhaust tower **155** which is accommodated at the rear of the oven **100,** *e.g.* approximately at the center or more or less proximate to a corner of the oven cabinet **110,** like the rear-left corner (looking the oven **100** frontally), as shown in the drawings (it is intended that the position of the vapor exhaust tower **155** is not at all limitative for the present invention).

[0037] The vapor exhaust tower **155** according to an embodiment of the present invention will be hereafter described with the help of the principle schematic of **FIG. 4.**

[0038] The concept at the basis of the vapor exhaust tower **155** according to the present invention is the (selective) superposition of three physical phenomena: a dehumidification, de-hydration, moisture condensation of the vapors coming from the oven chamber **105** (phenomenon **A**); a cooling of the vapors (phenomenon **B**), and an adiabatic intermixing of the vapors with relatively hot and dry air (phenomenon **C**).

[0039] In an embodiment of the present invention, phenomena **A** and **B** may take place concurrently, as depicted in the schema of **FIG. 4,** in a bottom section **405** of the exhaust tower **155;** phenomenon **C** takes place in a top section **410** of the exhaust tower **155.**

[0040] Referring back to **FIG. 1** and **FIG. 2,** the exhaust tower **155** is, at a bottom thereof (i.e., at a bottom of the bottom section **405**), fluidly connected to a vapor discharge duct **160** that, having an inlet **165** preferably at the bottom of the oven chamber **105** (*e.g.*, approximately in the central position), runs, preferably declining, towards an outlet **170** opening approximately at the bottom of the exhaust tower bottom section **405.**

[0041] The bottom of the exhaust tower bottom section **405** is also fluidly connected to a liquid drainage **175** (only part of which is shown), which, when the oven is installed in a kitchen, is connected to a kitchen water drainage spigot.

[0042] In the exhaust tower bottom section **405,** a tortuous, sinuous, serpentine, labyrinthic path is formed, for example, as in the example depicted in the drawings, by means of properly offset baffles **177.**

[0043] In a vertical position along the exhaust tower bottom section **405,** vertical position that in the shown embodiment is approximately at the top of the exhaust tower bottom section **405,** an inlet **415** for a cooling liquid is advantageously present, which for example may comprise a nozzle for spraying cooling water that is selectively fed, for example under control of a valve **420,** *e.g.* an electrovalve, controlled by an oven control unit (shown only schematically in **FIG. 4** and denoted **423**). The nozzle preferably is adapted to spray water in a nebulized form, *i.e.* as very small droplets. The cooling water is for example fed via a piping that, when the oven is installed, is coupled to a water outlet spigot of the kitchen.

[0044] Preferably, a temperature sensor **425** may be provided in a vertical position along the exhaust tower bottom section **405,** for example approximately at the bottom of the exhaust tower bottom section **405,** proximate to the outlet of the vapor discharge duct **160.** When present, the temperature sensor **425** is in signal connection with the oven control unit **423** to communicate thereto the readings about the temperature of the vapors exiting the oven chamber **105.** The oven control unit **423** may for example be programmed so as to activate the electrovalve **420** when the temperature of the vapors exiting the oven chamber **105** (and entering the vapor exhaust tower **155**) reaches a pre-set temperature, which may also depend on the specific cooking programme selected by the oven user.

[0045] At a top thereof, the exhaust tower bottom section **405** has an opening **430** leading into the exhaust tower top section **410,** which is for example more or less vertically aligned to the underlying bottom section **405.** The exhaust tower top section **410** has one or more inlets for relatively hot and dry air, which is introduced so as to be intermixed to the de-moisturized vapor that, after exiting the oven chamber **105,** has passed through the exhaust tower bottom section **405.** The exhaust tower top section **410** may include a first hot air inlet **433,** in the shown example located more or less midway the exhaust tower top section **410,** for admitting hot air that has been taken in from the outside ambient for cooling oven parts like the motor for the air propeller **130,** among which there may be the exhaust tower bottom section **405,** and a second hot air inlet **435,** in the shown example located more or less at the top of the exhaust tower top section **410,** for admitting the oven door cooling air **140,** that, after passing in the gap **135** formed in the oven door **120,** passes in a gap between the oven chamber **105** and a top panel of the oven cabinet **110.**

[0046] A fan **180** is advantageously provided at the top of the exhaust tower top section **410.** The fan **180,** that preferably is selectively activatable by the oven control unit **423,** creates a depression inside the exhaust tower **155** and sucks the vapor and the cooling fluxes inside it. Downstream the fan **180,** i.e. on top of it, the exhaust tower **155** opens into the external ambient or into a discharge duct.

[0047] For the sake of explanation of its principle of operation, the system for exhausting vapor according to an embodiment of the present invention can advantageously be regarded as made up by two so-called "control regions". A first control region is the exhaust tower bottom section **405,** where the phenomena **A** and **B** take place. A second control region is the exhaust tower top section **410,** where the phenomenon **C** takes place.

[0048] In the first control region **405,** the labyrinthic path formed by the baffles **177** allows compactizing the vapor exhaust tower **155,** thereby reducing its space occupation.

[0049] When the electrovalve **420** is open and the nozzle **415** sprays cooling water, thanks to the presence of the baffles **177** a sort of waterfall-type filter is formed, that at each fall condenses the vapors exiting the oven chamber **105** and filters them by retaining the particles of fat transported by the vapors.

[0050] The baffles **177** allows the cooling water, sprayed by the nozzle **415,** to have more time and surface area available for enhancing heat exchange between the sprayed cooling water and the vapors coming from the oven chamber **105.** In addition, the presence of the baffles **177** enables the sprayed cooling water to release at least part of the heat absorbed by the vapors to the baffles **177** and the walls of the vapor exhaust tower **155** (this heat can then be dispersed outside the vapor exhaust tower **155,** and may advantageously contribute to heating up the air that is then introduced into the exhaust tower top section **410** through the first air inlet **433).** Concurrently, the injected cooling water cools down the baffles **177,** on which the moisture contained in the vapors can condensate.

[0051] The injection of the cooling water by the nozzle **415** in the form of nebulized droplets, creates a sort of fog inside the first control region **405,** that contributes to the increase of the thermal exchange area and at the same time reduces the power and resources (water) consumption and the generated noise.

[0052] In the second control region **410,** the heat released by the vapors passing through the first control region (exhaust tower bottom section) **405** as well as by the operation of the oven (*e.g.,* the motor of the air propeller **130**) is caused to be absorbed by the cooling air (that enters into the vapor exhaust tower **155** through the first hot air inlet **433**), thereby increasing the temperature thereof. This allows to reduce the relative humidity of the cooling air (at constant specific humidity), thereby increasing the capacity of the cooling air of absorbing the residual humidity of the vapors exiting the first control region **405,** when they are mixed with the cooling air: in fact, by increasing the temperature of the cooling air, the specific humidity of the flow of intermixed vapors and cooling air remains substantially the same, while the relative humidity decreases; the capability of absorbing the humidity contained in the flow of vapors is thus increased.

[0053] **FIG. 5** schematizes again the vapor exhaust system according to an embodiment of the present invention, and should be referred to as an aid for the following analytical analysis of the energy and mass balance. Hereafter, for the purpose of notation, it is assumed that the normal to the control regions is directed as exiting the surface delimiting the control regions. The mechanical work is regarded as positive if exiting the control regions (*i.e.*, when directed as the normal to the control regions) whereas the heat is regarded as positive if entering into the control regions (*i.e.*, when opposite to the normal). The energy and mass flows are regarded as positive if directed as the normal to the control regions.

[0054] The vapor exhaust system according to an embodiment of the present invention can be regarded as comprised of three "control volumes" or "control regions": the first and second control regions **405** and **410** introduced in the foregoing, and a third control region made up by the union of the first and second control regions **405** and **410.**

[0055] For the purpose of notation, hereinafter the terms $\dot{m}$ denote mass flow rates of dry air; the subscript *"steam"* denotes the flows containing a certain amount of vapor. In any case, the term $\dot{m}$ is to be intended as referred to the fraction of dry air present in a flow, whereas the fraction of humid air present in a flow is denoted as $\dot{m} \cdot x$, with x denoting the specific humidity. The terms with subscript *"engine"* or *"door"* refer to the flux of cooling air of the engine of the air propeller **130** (entering into the vapor exhaust tower **155** through the inlet opening **433**) and, respectively, of the flux

140 of the cooling air of the oven door (entering into the vapor exhaust tower **155** through the opening **435**).

[0056] Let:

- r_0 be the water vaporization heat (water vaporization enthalpy), and
- c_p, c_V constants.

[0057] Then:

$$x = \frac{m_{vapour}}{m_{air}}, \qquad \phi = \frac{m_{vapour}}{m_{saturation}};$$

where x denotes the specific humidity and ϕ denotes the relative humidity, and where the mass flows rates $\dot{m}_{steam}$ and $\dot{m}_{steam2}$ of dry air entering and exiting the first control region **405** (equal to each other, since as mentioned above the mass flow rates are referred to the fraction of dry air) are defined as $\dot{m}_a$:

$$\dot{m}_a = \dot{m}_{steam} = \dot{m}_{steam2}$$

[0058] The energy and mass balance equations for the first control region **405** are:

$$Q_1^- = \dot{m}_a(h_{steam2} - h_{steam}) + \dot{m}_{H2O_{out}} h_{H2O_{out}} - \dot{m}_{H2O} h_{H2O} \qquad \text{Eq. (1)}$$

$$\dot{m}_{H2O_{out}} = \dot{m}_{H2O} + \dot{m}_a(x_{steam} - x_{steam2}) \qquad \text{Eq. (2)}$$

where the first equation (Eq. (1)) relates to energy (the suffix "-" for the heat Q_1 means that the heat exits the control region; the symbols *h* denote the enthalpy), and the second equation (Eq. (2)) relates to the mass of water. The term (x_{steam}-x_{steam2}) is due to the condensation of moisture.

[0059] In order to solve the first equation Eq. (1) for the energy, let **FIG. 6** be considered, showing a simplified Carrier diagram for humid air. The transformation "1 $\rightarrow$ 2" marked on the diagram can be decomposed into the two transformations "1 $\rightarrow$ 3" (latent contribution) and "3 $\rightarrow$ 2" (sensible contribution).

[0060] Considering that:

$$\dot{m}(h_2 - h_1) = \dot{m}\left[\left(\frac{\partial h}{\partial t}\right)_x \cdot \Delta t + \left(\frac{\partial h}{\partial x}\right)_t \cdot \Delta x\right] \qquad \text{Eq. (3)}$$

$$h = h_a + x \cdot h_v \qquad \text{Eq. (4)}$$

where h_a denotes the enthalpy of a dry air flow and h_v denotes the enthalpy of a flow of humid air, being:

$$h_a = c_{pa} \cdot t$$

$$h_v = r_0 + c_{pv} \cdot t$$

it follows that Eq. (4) becomes:

$$h = c_{pa} \cdot t + x \cdot (r_0 + c_{pv} \cdot t) \qquad \text{Eq. (5)}$$

and then, by derivation of Eq. (5):

$$\left(\frac{\partial h}{\partial t}\right)_x = c_{pa} + x \cdot c_{pv}$$

$$\left(\frac{\partial h}{\partial x}\right)_t = r_0 + c_{pv} \cdot t$$

[0061] The energy balance equation (Eq. (1)) can thus be developed as:

$$\begin{aligned} Q_1^- = {} & \dot{m}_a\left(c_{pa} + x_{steam2} \cdot c_{pv}\right)\left(t_{steam2} - t_{steam}\right) \\ & + \dot{m}_a\left(r_0 + c_{pv} \cdot t_{steam}\right)\left(x_{steam2} - x_{steam}\right) + \dot{m}_{H2O_{out}} h_{H2O_{out}} \\ & - \dot{m}_{H2O} h_{H2O} \end{aligned} \qquad \text{Eq. (6)}$$

[0062] By defining:

$$c_{pu} \triangleq \left(\frac{\partial h}{\partial t}\right)_x = c_{pa} + x \cdot c_{pv} \qquad \text{Eq. (7)}$$

and

$$h_v \triangleq r_0 + c_{pv} \cdot t \qquad \text{Eq. (8)}$$

the following developments are possible (introducing Eq, (2), Eq. (7) and Eq. (8) in Eq. (6)):

$$Q_1^- = \dot{m}_a c_{pu}(t_{steam2} - t_{steam}) + \dot{m}_a h_v (x_{steam2} - x_{steam}) + \dot{m}_{H2O}\left(h_{H2O_{out}} - h_{H2O}\right) + \dot{m}_a h_{H2O_{out}}(x_{steam} - x_{steam2})$$

$$Q_1^- = \dot{m}_a \Delta h_{sensible} + \dot{m}_a \Delta h_{latent} + \dot{m}_{H2O}\left(h_{H2O_{out}} - h_{H2O}\right) + \dot{m}_a h_{H2O_{out}}(x_{steam} - x_{steam2})$$

$$Q_1^- = Q_s^- + Q_\lambda^- + \dot{m}_{H2O}\left(h_{H2O_{out}} - h_{H2O}\right) + \dot{m}_a h_{H2O_{out}}(x_{steam} - x_{steam2}) \quad \text{Eq. (9)}$$

where: Q_1^- is the heat flow at the walls; Q_s^-, Q_λ^- are the fractions of sensible and latent energies of the flow of humid air; $\dot{m}_{H2O}$ (h_{H2Oout} - h_{H2O}) is the Energy fraction of the liquid; $\dot{m}_a h_{H2Oout}(x_{steam}$ - $x_{steam2})$ is the Energy fraction of the condensed water.

[0063] **FIG. 7** depicts the complete Carrier diagram of the humid air for the first control region **405.** The point on the diagram indicated as 1 corresponds to the state of the flow of vapors upon entering into the first control region; the point indicated as **2** corresponds to the state of the flow of vapors upon exiting the first control region. As can be appreciated looking at the diagram, the state of the flow of vapors exiting the first control region is rather close to the state indicated as s on the diagram, corresponding to the saturation condition (with relative humidity ϕ equal to 100%): thus, by spraying cooling water into the first control region, the temperature of the vapors decreases, and the relative humidity ϕ increases, but the specific humidity x decreases (because the flow of vapors exiting the first control region has a lower content of humidity).

[0064] Coming to the second control region **410, FIG. 8** depicts the respective humid air Carrier diagram. The point **2** on the diagram represents the starting state of the flow of vapors upon entering into the second control region (it corresponds to the point **2** on the Carrier diagram of **FIG. 7**).

[0065] The balance equations are:

$$\dot{m}_{door} h_{door} + \dot{m}_{engine} h_{engine} + \dot{m}_{steam2} h_{steam2} = \dot{m}_{final} h_{final} = (\dot{m}_{door} + \dot{m}_{engine} + \dot{m}_{steam2}) h_{final} \quad \text{Eq. (10)}$$

$$\dot{m}_{door} x_{door} + \dot{m}_{engine} x_{engine} + \dot{m}_{steam2} x_{steam2} = \dot{m}_{final} x_{final} = (\dot{m}_{door} + \dot{m}_{engine} + \dot{m}_{steam2}) x_{final} \quad \text{Eq. (11)}$$

where Eq. (10) is the energy balance equation and Eq. (11) is the mass balance equation.

[0066] Dividing the two equations above for $\dot{m}_{final}$ it follows:

$$h_{final} = \frac{\dot{m}_{door}}{\dot{m}_{final}} h_{door} + \frac{\dot{m}_{engine}}{\dot{m}_{final}} h_{engine} + \frac{\dot{m}_{steam2}}{\dot{m}_{final}} h_{steam2}$$

$$x_{final} = \frac{\dot{m}_{door}}{\dot{m}_{final}} x_{door} + \frac{\dot{m}_{engine}}{\dot{m}_{final}} x_{engine} + \frac{\dot{m}_{steam2}}{\dot{m}_{final}} x_{steam2}$$

[0067] The state of the flow of vapors, in the second control region, moves from point **2** to point **4,** which represents the state of the flow of vapors exiting the second control region. Points **5** and **6** represent the states of the flows of hot and dry air entering into the second control region and that are mixed with the flow of vapors: both are characterized by a low relative humidity ϕ).

[0068] The third control region is the union of the first and second control regions **405** and **410.** The energy and mass balance for the third control region can thus be obtained from the above equations. The result is that the variables related to the common surfaces to the first and second control regions are eliminated, *i.e.* $\dot{m}_{steam2}h_{steam2}$, and $\dot{m}_{steam2}x_{steam2}$ ($\dot{m}_{steam2} = \dot{m}_a$).

[0069] At the end, the flow of vapors exiting the second control region has a relatively low content of humidity.

[0070] **FIG. 9** is a simplified flowchart illustrating a possible way of operation of the oven **100** according to an embodiment of the present invention.

[0071] When the oven **100** is started, the oven control unit **423** reads the operation selected by the oven user (block **905**). The oven control unit **423** then decides whether or not the oven user has selected and started a cooking operation (decision block **910**). If the oven user has not decided to start a cooking operation (exit branch N of decision block **910**), the operation flow jumps back to block **905.** If instead the oven user has selected and started a cooking operation (exit branch **Y** of decision block **910**), the oven control unit **423** obtains information about the type of cooking selected by the oven user (block **915).**

[0072] Then, depending on the type of cooking selected by the oven user, the oven control unit **423** decides whether or not the air propeller **180** is to be activated (block **920**). If yes, the air propeller **180** is activated, if not, the air propeller **180** is kept off.

[0073] Still based on the type of cooking selected by the oven user, the oven control unit **423** determines (block **921**) at which pre-set temperature of the vapors entering the vapor exhaust tower **155,** the electrovalve **420** is to be activated to enable the intake of cooling water; such determination made by the control unit **423** may be carried out exploiting a database of parameters database, from which the oven control units **423** picks at which pre-set temperature of the vapors entering the vapor exhaust tower **155.** Then, by exploiting the readings of the temperature sensor **425,** the oven control unit **423** monitors the temperature of the vapors leaving the oven chamber **105** (block **923**). In particular, the oven control unit **423** checks if such temperature is over the pre-set intervention temperature (block **925**).

[0074] Until the temperature of the vapors leaving the oven chamber **105** and entering into the vapor exhaust tower **155** remains below the pre-set intervention temperature (exit branch **N** of decision block **925**), the oven control unit **423** checks whether the cooking process is terminated (decision block **930**): if the oven control unit **423** determines that the cooking process is terminated (exit branch **Y** of decision block **930**), the oven control unit **423** checks (decision block **931**) if the electrovalve **420** is currently open: in the affirmative case (exit branch **Y** of decision block **931)** the electrovalve **420** is closed (block **933**); after closing the electrovalve **420** (or leaving it closed, if it was already closed - exit branch **N** of decision block **931),** the oven control unit **423** checks (decision block **935**) whether the fan **180** is running: in the affirmative case (exit branch **Y** of decision block **935),** the fan **180** is left running for a predetermined time after the end of the cooking process, whereas if the fan **180** is not running (exit branch **N** of decision block **935**) the oven control unit **423** activates the fan **180** (block **940**) for a predetermined time. The operation flow then jumps back to block **905.** If the oven control unit **423** determines that the cooking process has not terminated yet (exit branch **N** of decision block **930**), the oven control unit **423** checks whether the electrovalve **420** is activated (decision block **943):** in the negative case (exit branch **N** of decision block **943**), the operation flow returns to block **923,** where the oven control unit **423** obtains a new reading of the temperature sensor **425;** if instead the oven control unit **423** assesses that the electrovalve **420** is activated (exit branch **Y** of decision block **943**), the oven control unit **423** de-activates the electrovalve **420** (block **945**) and then the operation flow returns to block **923.**

[0075] Let now be supposed that the temperature of the vapors leaving the oven chamber exceeds the pre-set temperature (decision block **925,** exit branch **Y):** the oven control unit **423** activates the electrovalve **420** (block **950**); cooling water thus starts to be sprayed by the nozzle **415** into the exhaust tower bottom section **405,** to cool the vapors exiting the oven chamber **105.**

[0076] The oven control unit **423** then determines whether the cooking process has terminated (decision block **955**): if not (exit branch **N** of decision block **955**), the operation flow jumps back to block **923** (where the oven control unit **423** obtains a new reading of the temperature sensor **425**; if instead the oven control unit **423** determines that the cooking process has terminated (exit branch **Y** of decision block **955**), the oven control unit **423** obtains (through the temperature sensor **425**) the temperature of the vapors entering into the vapor exhaust tower **155** (block **960**), and then the oven control unit **423** checks whether the temperature of the vapors exceeds the pre-set intervention temperature (decision block **965**): until the vapors temperature stays above the pre-set intervention temperature (exit branch **Y** of decision block **965**), the electrovalve **420** is kept open, and the oven control unit **423** continues to monitor the vapor temperature. When the vapor temperature falls below the pre-set intervention temperature (exit branch **N** of decision block **965**) the electrovalve **420** is closed (block **933**) and the same operations described above (blocks **935** and **940**) are performed. The operation flow returns to block **905.**

[0077] In other words, the injection of cooling water into the exhaust tower bottom section **405** (i.e., into the first control region of the vapor exhaust system) is selectively enabled based on an assessment of the temperature of the vapors that leaves the oven chamber **105** and enters into the vapor exhaust tower. Also the activation of the fan **180** is selective, depending on the cooking process.

[0078] The vapor exhaust system according to the described embodiment of the present invention comprises a sinuous, tortuous, labyrinthic vapors conduit arranged vertically, into which cooling water can (selectively) be injected. The tortuous shape of the conduit, thanks to the depression generated by a fan downstream the first control region (in the shown example, the fan **180**) allows exploiting the inertia of the particles of vapor/fat, pushing them against the baffles **177** (in particular, against the first ones, proximate to the bottom of the exhaust tower bottom section **405**). The spray of nebulized cooling water allows capturing the finest particulate (and this effect is also promoted by the baffles **177** proximate to the top of the exhaust tower bottom section **405,** which are cooled down by the water spray).

[0079] Experimental trials carried out by the Applicant have shown that the temperature of the vapor flow exiting the vapor exhaust system according to the described embodiment of the present invention, also in critical operating conditions (oven chamber temperature set to 250 °C and 100% of humidity), did not exceed 30 °C at a relative humidity of 25% (with 19 °C of ambient air temperature).

[0080] In **FIG. 10** there is depicted, schematically as in **FIG. 4,** a vapor exhaust tower according to a slightly different embodiment of the present invention; components, parts and elements that are identical, similar or equivalent to those described in connection with the previous embodiment are denoted with same reference numerals. A difference of the embodiment of **FIG. 10** compared to the previous embodiment resides in that at least part (one, more than one, possibly all) of the baffles **177,** like the baffles **1077** visible in the figure, are hollow at their interior and arranged to be run through by a relatively cold heat-exchange fluid **1005** (*e.g.*, liquid, like water), which receives heat released from the vapors passing through the first control volume **405.** In this way, the heat released by the vapors leaving the oven chamber can be at least partly collected by the heat-exchange fluid, instead of being only dissipated.

[0081] Another difference in the embodiment of **FIG. 10** compared to the previous embodiment is the different position of the nozzle **415** (which in this embodiment is not at the top of the first control region) and of the temperature sensor **425** (which in this embodiment is not at the bottom of the first control region). In particular, differently from the previous embodiment, in this embodiment the nozzle **415** is associated to a lower portion of the bottom section **405** with respect to the temperature sensor **425.**

[0082] In **FIG. 10** just one opening in the exhaust tower top section **410** is shown; this single opening may schematize the two openings **433** and **435** of the previous embodiment, but it might also be possible that through such single opening both of the two cooling air fluxes enter into the vapor exhaust tower. In still other embodiments, one of the two cooling air fluxes might be absent.

[0083] Also with the vapor exhaust tower of the embodiment of **FIG. 10,** the oven **100** may operate as described in connection with the previous embodiment (flowchart of **FIG. 9**).

[0084] In the foregoing, exemplary embodiments of the present invention have been presented and described in detail. Several modifications to the described embodiments, as well as alternative ways of practicing the invention are conceivable, without departing from the protection scope defined by the appended claims.

Claims

1. An oven **(100)** comprising an oven chamber **(105)** for the cooking of foods, heating means **(125)** for heating the oven chamber, and a vapor exhaust system **(155)** for treating vapors produced in the oven chamber during a food cooking process, **characterized in that** the vapor exhaust system comprises:

   a first region **(405)** in fluid communication **(160,165,170)** with the oven chamber so as to receive vapors exiting the oven chamber and wherein the vapors are de-moisturized and cooled down; and
   a second region **(410)** downstream the first region and wherein the de-moisturized and cooled down vapors exiting the first region are mixed to hot dry air **(140)** before being exhausted to the outside ambient.

2. The oven of claim 1, wherein said first region extends vertically.

3. The oven of claim 1 or 2, wherein in the first region a tortuous path for the vapors is formed.

4. The oven of claim 3, wherein said tortuous path is a duct comprising a plurality of baffles **(177;1077).**

5. The oven of claim 4, wherein at least one of said baffles is hollow and run through a heat-exchange fluid **(1005).**

6. The oven of claim 3, 4 or 5, wherein a coolant liquid feeding device **(415,420)** is associated with said first region, arranged for feeding a coolant liquid into the first region for cooling down the vapors.

7. The oven of claim 6, wherein said coolant liquid feeding device comprises at least one liquid feeding nozzle **(415)** adapted to spray coolant liquid into said first region in a nebulized form.

8. The oven of claim 6 or 7, wherein said coolant liquid feeding device is arranged to cause the coolant liquid to enter into the first region proximate to a top side thereof.

9. The oven of any one of claims 6 to 8, wherein said coolant liquid feeding device is connected to an activator adapted to selectively activate said coolant liquid feeding device for selectively feeding the coolant liquid.

10. The oven of any one of claims 6 to 9, wherein at least a temperature sensor **(425)** is associated with the first region, arranged for sensing the temperature of the vapors entering into the vapors exhaust system.

11. The oven of claim 10 when depending on claim 9, wherein said coolant liquid feeding device is selectively activated based on a sensed temperature of the vapors sensed by said temperature sensor.

12. The oven of any one of the preceding claims, comprising at least an air propeller **(180)** associated with said vapor exhaust system and configured for promoting the exit of vapors from the oven chamber and their flow through the vapor exhaust system.

13. The oven of claim 12, wherein said air propeller comprises an axial or radial fan arranged at the exit of the second region.

14. The oven of claim 12 or 13, wherein said air propeller is selectively activatable.

15. The oven of any one of the preceding claims, wherein said hot dry air comprises air exploited to cool down at least one among a door **(120)** of the oven and/or air exploited to cool down internal oven parts subjected to heat up during the oven operation.

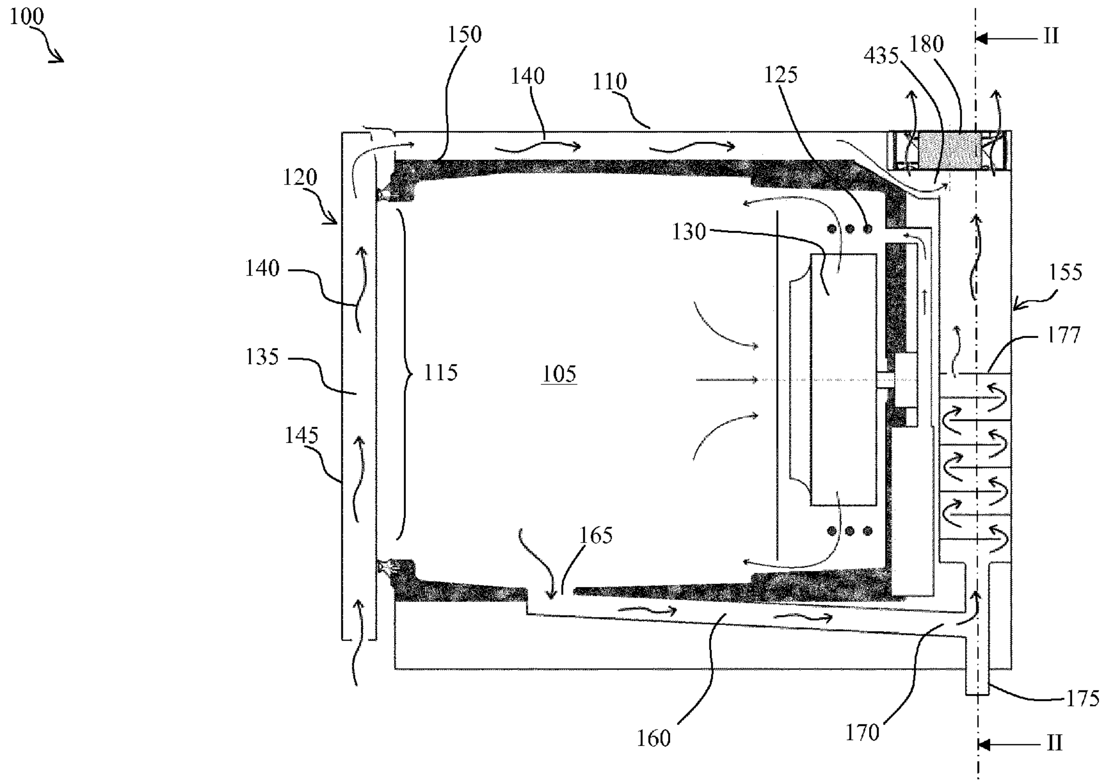

100
150
140
110
125
435
180
II
120
130
140
155
135
115
105
177
145
165
160
170
175
II

FIG. 1

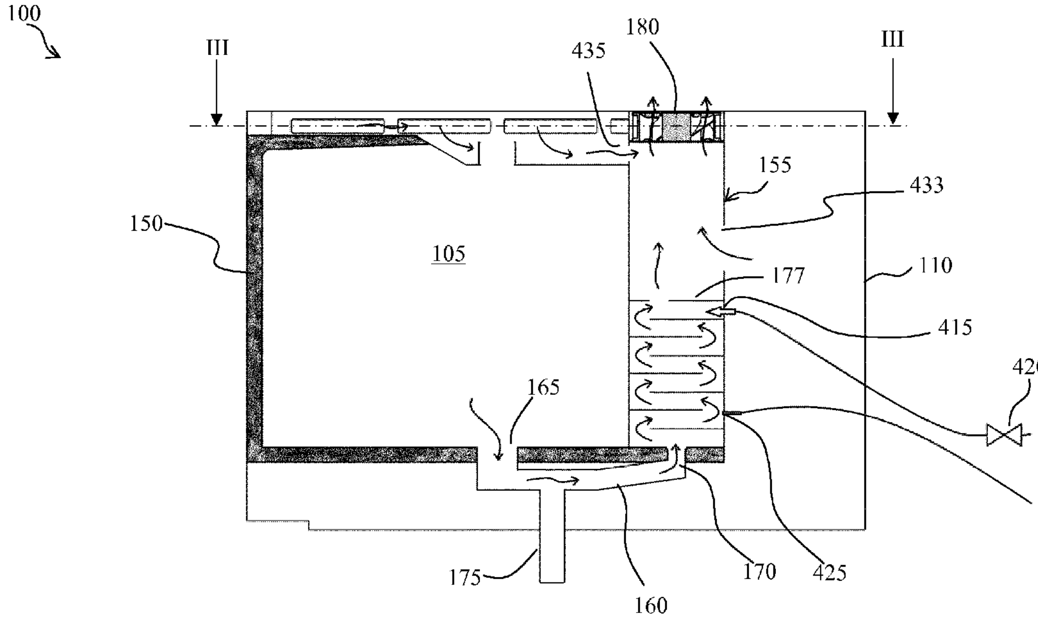

100
III
180
435
III
155
433
150
105
110
177
415
420
165
175
160
170
425

FIG. 2

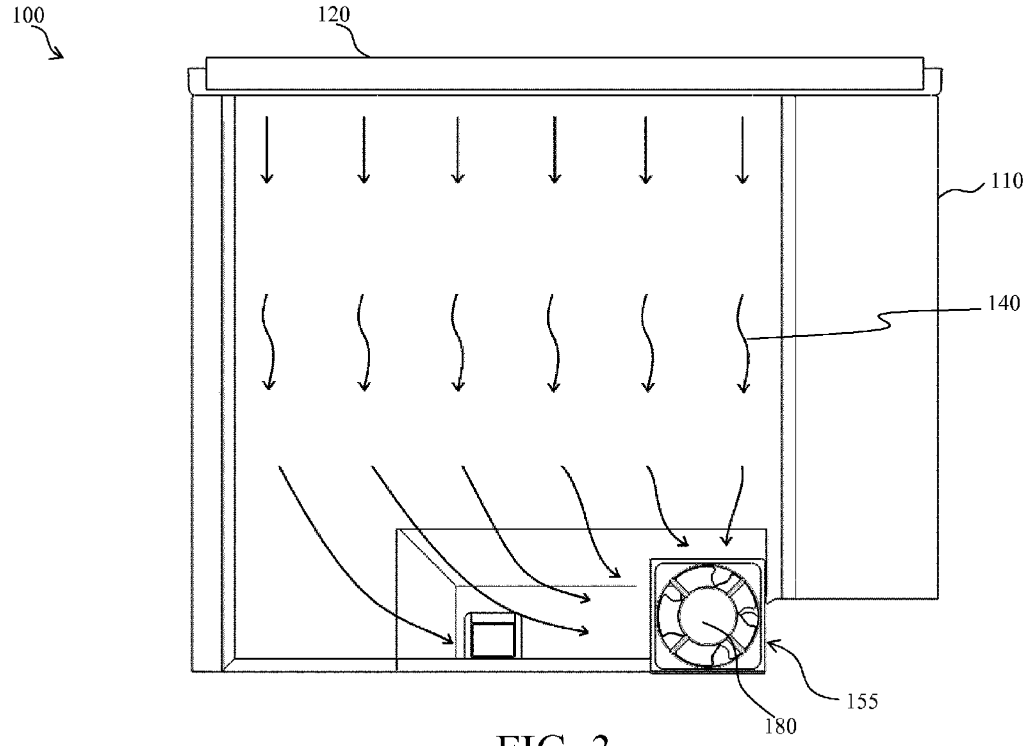


FIG. 3

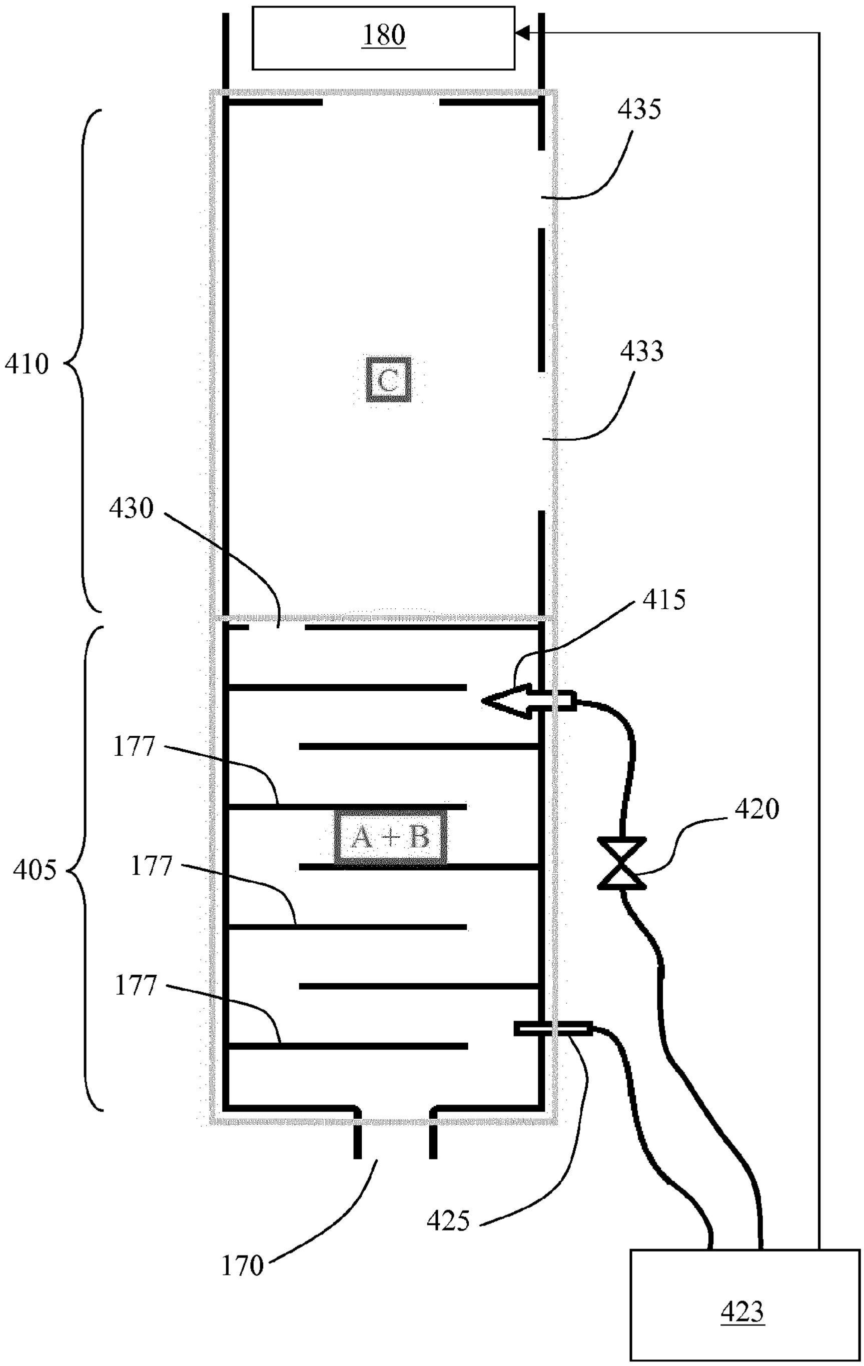
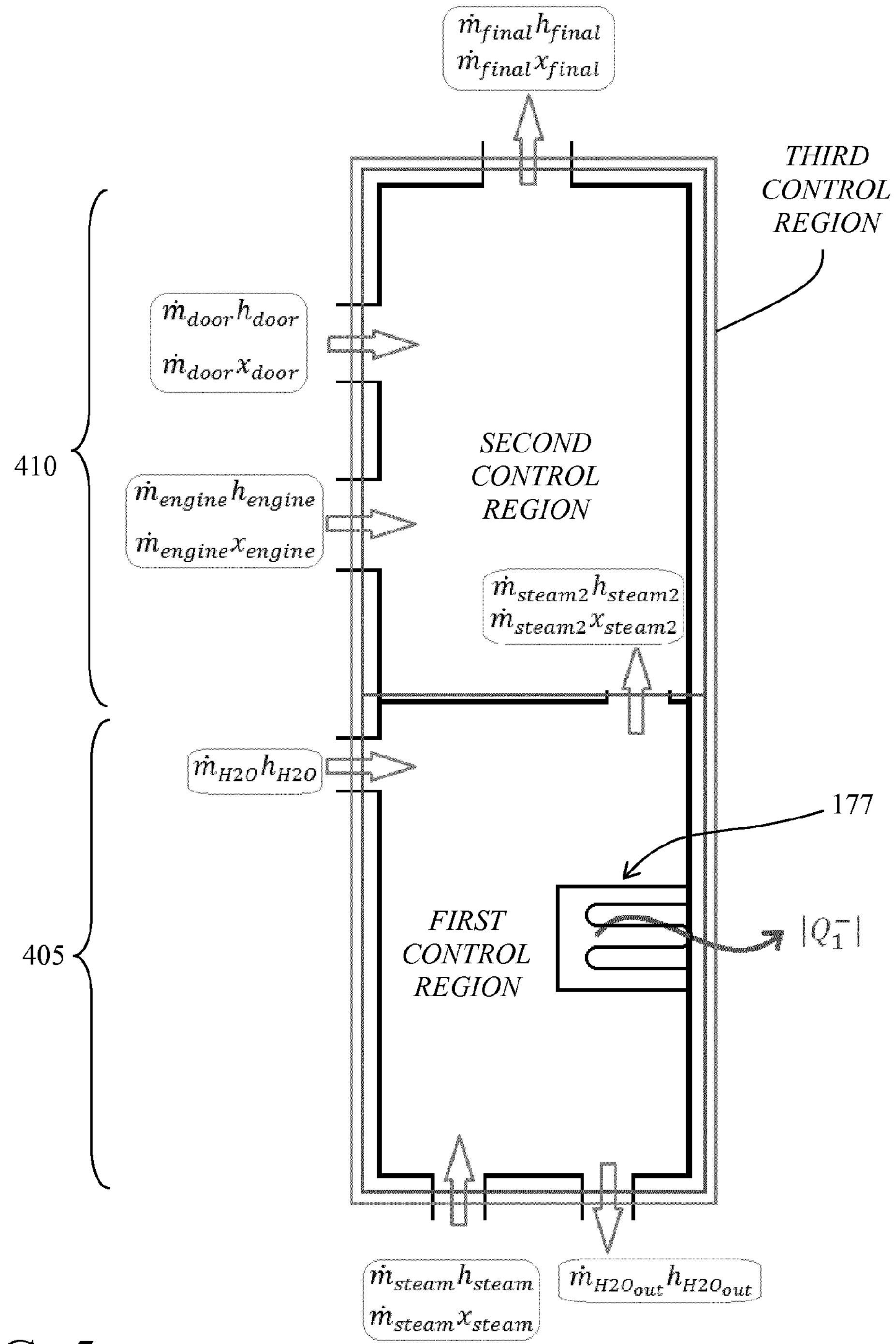


FIG. 4



$\dot{m}_{final}h_{final}$
$\dot{m}_{final}x_{final}$
THIRD CONTROL REGION
$\dot{m}_{door}h_{door}$
$\dot{m}_{door}x_{door}$
410
SECOND CONTROL REGION
$\dot{m}_{engine}h_{engine}$
$\dot{m}_{engine}x_{engine}$
$\dot{m}_{steam2}h_{steam2}$
$\dot{m}_{steam2}x_{steam2}$
$\dot{m}_{H2O}h_{H2O}$
177
405
FIRST CONTROL REGION
$|Q_1^-|$
$\dot{m}_{steam}h_{steam}$
$\dot{m}_{steam}x_{steam}$
$\dot{m}_{H2O_{out}}h_{H2O_{out}}$

FIG. 5

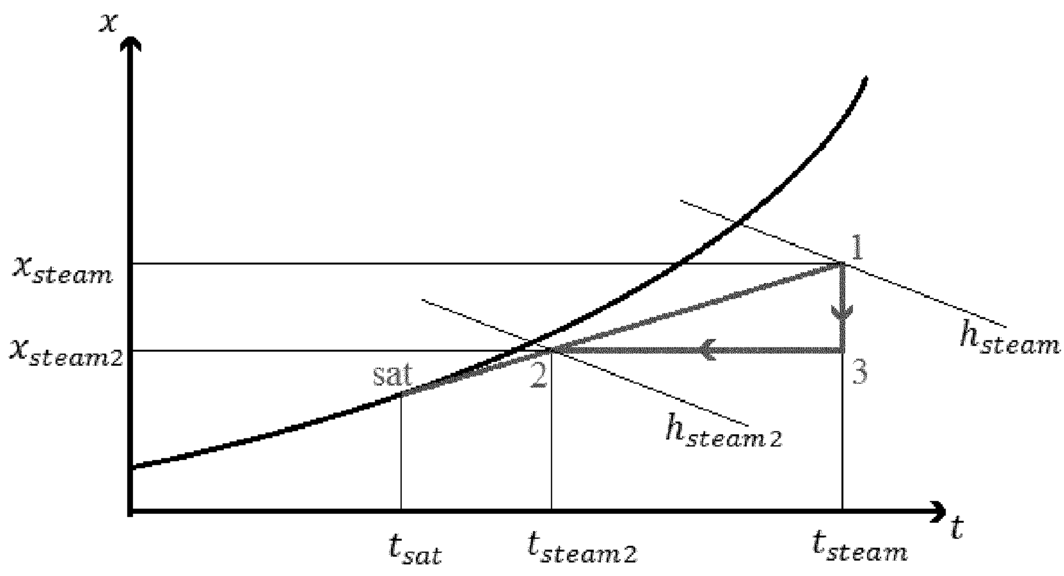

x
x_{steam}
x_{steam2}
1
h_{steam}
sat
2
3
h_{steam2}
t_{sat}
t_{steam2}
t_{steam}
t

FIG. 6

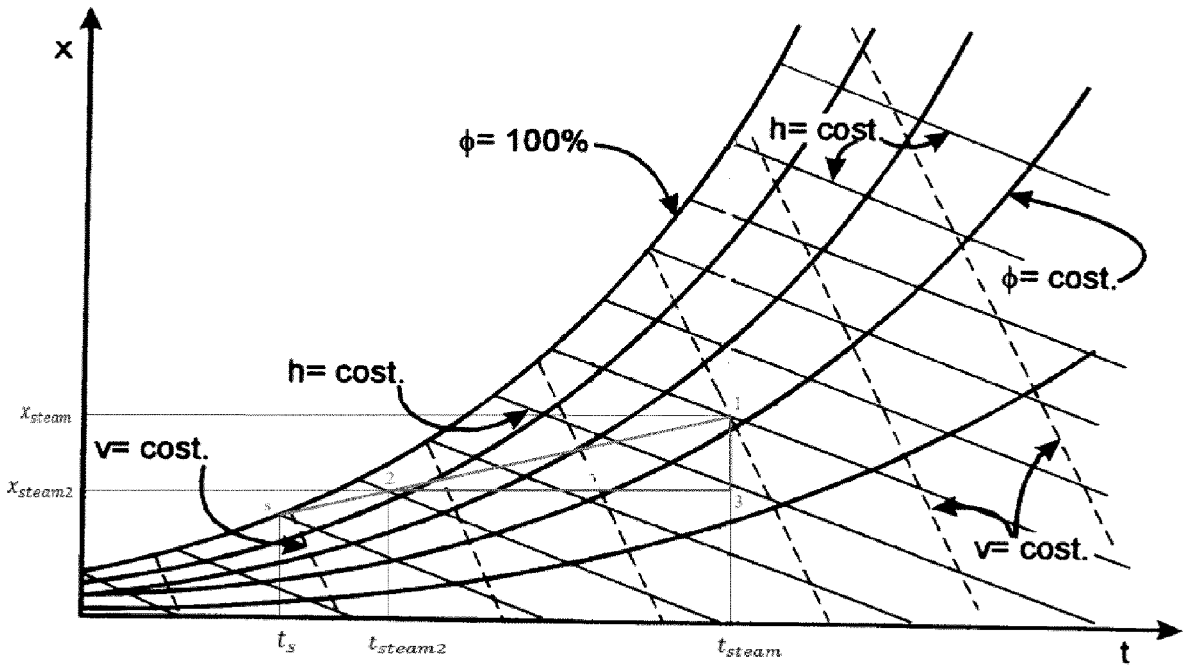
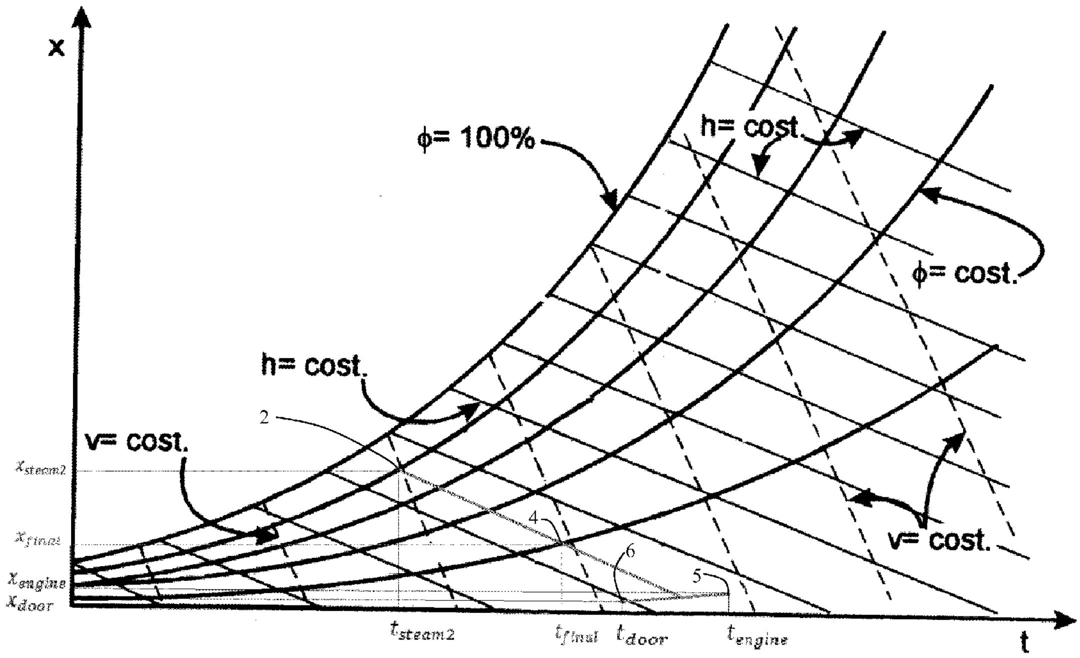

x
ϕ= 100%
h= cost.
ϕ= cost.
h= cost.
x_{steam}
v= cost.
x_{steam2}
v= cost.
t_s
t_{steam2}
t_{steam}
t

FIG. 7

FIG. 8


x
φ= 100%
h= cost.
φ= cost.
h= cost.
v= cost.
v= cost.
2
4
6
5
x_{steam2}
x_{final}
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t_{final}
t_{door}
t_{engine}
t

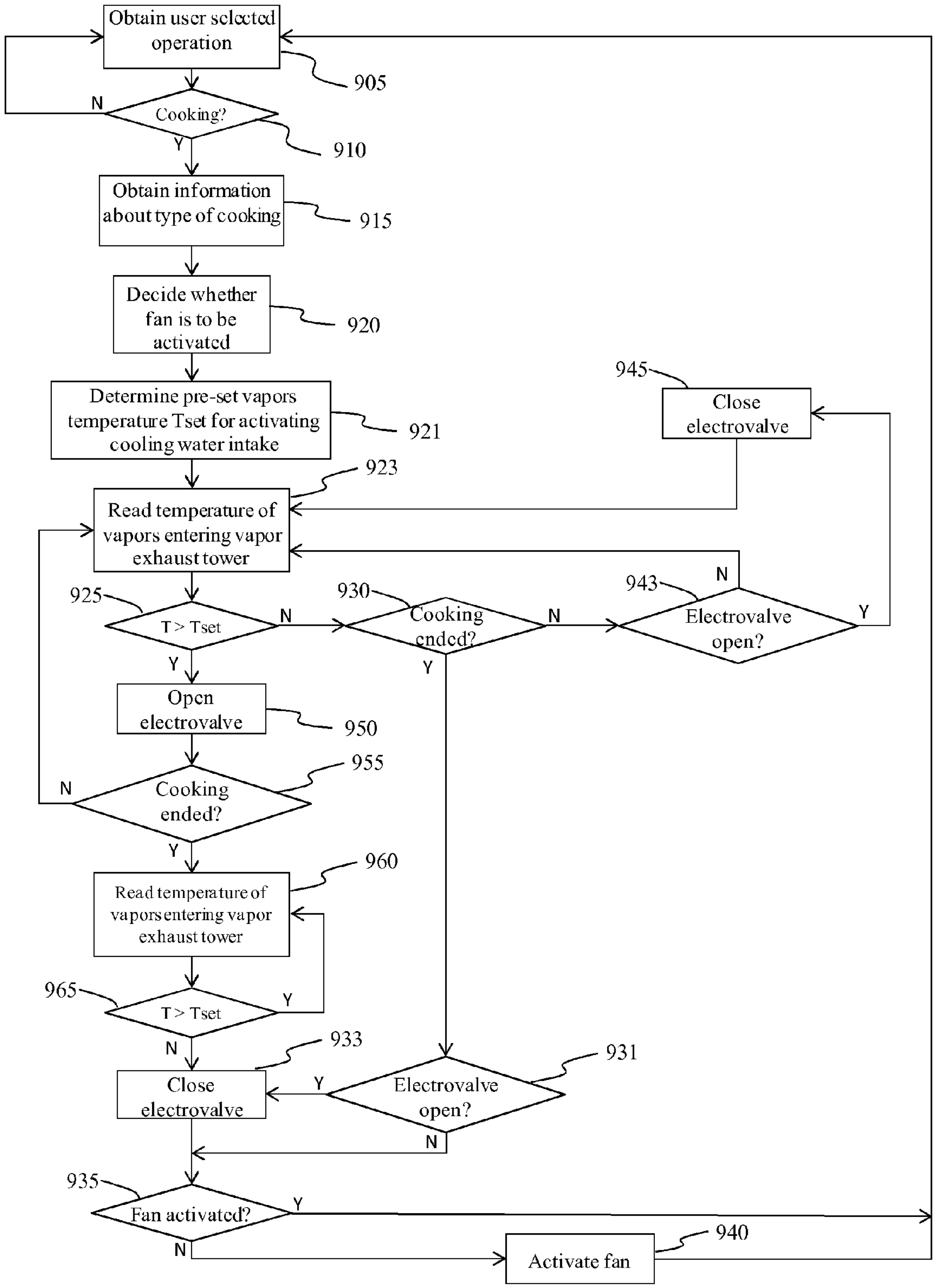
Obtain user selected operation
905
Cooking?
N
Y
910
Obtain information about type of cooking
915
Decide whether fan is to be activated
920
Determine pre-set vapors temperature Tset for activating cooling water intake
921
923
Read temperature of vapors entering vapor exhaust tower
945
Close electrovalve
925
T > Tset
N
Y
930
Cooking ended?
N
Y
943
Electrovalve open?
N
Y
Open electrovalve
950
955
Cooking ended?
N
Y
960
Read temperature of vapors entering vapor exhaust tower
965
T > Tset
Y
N
933
Close electrovalve
Y
Electrovalve open?
931
N
935
Fan activated?
Y
N
Activate fan
940

FIG. 9

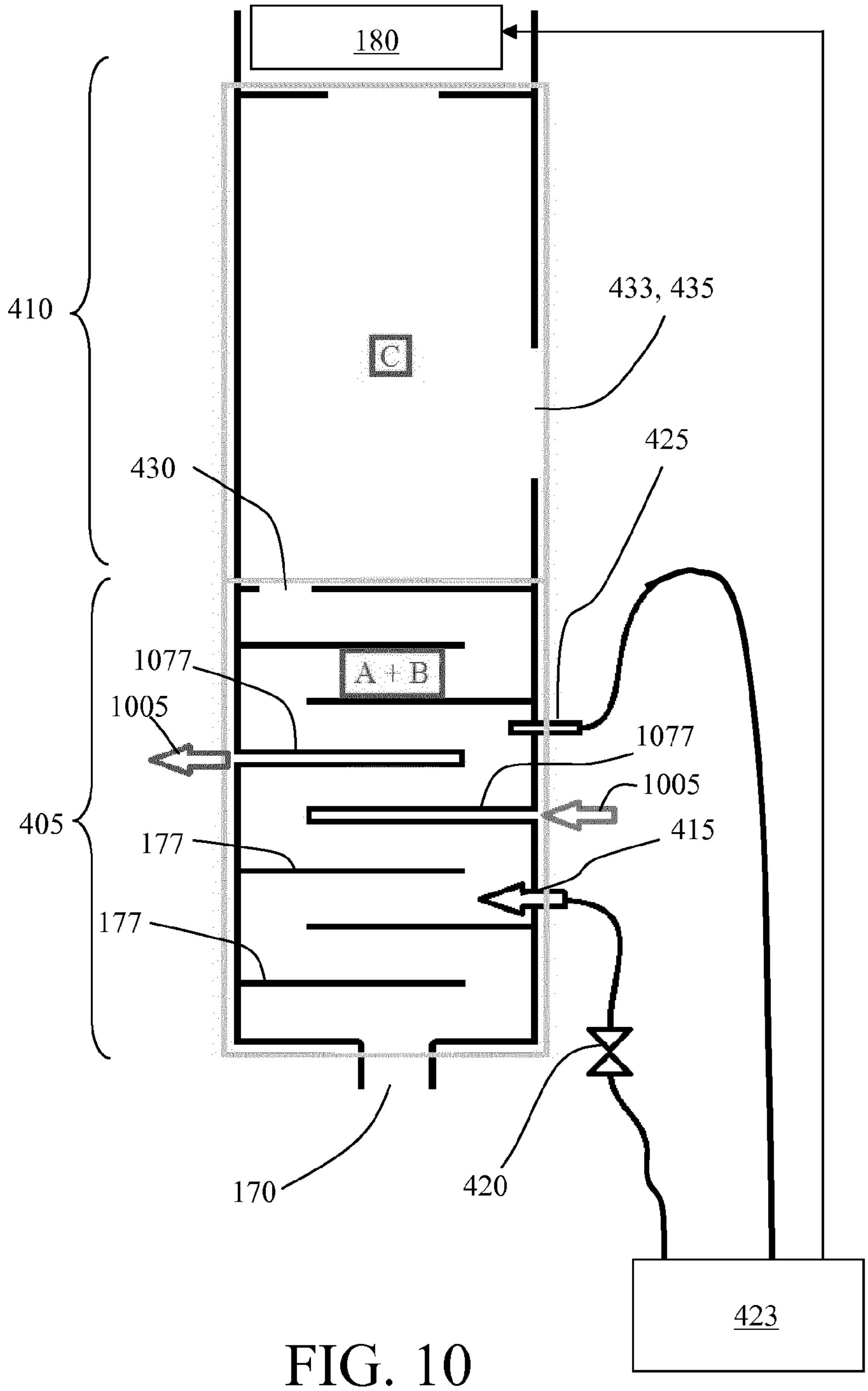
180
410
433, 435
C
425
430
1077
A + B
1005
1077
1005
405
415
177
177
170
420
423

FIG. 10

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EUROPEAN SEARCH REPORT

Application Number
EP 12 16 9715

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
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X : particularly relevant if taken alone
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2
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