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KR 1020120100552

(58) Field of Search:
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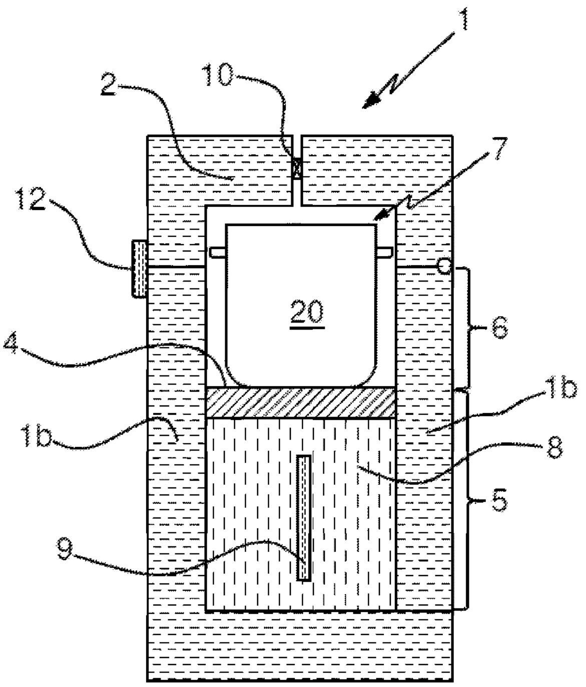
Other: **WPI, EPODOC**

(54) Title of the Invention: **Solar cooking apparatus with steam function and heat storage capacity**
Abstract Title: **Solar cooking apparatus with steam function and heat storage capacity**

(57) A cooking apparatus comprises a container having heat insulating bottom-wall 1a and heat insulating sidewall 1b. Releasable heat-insulating lid 2 forms an upper enclosure of the container. The container has an inner chamber 3 divided into lower 5 and upper 6 sections. A heat storage material 8, which is preferably a phase change material (PCM), fills the lower section. A preferably metallic heat transfer plate 4 divides the lower from the upper inner chamber section. The upper section of the chamber defines an inner space 7 adapted to receive and hold a cooking vessel 20 placed onto the heat transfer plate. An electric heating element 9 is in thermal contact with the heat storage material and in electric contact with an external source of electric power, which may be a photovoltaic solar panel (not claimed). The apparatus further comprises at least one pressure release valve 10 adapted to open at a pressure difference across the valve in the range from 0.1 to 909kPa. The use of a heat storage material allows for cooking to be carried out in areas and times where mains or photovoltaic electricity supply is unreliable or unavailable.

FIG. 1b



At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

GB 2596797 A

FIG. 1a

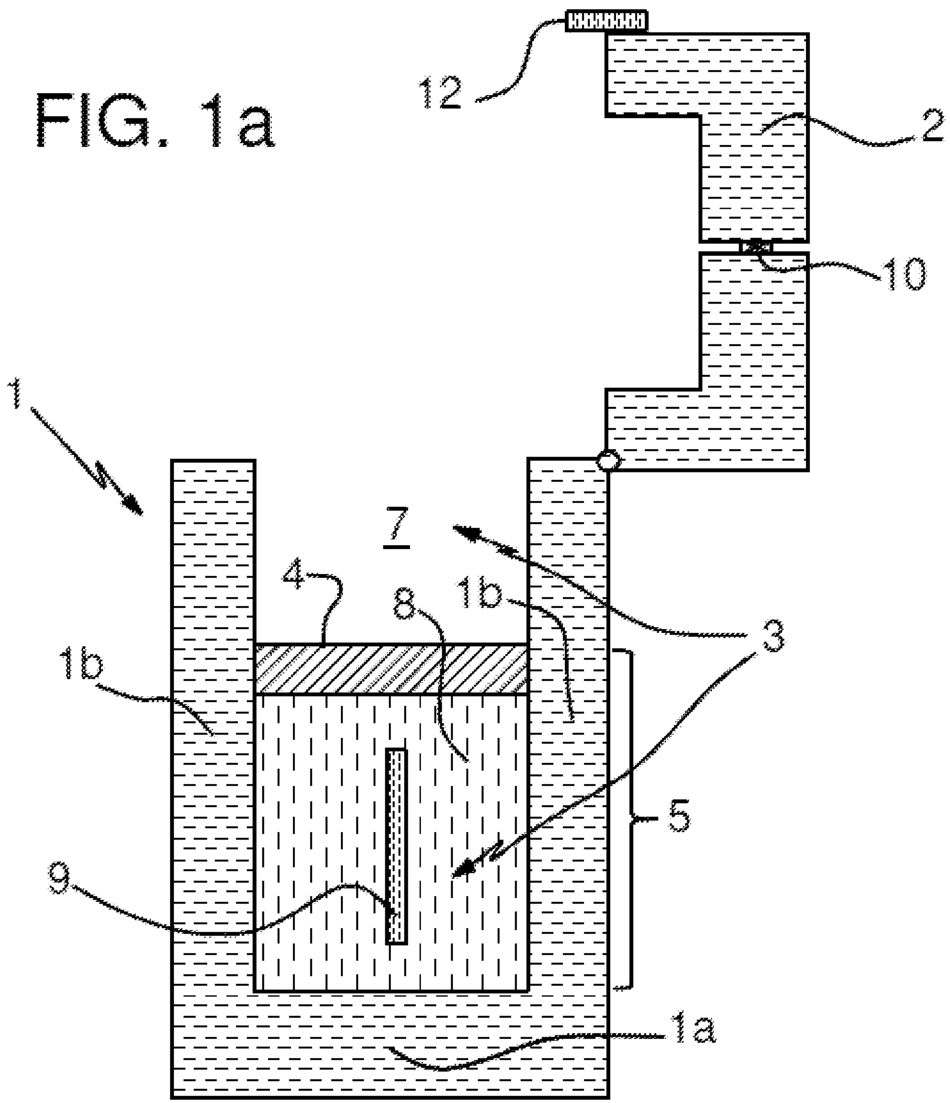


FIG. 1b

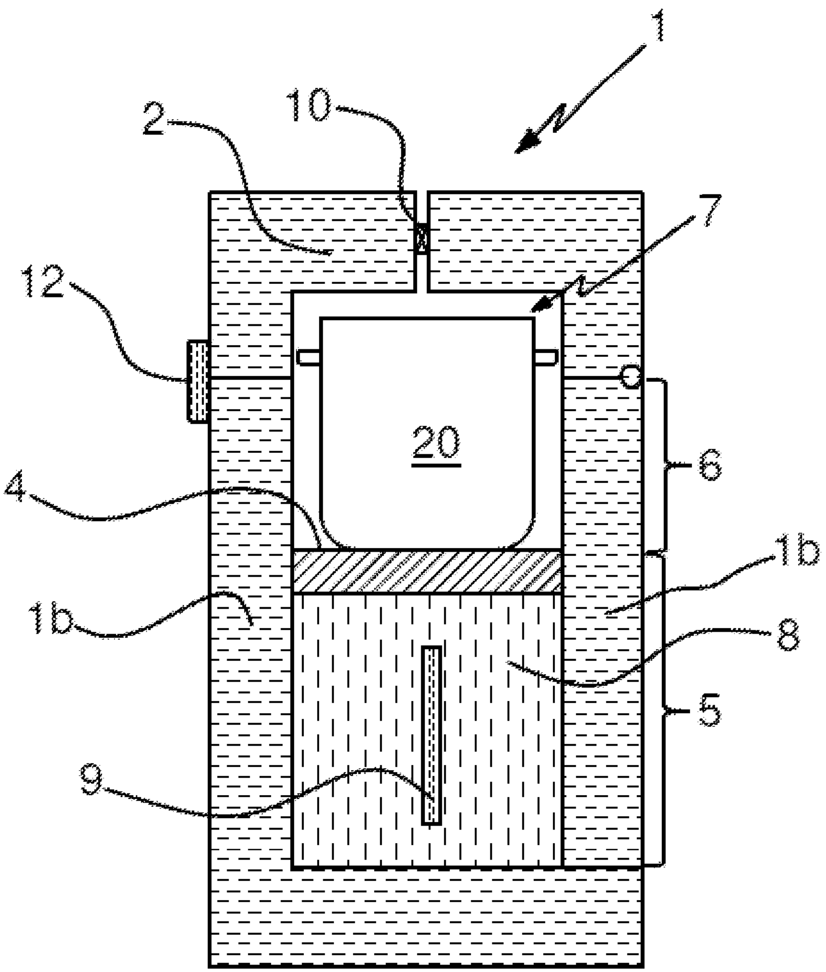


FIG. 2a

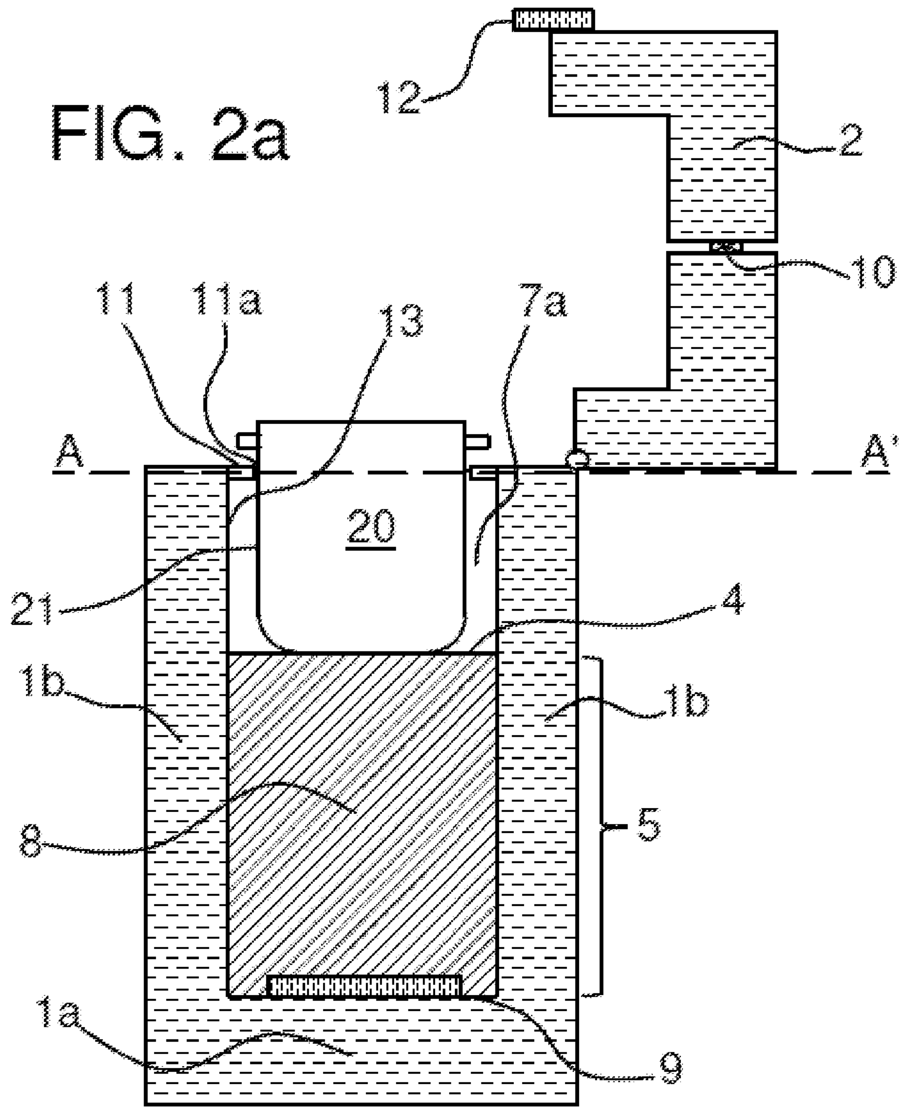


FIG. 2b

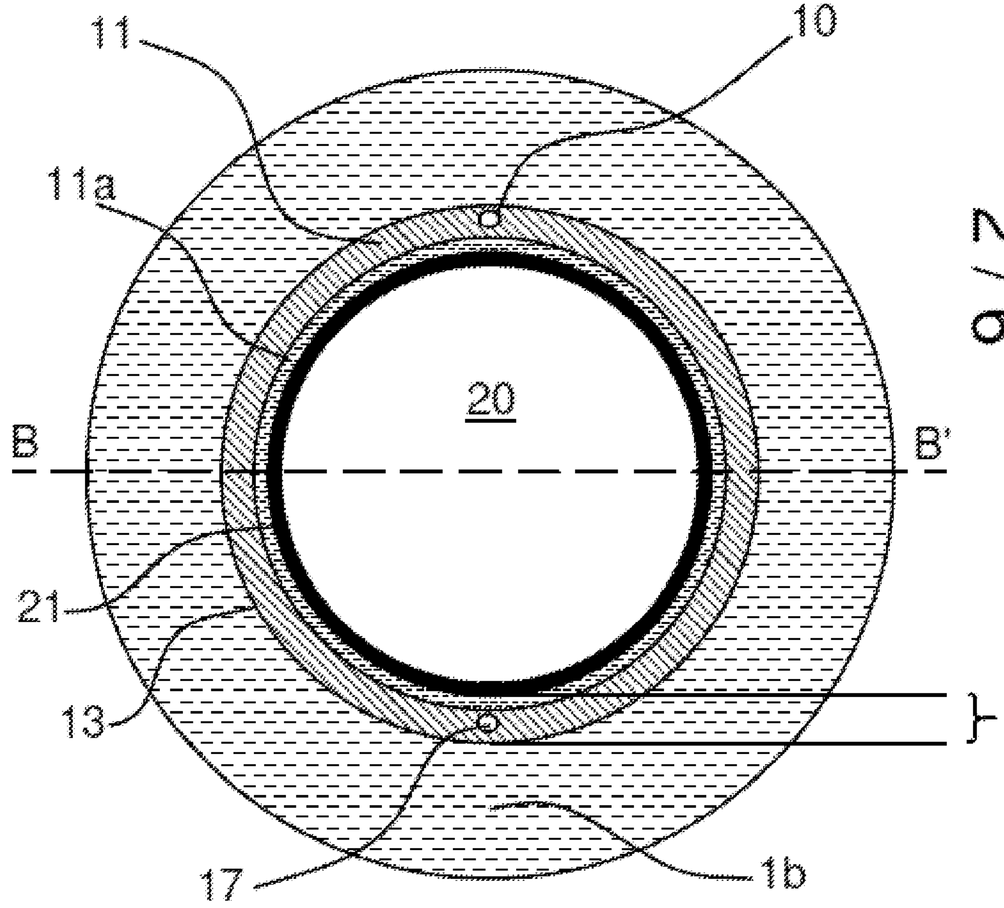


FIG. 3a

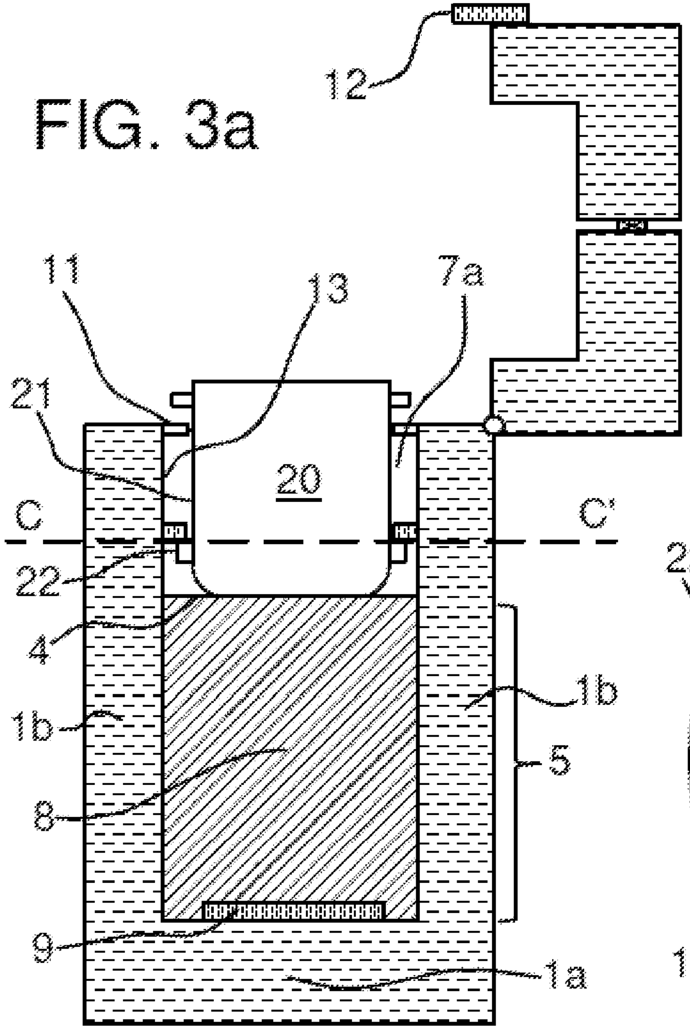
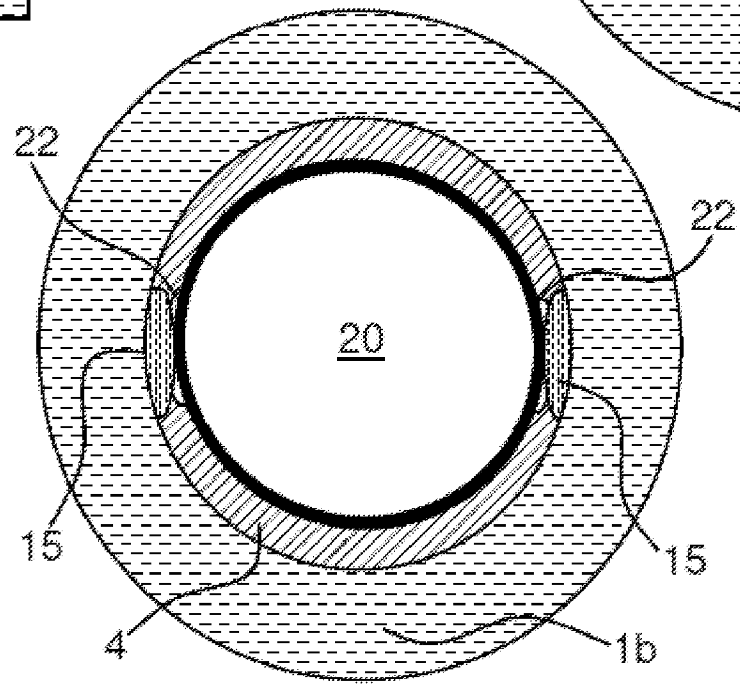


FIG. 3c



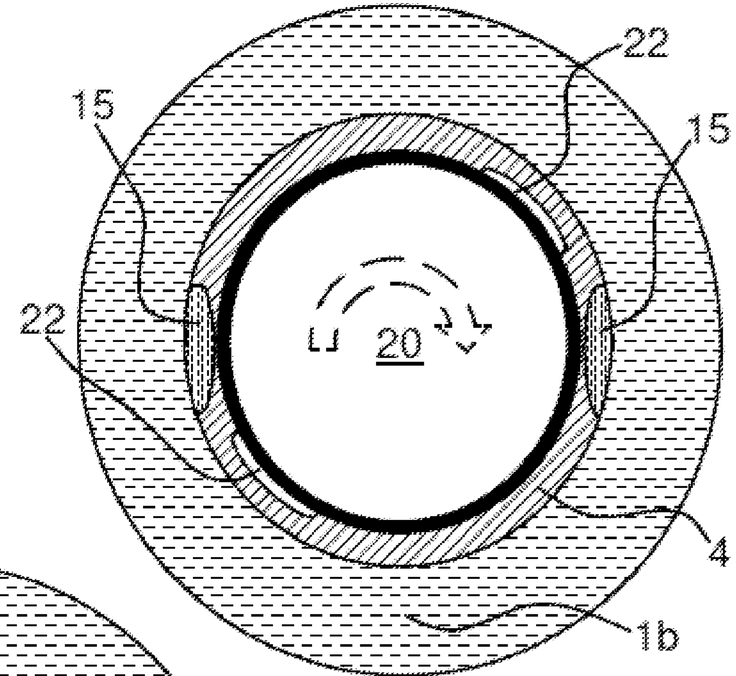


FIG. 3b

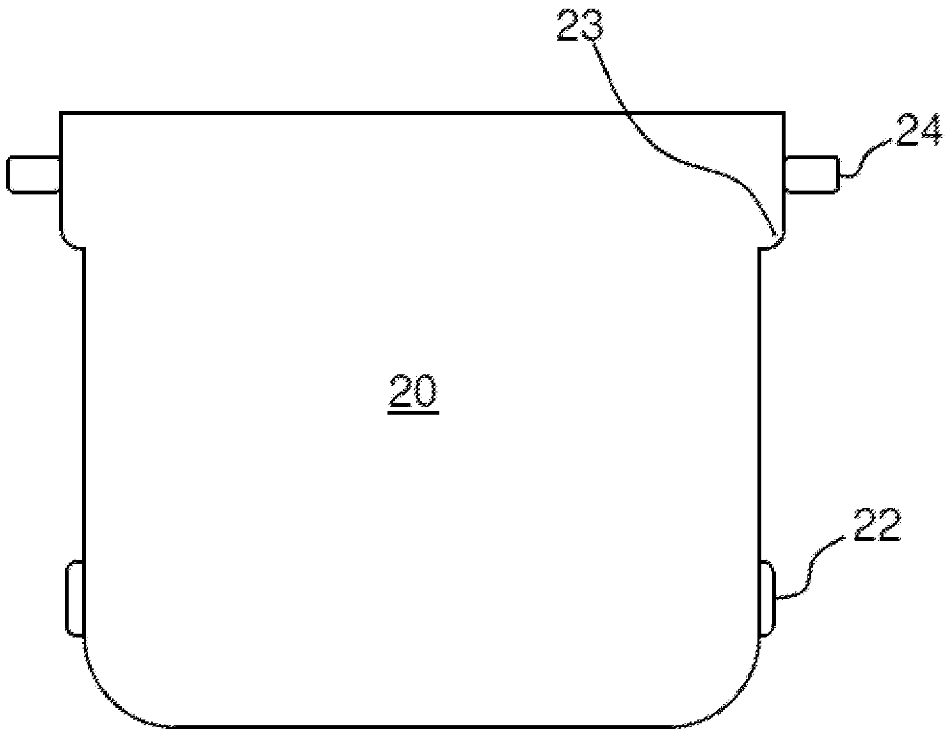


FIG. 4a

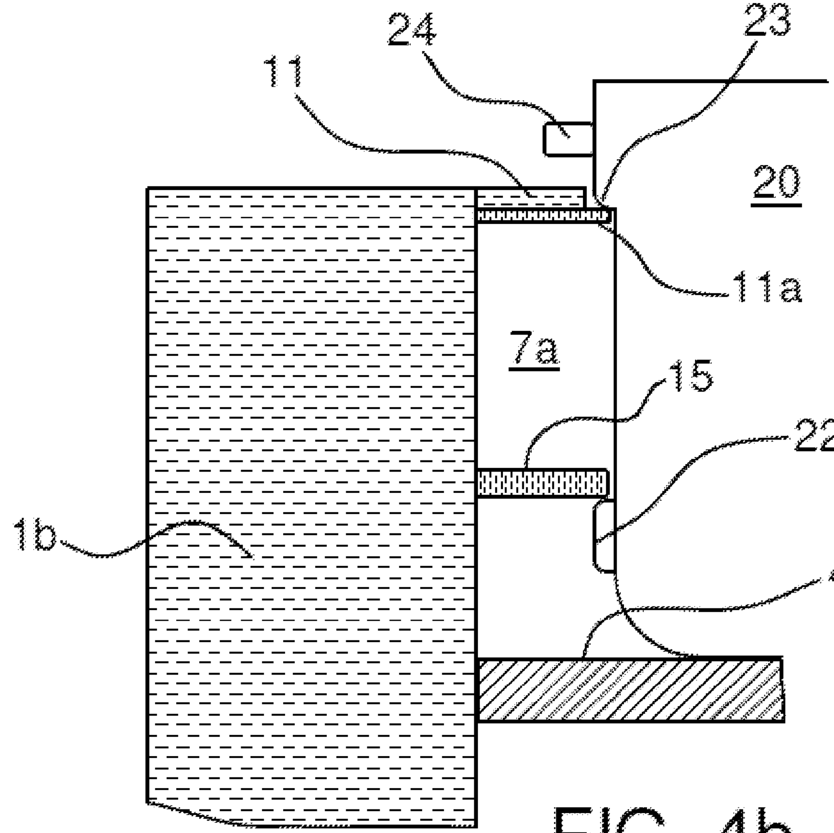


FIG. 4b

FIG. 5a

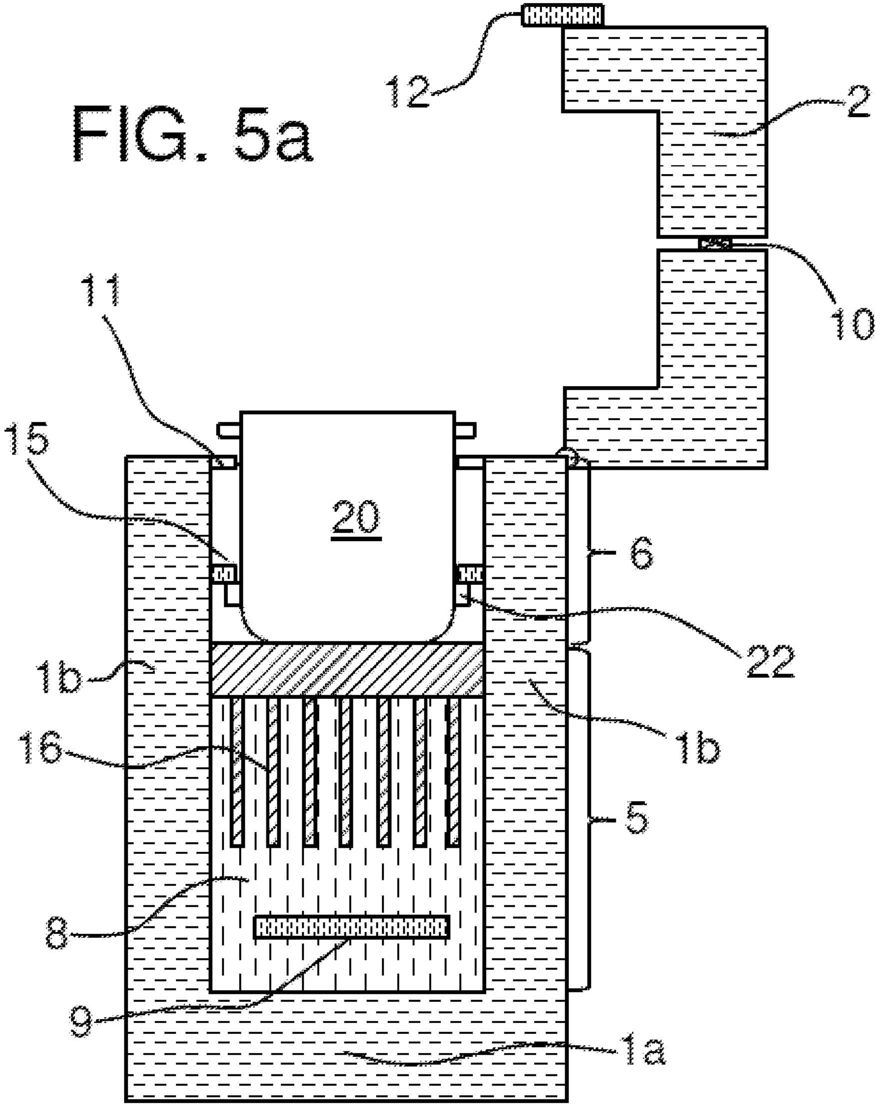
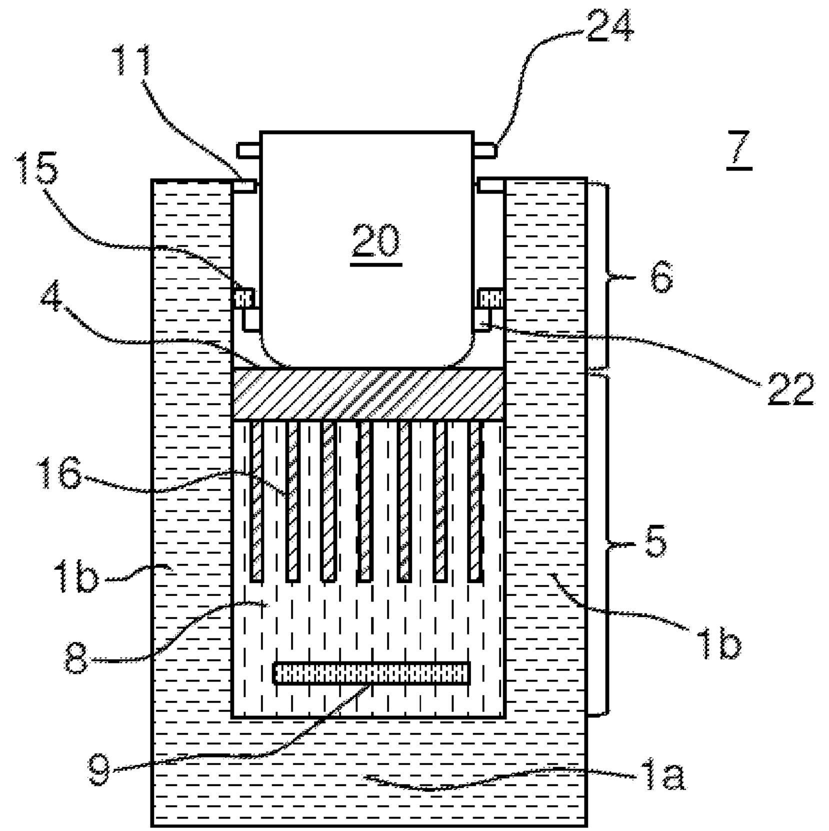


FIG. 5b



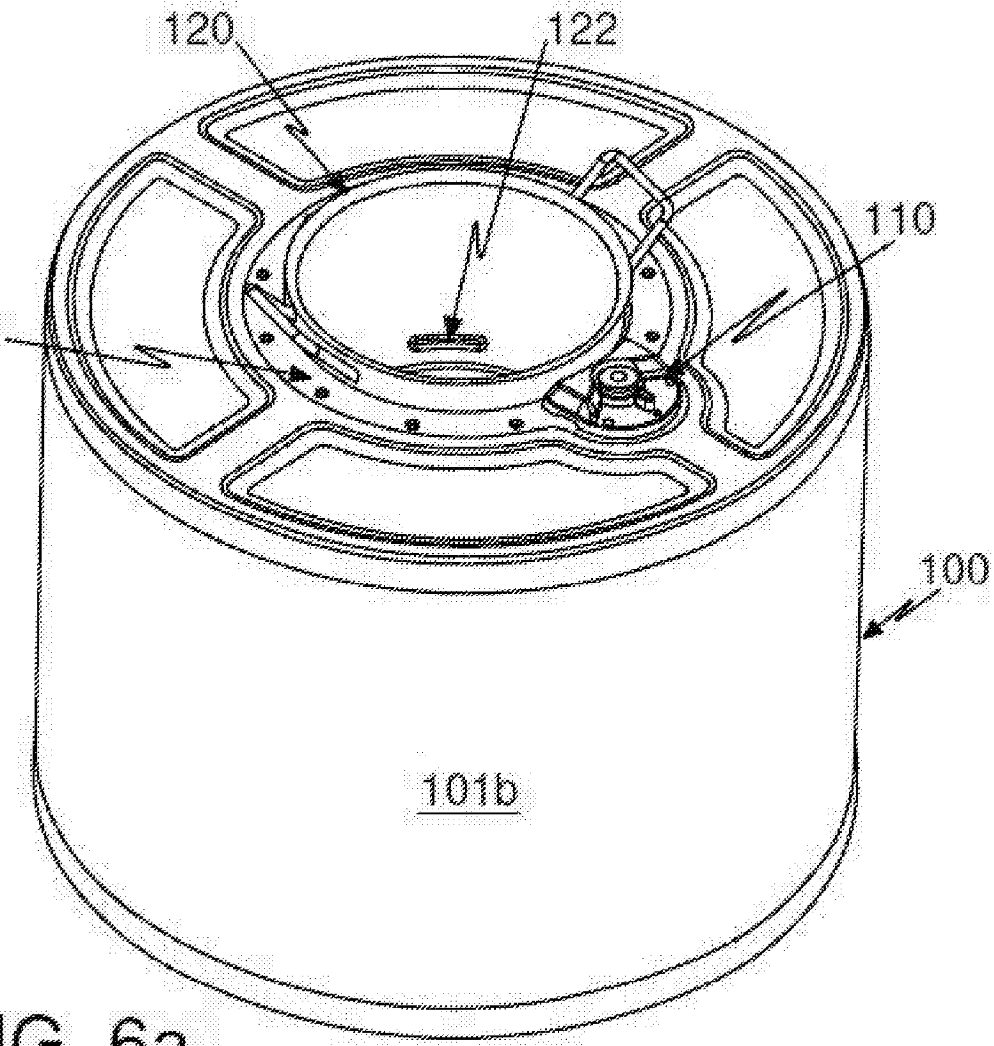

120
122
110
111
100
101b

FIG. 6a

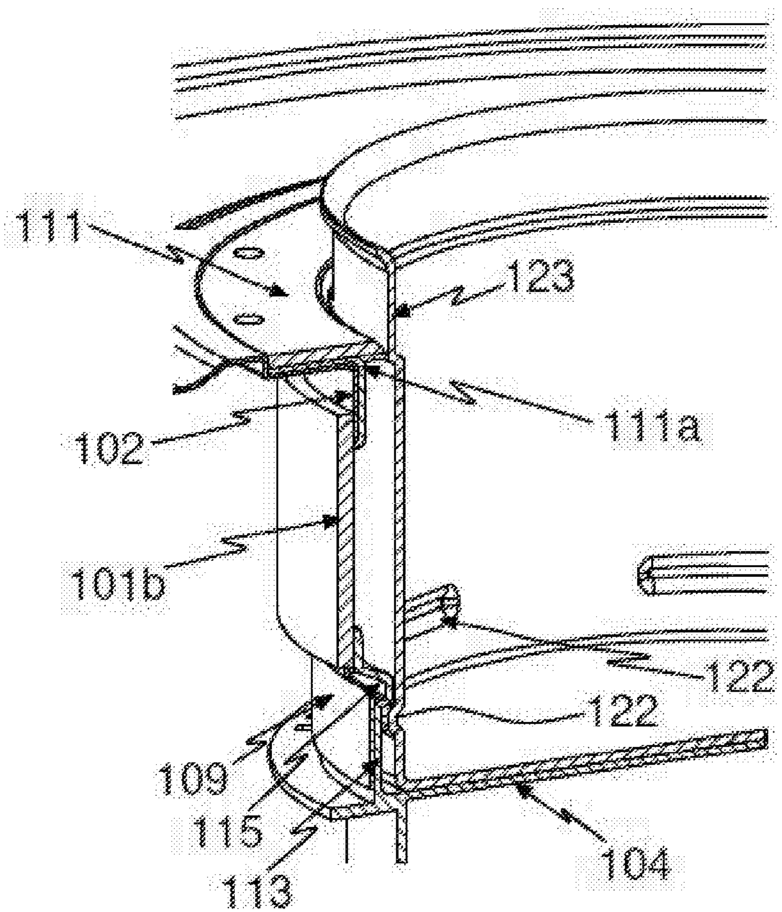

111
123
111a
102
101b
122
122
109
115
113
104

FIG. 6b

Solar cooking apparatus with steam function and heat storage capacity

The present invention relates to a cooker having steam function and storage capacity of heat.

Background

More than 1 billion people in the world live in areas without access to grid electricity. More than 2 billion people do not have access to clean cooking technology and do their cooking of food on open fire with no or inadequate venting of the smoke gas. The persistent exposure to combustion gases is a serious environmental and health problem. It is thus a need for cooking capabilities which are not too costly, and which do not rely on burning fire wood, coal or other combustion fuels as energy supply.

Nearly all the people with poor access to clean cooking have good solar insolation conditions making sun light an abundant and available source of energy.

Prior art

The energy in sun light may be harnessed thermally or by the photovoltaic effect. The simplest and most efficient harnessing of energy from sunlight is to absorb the sunlight in a material having a low albedo. This approach has the potential of capturing almost all energy of the incident sunlight and converting it to thermal energy. By using a mirror to focus and concentrate incident sunlight from a relatively large area onto a receiving area or object, the sunlight may heat the receiving area/object to several hundred degrees Celsius which is sufficient to cook or bake food.

There are known solar cookers and ovens using mirrors or similar reflective surfaces to harness incident sunlight to cook and/or bake food. One example of such a solar cooking apparatus is disclosed in e.g. document US 3938497. Such solar cookers have the benefit of having a relatively simple and inexpensive construction using free energy, making them very cheap apparatuses for cooking/baking food suited for use by low-income residents. They also have the benefit of obliviating the need for using open-fire to heat food and thus potentially significantly improving the in-house environment and health conditions. However, they have no heat storage capacity and stops working immediately if the sunshine is interrupted. They can only operate in direct sunshine, which significantly constrains indoor use and the very common use in late afternoons. This problem may be alleviated by using a heat storage material to accumulate and store solar energy until later use.

From CN 102 597 649 A, it is known a solar cooking device comprising a solar heat collector to collect and store solar heat, a heat storage and conducting material partially filling said solar heat collector and a set of solar cooking utensils. The utensil has an inner wall which is thermally connected to the heat storage, conducting material and the solar hear collector, so that the solar energy can be collected to cook food. The utensil also has a removable part for opening and closing said utensil during cooking. In one example embodiment, the heat storage material is a phase-change material and there is an electric heating element located in the heat storage material.

Panwar et al. [4] provides an overview of the prior art and the various ways of channeling solar irradiative heat directly or through an interim storage into energy for cooking purposes. The simplest solution is the “box type collector” where a glass insulation allows solar irradiation to pass through the glass and into the collector, while the glass is insulating reasonably well the heat that has been captured and stored. The box type collector can be made with or without mirrors to collect more irradiation. “The flat plate collector” has a separate panel collecting solar irradiation and converting it to steam, and then transferring the steam to the cooking utility. The “parabolic reflector direct cooker” has an advanced parabolic mirror that reflects irradiation from a larger area by the use of a parabolic mirror so that a strong concentrated irradiation can be achieved. The “parabolic reflector indirect cooker” uses the same parabolic mirror but directs the sunlight onto a heat storage medium that afterwards or elsewhere (indoors) is used for cooking. Unfortunately, none of the above methods have been able to provide a low cost, reliable cooking method with limited needs for maintenance and which allows the user to decide freely when to cook.

Lameck NKhonera et al. [5] has investigated finned thermal box-type collectors for solar cooking at 150 – 200 °C using the pentaerythritol as phase-change material (PCM) for storing latent heat collected from irradiation. The study investigated the performance of the thermal storage units as function of the volume ratio of PCM : fin in a cookstove designed for use within 1 to 4 hours after being fully charged by the sun. The article discloses a thermal storage unit consisting of an aluminium container being filled with pentaerythritol and a set of aluminium fins standing edgewise in parallel, and which in their upper end is attached to an aluminium top plate having a set of electric heating elements incorporated therein in order to simulate solar radiative heating providing a surface temperature of 220 °C under a glass. The thermal storage unit was insulated with Rockwool on the sides and in the bottom.

EP 0 221 575 discloses a heating and/or coating device comprising a heat storage unit (2) surrounded by heat insulation (1), a heating element (3) arranged in said storage unit (2), at least one heat consumer (5) and a heat transfer element (6) emerging from the heat storage unit (2) and routed through the insulation (1) to the heat consumer (5), whereby the heat transfer power of said element (6) is adjustable via a regulator (7). The output of the device is considerably improved and its controllability simplified in a universal manner by the fact that the heat transfer element is a heat exchange tube (6) rising from the heat storage unit (2) to the heat consumer (5) and that the steam/liquid flow in said tube (6) can be regulated by the regulator (7), which may be a valve or a server-valve linked with an electrical or electronic control system.

Objective of the invention

The main objective of the invention is to provide a low-cost and reliable solar energy and optionally net electric energy driven cooking apparatus having steam function and heat storage capacity suitable for use in areas where the grid electricity is not reliably present every day.

Description of the invention

The present invention utilizes a heat storage to store thermal energy supplied by an electric resistance heating element combined with a photovoltaic panel and an electric resistance heating element as energy source. The invention further applies steam to increase the heat transfer from the heat storage to the cooking vessel.

Thus, in a first aspect, the present invention relates to a cooking apparatus comprising:

a container (1) having an inner chamber (3) and being defined by a heat insulating bottom-wall (1a), a heat insulating sidewall (1b) and a releasable heat insulating lid (2) constituting an upper releasable enclosure of the container, where the inner chamber (3) comprises a lower (5) and a higher (6) section, wherein the lower section (5) of the inner chamber (3) comprises:

a heat storage material (8) filling the lower section (5), and

a substantially horizontally oriented heat transfer plate (4) in thermal contact with the heat storage material (8),

and the upper section (6) of the inner chamber (3) comprises:

an inner space (7) adapted to receive and hold a cooking vessel (20) placed onto the heat transfer plate (4) ,

and in that the cooking apparatus further comprises:

an electric heating element (9) is in thermal contact with the heat storage material (8) and in electric contact with an external source of electric power, and

at least one pressure release valve (10) adapted to open at a pressure difference across the pressure release valve (10) in the range from 0.1 to 909 kPa, preferably of from 0.1 to 707 kPa, more preferably of from 0.1 to 505 kPa, more preferably of from 0.1 to 303 kPa.

As used herein, the terms “upper”, “lower”, “top”, “bottom” refer to the relative height position in the cooking apparatus, and the terms “horizontal” and “vertical” refer to the earth gravity field.

An example embodiment of the invention according to the first aspect is drawn schematically in figures 1 a) and 1b). The drawings are cut views as seen from the side. In figure 1a) the example embodiment is shown with the lid (2) in open position and thus made ready to receive a cooking vessel. The example embodiment comprises a container (1) defined by heat-insulating walls (1a) and (1b) and the releasable lid (2), which when the lid is in closed position as shown in figure 1b), encompasses an inner space (3) of the container. The lower section (5) of the inner space (3) is filled with a heat storing material (8). When the lid (2) is in closed position, the entire inner space (3) is thermally insulated from its surroundings enabling storing the accumulated heat for many hours and maintain a sufficient storage of thermal energy to cook food.

The heat storing material is heated by an electric heating element (9) at periods with available electric power to accumulate thermal energy in the heat storing material (8). A heat transfer plate (4) is located on top of the heat storing material (8) and being in direct thermal contact to enable an efficient heat transfer from the heat storage material to a cooking vessel placed onto the heat transfer plate.

The cooking apparatus enables an effective and energy efficient way of transferring heat from the heat storage material into a cooking vessel placed on the heat transfer plate by adding an amount of water onto the heat transfer plate. By closing the lid, as shown in figure 1b), the remaining available space of the inner space (7) will be filled with heated steam which heats the food inside the cooking vessel (20). The example embodiment comprises further a locking mechanism (12) to ensure a tight and secure locking of the lid.

The heat storage material (8) may be a monolithic metal object made of (preferably) a light metal such as e.g. aluminium or magnesium, or iron, or steel. In this example embodiment, the heat transfer plate (4) may simply be a planar upper surface of the monolithic metallic heat storage material (8). Alternatively, the heat transfer plate may be a metal plate located onto and in direct contact with the monolithic metallic heat storage material (8). The thickness of the metal plate may in one embodiment be 1 to 20 mm, preferably 1 to 10 and most preferably 1 to 5 mm thick. Alternatively, the heat storage material may be a cement.

Alternatively, the heat storing material (8) may be a phase-change material. In this embodiment, the heat transfer plate (4) may advantageously be a metal plate located onto and in direct contact with the phase-change material. The thickness of the metal plate may in one embodiment be 1 to 20 mm, preferably 1 to 10 and most preferably 1 to 5 mm thick. The heat transfer plate (4) may in this example embodiment be made of any material known to the skilled person suited for use as cooking plates. In practice, the material of the heat transfer plate may advantageously have a thermal conductivity, of at least 1 W/mK, preferably of at least 10 W/mK, more preferably of at least 20 W/mK, more preferably of at least 30 W/mK, and most preferably of at least 50 W/mK. Examples of suited thermal conductive materials include, but are not limited to; metals such as Fe, Cu, Al, Zn, Sn, W, and alloys thereof such as e.g. bronze, brass, constantan, various steel alloys, pinchbeck; ceramics such as aluminium oxide, crystalline silicon dioxide, porcelain, Pyrex glass, etc.

The term “phase-change material” as used herein, means any chemical compound or mixture of chemical compounds going through a reversible phase-change enabling absorbing or releasing a useful amount of latent heat, preferably more than 100 kJ/kg phase-change material, at a temperature in the range from 80 to 500 °C, preferably from 90 to 450 °C, more preferably from 100 to 400 °C, and most preferably from 120 to 300 °C. The phase-change may either be a solid-solid phase change or a solid-liquid phase change. The invention may apply any phase-change material known to the skilled person having a phase-transition temperature suitable for use in a cooking apparatus.

Examples of suited solid-liquid phase-change materials include, but are not limited to; inorganic salts such as e.g. $NaNO_3$ (310 °C, 174 kJ/kg), $NaNO_2$ (282 °C, 212 kJ/kg), $MgCl_2{\cdot}6H_2O$ (117 °C, 168,6 kJ/kg), NaOH (318 °C, 158 kJ/kg), KOH (360 °C, 167 kJ/kg), KNO_3 (337 °C, 116 kJ/kg), $LiNO_3$ (261 °C, 370 kJ/kg), and mixtures thereof; mixtures (by weight) of salts such as e.g. 26.8 % NaCl and the rest being NaOH (370 °C, 379 kJ/kg), 7.2 % Na_2CO_3 and the rest being NaOH (283 °C, 340 kJ/kg), 5 % $NaNO_3$ and the rest being NaCl (284 °C, 171 kJ/kg), 49 % $LiNO_3$ and the rest being $NaNO_3$ (194 °C, 265 kJ/kg); 31,9 % ZnCl and the rest being KCl (235 °C, 198 kJ/kg); organic compounds such as erythritol (IUPAC-name; (2R,3S)-butane-1,2,3,4-tetraol, 121 °C, 339 kJ/kg), or acetanilide (IUPAC-name; N-phenylacetamide, 114.3 °C, 222 kJ/kg), or d-mannitol (IUPAC name; (2*R*,3*R*,4*R*,5*R*)-Hexane-1,2,3,4,5,6-hexol; 167°C, 310 kJ/kg), or dulcitol/galactitol (IUPAC name; (2*R*,3*S*,4*R*,5*S*)-hexane-1,2,3,4,5,6-hexol; 188 °C, 350 kJ/kg). The temperatures and kJ/kg figures set in parenthesis above are the melting point and heat of fusion, respectively, of the phase-change material.

Examples of suited solid-solid phase-change materials include, but are not limited to; pentaerythritol (IUPAC-name; 2,2-bis(hydroxymethyl)propane-1,3-diol, 184.2 °C, 222.5 kJ/kg), or pentaglycerine (IUPAC-name; 2-(hydroxymethyl)-2-methylpropane-1,3-diol, 89 °C, 139 kJ/kg); mixtures (in molar %) of pentaerythritol (PE), trimethylol ethane (TME) and neopentyl glycol (NPG) of e.g. 30 PE, 10 TME, and 60 NPG (127 °C); 45 PE, 45 TME, and 10 NPG (109 °C), 45 PE, 10 TME, and 45 NPG (140 °C), or 70 PE, 15 TME, and 15 NPG (158 °C). Neopentyl glycol has IUPAC-name 2,2-Dimethylpropane-1,3-diol, and trimethylol ethane has IUPAC-name 2-(hydroxymethyl)-2-methylpropane-1,3-diol. The temperatures and kJ/kg figures (if given) set in parenthesis above are the solid-solid phase-transition temperature and heat of fusion, respectively, of the phase-change material.

Materials expand and contract with temperature changes according to their coefficient of expansion. Thus, the term “heat storage material filling the lower section” as used herein encompasses eventual spatial vacancies caused by differences in thermal expansion between the heat storage material and the container.

The term “substantially horizontally oriented heat transfer plate” as used herein is related to the orientation of the heat transfer plate when the cooking apparatus is in use and is to be interpreted in view of the heat transfer plate’s function of heating food inside a cooking vessel such as a kettle, pot, frying pan, casserole etc. being placed onto the heat transfer plate without noteworthy risk of sliding off or spilling any of the food content to be heated. The heat transfer plate will therefore function when being somewhat inclined, it does not need to be perfectly horizontal in the strict meaning of the term but may function well with inclinations of up to 5°, maybe 10°, or maybe up to 20°, relative to the earth’s gravity field.

The invention may apply any material known to the skilled person suited for use as heat transfer plate. In practice, the material of the heat transfer plate may advantageously have a thermal conductivity, of at least 1 W/mK, preferably of at least 10 W/mK, more preferably of at least 20 W/mK, more preferably of at least 30 W/mK, and most preferably of at least 50 W/mK. Examples of suited thermal conductive materials include, but are not limited to; metals such as Fe, Cu, Al, Zn, Sn, W, and alloys thereof such as e.g. bronze, brass, constantan, various steel alloys, pinchbeck; ceramics such as aluminium oxide, crystalline silicon dioxide, porcelain, Pyrex glass, etc.

In the example embodiment of applying phase-change material as the heat storage materials, the heat transfer plate should be in sufficient thermal contact with the underlying phase-change material. However, the phase-change material may undergo a volume change when shifting between its solid and liquid or between its two solid phases. This may lead to inadequate thermal contact. Furthermore, the phase change during cooking (i.e. cooling) will begin first in the coldest part near the cooking plate and thereafter progress further away from the cooking plate. Since some phase change materials have poor thermal conductivity this will gradually lead to less and less energy being transport to the cooking plate. Thus, in one example embodiment, the thermal contact between the phase-change material and the heat transfer plate may be obtained by providing one or more elongated members (16) extending from beneath the heat transfer plate downward into the heat storage material, and thus functioning as a heat bridge thermally connecting the heat transfer plate to the underlying heat storage material, see also figures 5a) and

5b). The elongated member may advantageously be made of material having good thermal conductivity, such as e.g. the same materials listed above for the cooking zone. In the example embodiment where the elongated members and the heat transfer plate are made of aluminium, they may advantageously be manufactured simultaneously by extrusion. Alternatively, the elongated members may be made of one or more thin aluminium plates/ foils that are folded in a way such that the desired spacing (to be filled with phase change material) is obtained and thereafter soldered onto the cooking plate.

The invention is not tied to any particular way of obtaining the heat-insulation of the inner chamber (3) of the container (1), but may apply any known or conceivable solution known to the person skilled in the art having the necessary mechanical strength for being used in a container pressurised up to about 3 atmospheres and which provides a specific thermal resistivity, R, across the container walls of at least 10 Km/W, preferably of at least 12 Km/W, more preferably of at least 15 Km/W, more preferably of at least 20 Km/W, and most preferably of at least 25 Km/W. For example, the heat insulating wall (1a, 1b) and the lid (2) may be a hollow metallic shell construction, where the metallic shell provides the mechanical strength, and which has hollow interior filled with a material having a thermal conductivity in the range of from 0.03 W/Km to 0.10 W/Km. The contained wall thickness may e.g. be in the range of from 5 to 30 cm. A thinner insulation may either be costlier and/or allow heat storage for a few hours, i.e. making it possible to cook for example at 11 am, but not at 6 am. A thicker insulation may be less expensive and/or allow heat storage throughout the night. Examples of suited thermal insulating materials include, but are not limited to; calcium silicate, cellular glass, fiberglass, mineral wool, rock wool, ceramic foam, polyurethane, foamed polyurethane (such as e.g. commercially available under the trademark Puren), and other porous materials having air filled pores, etc.

The invention may apply any electric heating element known to the skilled person which enables heating the heat storing material to its intended heat storing temperature, and which can withstand the chemical environment in the heated heat storing material. Alternatively, the electric heating element may be located outside the heat storing material as long as it is in thermal contact with the heat storing material. In one embodiment the electrical heating element is one or more metal wires going in a circle around the outer edge of the heat transfer plate (4). In another embodiment there are heat conducting walls protruding upwards 20-50 mm from the edge of the heat transfer plate (4), and the heating element can be located directly on the outside of such a wall. The heat generated will then go downwards through this wall, down into the cooking plate and from the cooking plate down into the phase change material – either directly or through the elongated members (16).

The source of electric energy may be any available source, including small-scale wind power, electric power from a photovoltaic panel, grid electricity, etc.

The cooking apparatus according to the first aspect, may further comprise a sealing enclosure (11, 11a) adapted to seal a gap formed between the inner surface (13) at the upper section of the sidewall (1b) and the outer surface (21) of the cooking vessel (20) when the cooking vessel is placed on the heat transfer plate (4). This feature enables employing the cooking apparatus in a “normal cooking mode” by having the lid in open position, or removed entirely, to gain access to the cooking vessel for active food cooking, stirring, adding ingredients etc., and still utilise the benefit of the effective heat transfer caused by the steam which fills the space (7a) confined by the container sidewall (1b), the heat transfer plate (4), the sealing enclosure (11, 11a) and the cooking vessel (20). By adding water to the heat transfer plate, of typically 1 to 50 cm^3, the space (7a) will be rapidly filled with heated steam which effectively transfers heat to the cooking vessel. The use of a sealing enclosure combined with addition of water is both enhancing the heat transfer coefficient and the heat transfer area of the cooking vessel thereby having a large impact on cooking time. The invention is also making the cooking apparatus much more tolerant to uneven bottoms in the cooking tools, something which is often the situation in less affluent societies.

An example embodiment of a cooking apparatus having a sealing enclosure is shown schematically in figures 2a) and 2b). Figure 2a) is a drawing showing a vertical cut-view as seen from the side taken along a vertical plane indicated by the stapled line marked B-B’ in figure 2b). The example embodiment applies a heat storage material (8) made of a monolithic object of aluminium filling the lower section (5) of the inner chamber of container (1). The heat transfer plate (4) is in this example embodiment an upper planar surface of the monolithic object of aluminium. A sealing enclosure (11, 11a) is located at the upper part of the container (1) and is adapted such that when a cooking vessel (20) is inserted into the open space (7) and placed onto the heat transfer plate (4), there is formed a confined space (7a) enclosed by the cooking vessel, heat transfer plate, container wall and the sealing enclosure. Figure 2b) is a drawing showing a horizontal cut view taken along the horizontal plane indicated by the stapled line marked A-A’ in figure 2a). As seen on the figure, the sealing enclosure (11) comprises in this example embodiment an annular metal part (11) closing the major part of the gap between the outer surface (21) of the cooking vessel (20) and the inner surface (13) of the container wall (1b) and a silicon or other polymer ring (11a) attached to the annular metal part (11), and which abuts against the outer surface (21) of the cooking vessel (20).

The cooking apparatus comprises a pressure release valve (10) which, in different example embodiments, may be located either in the container wall (1b), or in the lid

(2), or in the sealing enclosure (11). The pressure release valve (10) may either be a pre-set valve adapted to open at a specific pressure difference across the valve or be adjustable to enable varying at which pressure difference the valve will open. In the case of having a pressure release valve (10) located in the lid (2), the pressure relief valve ensures that gas pressure inside the inner space (7) does not become higher than the intended maximum pressure. In the case of having the pressure release valve (10) located in the sealing enclosure (11), the pressure relief valve (10) ensures that the gas pressure inside the space (7a), confined by the container sidewall (1b), the heat transfer plate (4), the sealing enclosure (11, 11a) and the cooking vessel (20), does not become higher than the intended maximum pressure. In the case of having the pressure release valve (10) located in the sidewall (1b), it may ensure that the gas pressure inside either the inner space (7) or the space (7a) does not become higher than the intended maximum pressure, depending on its location and the configuration of the cooking apparatus being employed. In one embodiment, there may be one pressure relief valve in the lid and one in the sealing enclosure. The pressure relief valve (10) may be adapted, by being pre-set or adjustable, to open at a pressure difference across the valve of from approx. 0 to 9 atmospheres (0.1 to 901 kPa), preferably from approx. 0 to 7 atmospheres (0.1 to 707 kPa), more preferably from approx. 0 to 5 atmospheres (0.1 to 505 kPa), and most preferably from approx. 0 to 3 atmospheres (0.1 to 303 kPa). The actual gas/steam pressure inside either the inner space (7) or space (7a) will, due to the ambient atmosphere of the cooking apparatus, be approx. 1 atmosphere higher than the pressure difference at which the pressure relief valve opens.

The feature of an adjustable pressure release valve (10) and thus enablement to set any pressure difference value at which the pressure release valve shall open during use of the cooking apparatus provides the opportunity to regulate the temperature in the gas/steam filled part of the inner chamber (7) and/or space (7a) since water boils and releases steam at 100 °C at a vapour pressure of 1 atm and at approx. 180 °C at a vapour pressure of 10 atm. This feature has a significant impact upon the heat transport from the heat transfer plate to the cooking vessel and enables e.g. frying food, rapid heating of water etc. in the cooking vessel.

The sealing enclosure may in one embodiment further comprise a safety pressure relief valve (17) pre-set to release gas/steam at a gas pressure inside the confined space (7a) of from 10 to 100 kPa higher than the pre-set pressure relief pressure of the pressure relief valve (10), or alternatively, when the pressure relief valve (10) is adjustable, is pre-set to release gas/steam at a gas pressure inside the confined space (7a) of from 10 to 100 kPa higher than the maximum adjustable pressure difference across the valve.

A gas pressure difference across the sealing enclosure causes an uplift force on the cooking vessel which may lift the cooking vessel. The cooking apparatus according to the first aspect of the invention may, in one embodiment, further comprise a mechanical lock (15) adapted to grip and hold the cooking vessel (20) to prevent it from being lifted out of position. The mechanical lock may e.g. be a bayonet locking mechanism where a male protrusion on the outer surface of the cooking vessel enters and become locked by a female receiver located at the inner surface of the container wall, a clamping mechanism attached to the container and which is adapted to grip and hold the top edge of the cooking vessel, a set of protrusions on the container and the cooking vessel adapted to interlock each other, etc. An example embodiment of a locking mechanism is illustrated schematically in figures 3a) to 3c). Figure 3a) is a similar cut-view of a similar example embodiment of the cooking apparatus as shown in figure 2a) except for also comprising a mechanical lock adapted to grip and hold the cooking vessel (20). As seen on figures 3b) and 3c), which are horizontal cut views taken along the stapled line marked C-C', the locking mechanism may simply be a protrusion (15) on the inner surface of the container wall being adapted to grip a protrusion (22) on the cooking vessel. The mechanical lock is in this embodiment obtained by simply inserting the cooking vessel at a rotational angle where two protrusions (22) do not overlap with two protrusions (15) from the cylinder wall and then turn the cooking vessel until these protrusions (15, 22) overlap each other.

The cooking vessel may, in one example embodiment, have a circumferential extension (23) creating a circumferential widening/"overhang" at which the sealing enclosure (11) may abut against and be pressed towards by the pressure difference across the sealing enclosure to ensure an effective gas blocking effect. An example embodiment of the cooking vessel (20) having a widening/extension (23) is shown in figures 4a) and 4b). This example embodiment also comprises a protrusion (15) adapted to abut against a protrusion (15) on the inside of the container sidewall (1b). The cooking vessel may advantageously also comprise a couple of grip handles (24). Figure 4a) is a vertical cut-view drawing of this example embodiment of the cooking vessel (20). Figure 4b) is an enlarged vertical cut-view drawing enlarging details of the interaction between the sealing enclosure and the cooking vessel and the locking mechanism. As seen on figure 4b), the sealing enclosure in this embodiment comprises an upper annular metallic seal (11) and an underlying annular silicon rubber flange (11a) which is adapted to abut against the "overhang" (23) of the cooking vessel. Similarly, the protrusion (15) of the container is adapted to abut against the upper side of the protrusion (22) of the cooking vessel.

In a second aspect, the invention relates to a cooking vessel, characterised in that the cooking vessel (20) comprises a circumferential extension (23) forming a circumferential widening/"overhang" on its outer surface (21).

The cooking vessel of the second aspect of the invention may in one embodiment, further comprise a set of at least two protrusions (22) on an outer surface (21).

In a third aspect, the invention relates to a system for cooking food, characterised in that it comprises:

- a cooking apparatus according to the first aspect of the invention comprising a sealing enclosure (11, 11a), and
- a cooking vessel (20) according to the second aspect,

and wherein the sealing enclosure (11) and the circumferential extension (23) are adapted such that the sealing enclosure (11) abuts against the circumferential widening of the outer surface (21) when the cooking vessel (20) is placed onto the heat transfer plate (4) of the cooking apparatus.

In one embodiment, the system according to the third aspect may comprise a cooking apparatus according to the first aspect of the invention further comprising a set of at least two protrusions (15) and the cooking vessel further comprises a set of at least two protrusions (22), and wherein the protrusions (15) and the protrusions (22) are adapted such that when the cooking vessel (20) is placed onto the heat transfer plate (4) and rotated, that the protrusions (22) is made to abut against the lower side of a corresponding protrusion (15) of the container sidewall (1b).

The feature of having a pressure relief valve (10), either in the lid (2) or in the sidewall (10), which may set the gas/steam pressure inside the inner space (7) of container to any pressure in the interval from approx. 101 to 1010 kPa enables adjusting the temperature inside the inner chamber (7) since water boils and produces steam at 100 °C at a gas pressure of 101 kPa and at around 180 °C at a gas pressure of 1010 kPa. Furthermore, at a vapour pressure of 302 kPa, water boils and releases steam at 134 °C which is sufficiently high temperature to qualify as an autoclave for sterilising medical equipment.

Thus, in a fourth aspect, the invention relates to a method for sterilising equipment, wherein the method comprises:

applying a cooking apparatus according to the first aspect of the invention having an adjustable pressure relief valve (10) set to a first pressure difference value of at least 210 kPa,

open the lid (2) and adding from 30 to 200 cm^3 water to the heat transfer plate (4) and placing a cooking vessel containing the medical equipment to be sterilised onto the heat transfer plate (4) and closing the lid (2),

allow the added water to boil and produce steam for at least 4 minutes and then adjust the adjustable pressure relief valve (10) to a second pressure difference value of 0.1 to 1 kPa, and

wait until the steam pressure inside the inner space has reached 0.1 to 1 kPa to open the lid for accessing the cooking vessel containing the sterilised equipment.

List of figures

Figures 1a) and 1b) are vertical cut-view drawings of an embodiment of the cooking apparatus according to the first aspect of the invention. Figure 1a) illustrates the cooking apparatus with open lid and figure 1b) illustrates the same embodiment in a working condition with a closed lid and a cooking vessel located therein.

Figure 2a) is a vertical cut-view drawing of an embodiment of the cooking apparatus according to the first aspect of the invention comprising a sealing enclosure. Figure 2b) is a horizontal cut-view drawing of the same embodiment taken along the stapled line marked A-A' in figure 2a).

Figures 3a) to 3c) are vertical cut-view drawings of an embodiment of the cooking apparatus according to the first aspect of the invention comprising a sealing enclosure and a locking mechanism. Figure 3a) is a vertical cut-view, while figures 3b) and 3c) are horizontal cut-views taken along the stapled line marked C-C' in figure 3a).

Figure 4a) is a cut-view drawing of an example embodiment of a cooking vessel according to the second aspect of the invention. Figure 4b) is an enlarged vertical cut-view drawing enlarging details of the interaction between the sealing enclosure and the cooking vessel and the locking mechanism.

Figures 5a) and 5b) are vertical cut-view drawings of an embodiment of the cooking apparatus according to the first aspect of the invention comprising elongated heat conducting elements into the heat storage material to enhance the heat transfer to the heat transfer/cooking plate. Figure 5a) illustrates the cooking apparatus with open lid and figure 5b) illustrates the same embodiment with the releasable lid removed.

Figure 6a) is a drawing of an example embodiment of the system according to the third aspect of the invention.

Figure 6b) is an exploded view drawing illustrating details of the sealing enclosure and locking mechanism of the system.

Example embodiment

The invention is further described by way of an example embodiment of the cooking system according to the third aspect of the invention comprising a cooking apparatus according to the first aspect of the invention and a cooking vessel according to the second aspect of the invention.

As seen from figures 6a) and 6b), the example embodiment of the cooking system comprises a cooking apparatus (100) and a cooking vessel (120). The cooking apparatus comprises a container (101) having bottom and outer sidewalls (101a) made of steel. The main inner sidewall (101b) is made of a high temperature silicon, which is a poor heat conductor and also tolerates both the temperature and pressure. Below the inner sidewall (101b) there is a lower sidewall (113) made as a direct extension of the heat transfer plate (4), and below the heat transfer plate is the heat storing material (8). The space between the outer sidewalls (101a) and the centre structure formed by the inner sidewall (101b), lower sidewall (113), heat transfer plate (4) and heat storing material (8) is filled with Rockwool as thermal insulation.

A cooking vessel (120) is inserted into the inner space of the container. The gap between the container wall (101b) and the cooking vessel (120) is closed by a sealing enclosure (111) consisting of a metal ring of steel laid onto a horizontally oriented annular deepening/insertion (102) of the container wall (101b) and wherein a flange (111a) of silicon is interposed between the sealing ring and annular deepening and made to protrude a distance out to the side of the sealing ring and annular deepening.

The lower section of the inner chamber of the container has a volume of 4800 cm^3. This volume is filled with an 0,3 mm thick and vertical aluminium foil that is rolled (like a roll of toilet paper) with a fixed spacing of 1,4 mm between the plates in each round. The foil is soldered directly onto the vertical heat transfer (104) plate along the edges of the foil. The 1,4 mm gaps between each turn of the aluminium foil is filled with pentaerythritol as heat storage material, in total 4000 cm^3. The heat transfer plate (104) is a disc of aluminium of 4 mm thickness. When a sufficient amount of water (for example 30 gram) is added to the heat transfer plate (104), there will be a one-to-one relationship between pressure and temperature, and at 0.9 bar overpressure the temperature in the steam chamber will be about 119 °C. At 0.6 bar overpressure the temperature will be 114 °C.

An electrical resistance element (109) is wired around the outside of the lower sidewall (113). The heat flux during charging goes from the resistance element into the sidewall (113) made of aluminium and thereafter straight into the cooking plate (104) made of aluminium, down into the vertical aluminium foil below and from the aluminium foil into the pentaerythritol (8). During cooking the heat flux goes in the opposite direction until the heat has reached the cooking plate (104) from which it will either go straight into the cooking vessel (120) or be used to produce steam that thereafter condenses on the cooking vessel (120).

The cooking vessel has a widening/extension (123) of its outer diameter at a location/height such that the silicon flange (111a) of the sealing enclosure (111) abut against the extension made by the widening/”overhang” (123) when the cooking vessel is located onto the heat transfer plate (104) of the cooking apparatus. The sealing enclosure (111) comprises an adjustable pressure relief valve (110) able to create an overpressure in the chamber below the sealing enclosure of up to about 0.5 – 1.5 bar.

The locking mechanism consists of a set of protrusions (122) at the lower part of the cooking vessel and a set of protrusions (115) from the cylinder wall, and where which are mutually adapted to abut against each other such that when the cooking vessel (120) is placed onto the heat transfer plate (104) and rotated, that the protrusions (122) is made to abut against the lower side of a corresponding protrusion (115) of the container sidewall (101b).

For safety reasons one of the protrusions (115) on the cylinder wall extends downward in one of its ends so that the rotation stops when cooking vessel is rotated at a position where there is maximum overlap of the protrusions (115) and (122). Furthermore, all the protrusions (115 and 122) are slightly non-horizontal so that after the pressure has been increased and the cooking pot is pushing against the protrusions (115) on the sidewall, one will need to push the cooking vessel (120) downward in order to rotate it back into an open position.

CLAIMS

1. A cooking apparatus comprising:

a container (1) having an inner chamber (3) and being defined by a heat insulating bottom-wall (1a), a heat insulating sidewall (1b) and a releasable heat insulating lid (2) constituting an upper releasable enclosure of the container, where the inner chamber (3) comprises a lower (5) and a higher (6) section, wherein the lower section (5) of the inner chamber (3) comprises:

a heat storage material (8) filling the lower section (5), and

a substantially horizontally oriented heat transfer plate (4) in thermal contact with the heat storage material (8),

and the upper section (6) of the inner chamber (3) comprises:

an inner space (7) adapted to receive and hold a cooking vessel (20) placed onto the heat transfer plate (4) ,

and in that the cooking apparatus further comprises:

an electric heating element (9) is in thermal contact with the heat storage material (8) and in electric contact with an external source of electric power, and

at least one pressure release valve (10) adapted to open at a pressure difference across the pressure release valve (10) in the range from 0.1 to 909 kPa, preferably of from 0.1 to 707 kPa, more preferably of from 0.1 to 505 kPa, more preferably of from 0.1 to 303 kPa.

2. The cooking apparatus according to claim 1, wherein the heat storing material (8) is a phase change material being:

either

a chemical compound chosen from the group consisting of; $LiNO_3$, $NaNO_3$, $NaNO_2$, $MgCl_2 \cdot 6H_2O$, NaOH, KOH, KNO_3, or a mixture thereof,

or

a mixture of either;

26.8 % by weight NaCl and the rest being NaOH,

7.2 % by weight Na_2CO_3 and the rest being NaOH,

5 % by weight $NaNO_3$ and the rest being NaOH,

49 % by weight $LiNO_3$ and the rest being $NaNO_3$, or

31.9 % by weight ZnCl and the rest being KCl

or

a chemical compound chosen from the group consisting of; erythritol, acetanilide, pentaerythritol, pentaglycerine, d-mannitol, or dulcitol/galactitol, or a mixture thereof,

or

a mixture in molar % of pentaerythritol (PE), trimethylol ethane (TME) and neopentyl glycol (NPG) of: 30 PE, 10 TME, and 60 NPG; 45 PE, 45 TME, and 10 NPG; 45 PE, 10 TME, and 45 NPG; or 70 PE, 15 TME, and 15 NPG.

3. The cooking apparatus according to claim 1 or 2, wherein the heat storage material (8) is
either:
a monolithic metal object made of aluminium, iron, steel, or magnesium,
or:
a concrete.

4. The cooking apparatus according to any of claims 1 – 3, wherein the heat transfer plate (4) is a metal plate located onto and in thermal contact with the phase-change material and being made of a material chosen from: Fe, Cu, Al, Zn, Sn, W, or an alloy thereof, bronze, brass, constantan, steel alloys, pinchbeck, aluminium oxide, crystalline silicon dioxide, porcelain, or Pyrex glass.

5. The cooking apparatus according to any preceding claim, wherein the cooking apparatus further comprises one or more elongated members (16) extending from the heat transfer plate (4) downward into the heat storage material (8), and where the elongated members are made of a material chosen from: Fe, Cu, Al, Zn, Sn, W, or an alloy thereof, bronze, brass, constantan, or steel.

6. The cooking apparatus according to any preceding claim, wherein the cooking apparatus further comprises a sealing enclosure (11, 11a) adapted to seal a gap formed between the inner surface (13) of the sidewall (1b) in the upper section and an outer surface (21) of the cooking vessel (20) when the cooking vessel is placed on the heat transfer plate (4).

7. The cooking apparatus according to any preceding claim, wherein the at least one pressure release valve (10) is located either in the lid (2), or in the container sidewall (1b), or in the sealing enclosure (11).

8. The cooking apparatus according to claim 7, wherein the at least one pressure relief valve (10) is adjustable and adapted to set the gas pressure difference value at which the valve (10) opens in the range from 0.1 to 909 kPa, preferably of from 0.1 to 707 kPa, more preferably of from 0.1 to 505 kPa, more preferably of from 0.1 to 303 kPa.

9. The cooking apparatus according to any of claims 6 to 8, wherein the sealing enclosure comprises a safety valve (17) pre-set to release gas when the gas pressure difference across the safety valve becomes equal to:
either, when applying a pre-set pressure relief valve (10):
from 10 to 100 kPa higher than the pre-set pressure difference value of the pressure relief valve (10),
or, when applying an adjustable pressure relief valve (10):
from 10 to 100 kPa higher than the maximum adjustable pressure difference value of the adjustable pressure relief valve (10).

10. The cooking apparatus according to any preceding claim, wherein the cooking apparatus further comprises a mechanical lock (15) adapted to grip and hold the cooking vessel (20) to prevent it from being lifted out of position by the gas pressure inside a space (7a) enclosed by the cooking vessel (20), heat transfer plate (4), container sidewall (1b) and the sealing enclosure (11).

11. The cooking apparatus according to claim 3, wherein the heat transfer plate (4) is a planar upper surface of the monolithic metal object made of aluminium, iron, steel, or magnesium.

12. A cooking vessel, comprising a bottom, a sidewall and a gripping handle, characterised in that the cooking vessel (20) further comprises two or more protrusions (22) on an outer surface (21) of the sidewall.

13. The cooking vessel according to claim 12, wherein the cooking vessel (20) further comprises a circumferential extension (23) forming a circumferential widening of the outer surface (21).

14. A system for cooking food,
characterised in that it comprises:
- a cooking apparatus according to any of claims 6 – 11, and
- a cooking vessel (20, 200) according to claim 12 or 13.

15. The system according to claim 14, wherein the mechanical lock is:
a bayonet locking mechanism where one or more male protrusion(s) on the outer surface of the cooking vessel (20, 200) enters and become locked by one or more female receiver(s) located at the inner surface (13, 113) of the container sidewall (1b, 101b), or
a clamping mechanism attached to the container (1, 100) and which is adapted to grip and hold the top edge of the cooking vessel (20, 200).

16. The system according to claim 15, wherein the mechanical lock comprises a set of at least two protrusions (15, 115) on the inner surface (13, 113) of the container sidewall (1b, 101b) and a set of at least two protrusions (22, 220) on the outer surface (21, 121) of the cooking vessel (20, 120), and wherein the protrusions (15, 115) and the protrusions (22,220) are adapted such that when the cooking vessel (20. 120) is placed onto the heat transfer plate (4,104) and rotated, that the protrusions (22, 220) is made to abut against the lower side of a corresponding protrusion (15, 115) of the container sidewall (1b, 101b).

17. The system according to any of claims 14 to 16, wherein the sealing enclosure (11, 111) comprises a metal ring laid onto a horizontally oriented annular insertions (102) of the container sidewall (1b, 101b) and wherein a flange (11a, 111a) of silicon is interposed between the sealing ring and annular deepening and

made to protrude a distance out to the side of the sealing ring and the annular deepening, and wherein the cooking vessel (20, 120) has an extension (23, 123) of its outer diameter at a location/height such that the silicon flange (11a, 111a) of the sealing enclosure (11, 111) abut against the widening made by the extension (23, 123) when the cooking vessel is located onto the heat transfer plate (4, 104) of the cooking apparatus.

18. A method for sterilising equipment, wherein the method comprises:

applying a cooking apparatus any of claims 1 - 11 having an adjustable pressure relief valve (10) set to a first pressure difference value of at least 210 kPa,

open the lid (2) and adding from 30 to 200 cm^3 water to the heat transfer plate (4) and placing a cooking vessel containing the medical equipment to be sterilised onto the heat transfer plate (4) and closing the lid (2),

allow the added water to boil and produce steam for at least 4 minutes and then adjust the adjustable pressure relief valve (10) to a second pressure difference value of 0.1 to 1 kPa, and

wait until the steam pressure inside the inner space has reached 0.1 to 1 kPa to open the lid for accessing the cooking vessel containing the sterilised equipment.

Intellectual Property Office

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Claims searched:	1-11 and 18	**Date of search:**	30 November 2020

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X,Y	X: 1 and 4, Y: 5	US4246955 A (SKALA STEPHEN F) see figure 1, description column 5 lines 25-50, column 6 line 34-column 7 line 54
Y	5	WO2017/205864 A1 (LITCHFIELD et al) see figure 2, description paragraph 56
A	-	CN110114617 A (LIN HUAZI) see figures 1 and 7, detailed description paragraphs 1-8
A	-	GB2571298 A1 (DIFFER AS) see figures 1a and 1b, description first example embodiment of the invention
A	-	TW200826883 A (CHEN CHANG-REN et al) see abstract, figure 1
A	-	DE102011088092 A1 (BSH BOSCH SIEMENS HAUSGERAETE) see whole document
A	-	KR 1020120100552 A (KOREA FOOD RES INST) see figures 2a-2c, description paragraph [0026]

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
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Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{X} :

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A47J; F24C; F24S; F28D

The following online and other databases have been used in the preparation of this search report

Intellectual Property Office

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International Classification:

Subclass	Subgroup	Valid From
A47J	0027/00	01/01/2006
F24C	0015/34	01/01/2006
F24S	0020/30	01/01/2018
F24S	0060/10	01/01/2018
F28D	0020/02	01/01/2006