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(73) Octrooihouder(s):
Neo Joule B.V. te MAASBRACHT

(72) Uitvinder(s):
Andrew Charles Dorn te MAASBRACHT
Maria Costa te MAASBRACHT

(74) Gemachtigde:
ir. A. Blokland c.s. te Eindhoven

(54) **Method for combustion of a biological material and a process for cremating a human or animal body or body part**

(57) The present invention relates to a method for combustion of a biological material by means of microwave radiation, said method comprising the steps of: providing said biological material to be combusted, a microwave absorbing susceptor and an apparatus comprising a chamber and a source of microwave radiation, preferably in such a manner that said biological material and said susceptor are present in said chamber such that said biological material at least partly occludes said susceptor; and directing microwave radiation from said source of microwave radiation to said biological material and said susceptor to combust said biological material. The present invention further relates to a process for cremating a human or animal body or body part comprising said method.

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Title: Method for combustion of a biological material and a process for cremating a human or animal body or body part

TECHNICAL FIELD

The present invention relates to a method for combustion of a biological material by means of microwave radiation. The invention further relates to a process for cremating a human or animal body or body part.

BACKGROUND

Conventional cremators for the cremation of human bodies in coffins may vary considerably in their structural design but the heating means are invariably gas burners, oil burners or electrical heating elements.

Using such conventional heating techniques the heat for initiating and maintaining combustion is applied to the body externally and the outer layers of the body must be burnt before successively deeper layers can be exposed and consumed by the flames. Wherein body is refered to in the description, this can also be read as body part unless stated otherwise. A significant factor inhibiting the rate of combustion is the water content of a body. In the average human about 50 to 70% of the body weight is attributable to water. This moisture has to be driven off before the ignition temperature can be reached.

Retention of liquid water within the body prevents the temperature of the biological material from exceeding the so-called wet bulb temperature of the body material until an appreciable amount of evaporation as occurred and the body is relatively dry.

Due to the extreme heat required to evaporate the water from the body and successively combust the dried remains (dried biological material), a large part of the bodily flesh is blown into particulates and carried out of the combustion chamber with the present air/gases. These particulates must be then filtered out of the air/gases, since they may comprise harmful compounds including highly toxic, non-biodegradable dioxins that steadily accumulate in the environment.

Furthermore, because of the required high temperatures the cremation ovens are often heated continuously to avoid long heating and cooling periods, and reduce the amount of total energy required for heating. The ovens are often also heated in the periods between cremation processes and during the night. This requires a significant use of energy and fuel, which is undesirable from a cost and environmental perspective

GB2032596 from 1979 discloses a method for the cremation of human or animal remains wherein conventional heat sources (gas, oil etc.) are replaced or supplemented by microwave heating. Microwave pre-treatment may be followed by conventional heating. The use of microwave heating only is disclosed to be impractical because of the high power requirement.

DE4417701 from 1994 discloses a method for the cremation of human bodies. The method using weighing of the human remains prior and during the cremation process to control the heating curve of the furnace based on weight loss. The initial temperature is set in a range of approximately 500°C and this is increased depending on the weight loss and the gases escaping from the furnace.

US 5 886 326 A1 from 1996 discloses a method of incinerating garbage by preliminary microwave irradiation in vacuum, subsequent introduction of oxygen and continued irradiation to cause combustion. The method uses a silicon carbide shroud surrounding the garbage to be incinerated, that is heated to a temperature of 500 to 1000 °C by absorption of microwave energy to ignite the material to be disposed of.

EP1212569 from 2000 discloses a process for the treatment of carbon containing material, such as coffins with bodies by irradiation with microwaves in an oxygen depleted atmosphere, followed by the introduction of oxygen or air, a combustible gas and igniting said mixture.

There is a need for a cremation process that is environmental friendly and safe, energy efficient, and that does not require the use of fossil fuel.

SUMMARY

It is an object of the present invention to provide an improved method for combustion of a biological material.

It is a further object of the present invention to provide a method for combustion of a biological material that is environmental friendly.

It is a further object of the present invention to provide a method for combustion of a biological material and/or a cremation process that is energy efficient.

It is a further object of the present invention to provide a method for combustion of a biological material and/or a cremation process that does not require the use of fossil fuel.

The invention relates in a first aspect to a method for combustion of a biological material by means of microwave radiation, said method comprising the steps of:

i) providing said biological material to be combusted, a microwave absorbing susceptor and an apparatus comprising a chamber and a source of microwave radiation, preferably in such a manner that said biological material and said susceptor are present in said chamber such that said biological material at least partly occludes said susceptor from microwave radiation;

wherein the biological material includes a human or animal body or body part, and optionally a containerand

ii) directing microwave radiation from said source of microwave radiation to said biological material and said susceptor to combust said biological material.

The invention relates in a second aspect to a process for cremating a human or animal body or body part comprising the method of the first aspect.

The microwave absorbing susceptor in the first or second aspect may comprise a susceptor material; preferably wherein said susceptor material is silicon carbide.

The microwave absorbing susceptor in the first or second aspect may be in the form of tiles.

The source of microwave radiation in the first or second aspect may be connected to at least one waveguide.

The microwave radiation in the first or second aspect may be directed from said source of microwave radiation to said biological material is of a single frequency.

The microwave radiation in the first or second aspect may have a frequency between 1 MHz and 3 GHz. The microwave radiation in the first or second aspect may have a frequency between 100 MHz and 3 GHz. The microwave radiation in the first or second aspect may have a frequency between 500 MHz and 1.5 GHz. The microwave radiation in the first or second aspect may have a frequency between 700 MHz and 1.1 GHz.

The method and the process may comprising in step ii) a two-phase combustion process, wherein in a first phase of said combustion process said radiation heats said biological material to evaporate water from the biological material and obtain a dried biological material, and wherein in a second phase of said combustion process said radiation heats the microwave absorbing susceptor to an ignition temperature, to combust said dried biological material and obtain combusted biological material.

The microwave radiation in the first or second aspect may be applied from the beginning of step ii) at least until the point of ignition of said biological material.

The method or process may take place under atmospheric pressure. The method or process will preferably take place in the presence of oxygen, preferably air.

The method or process may include the step of determining the starting weight of the biological material to determine the energy level of the microwave radiation. The method or process may include the step of determining the starting weight of the biological material to determine the duration for direction of microwave radiation. The method or process may include the step of determining the starting weight of the biological material to determine the energy level of the microwave radiation and the duration for direction of microwave radiation.

The biological material according to the first or second aspect may include a human body or one or more body parts. The biological material according to the first or second aspect may include an animal body or one or more body parts. The biological material according to the first or second aspect may include a human body or one or more body parts and a container. The biological material according to the first or second aspect may include an animal body or one or more body parts and a container.

LIST OF DEFINITIONS

The following definitions are used in the present description and claims to define the stated subject matter. Other terms not cited below are meant to have the generally accepted meaning in the field.

“Combustion” as used in the present description means: a high-temperature exothermic redox chemical reaction between a fuel (the reductant), being the biological material, and an oxidant, usually oxygen, e.g. from air (atmospheric oxygen), that produces oxidised, often gaseous products, in a mixture termed as smoke as well as a solid residue.

“Spontaneous combustion” as used in the present description means: a type of combustion which occurs by self-heating (increase in temperature due to exothermic internal reactions), followed by thermal runaway (self-heating which rapidly accelerates to high temperatures) and finally, ignition.

“Ignition temperature” as used in the present description means: the lowest temperature at which the biological material starts combustion.

“Pyrolysis” as used in the present description means: the thermal decomposition of materials at elevated temperatures in an inert atmosphere (e.g. an oxygen depleted atmosphere). This inert atmosphere may be vacuum. Pyrolysis involves a change of chemical composition but is not an oxidation reaction.

“Microwaves” as used in the present description means: a form of electromagnetic radiation with wavelengths ranging from about one meter to one millimeter; with frequencies between 300 MHz (1 m) and 300 GHz (1 mm).

“Drying” as used in the present description means: reducing the water content of the biological material. For human bodies, the water content is generally at least 50% of the total weight. The water content varies with age, sex, length and weight, and the Watson formula may be used to estimate the water content:

Men: 2.447 – (0.09145 x age) + (0.1074 x height in centimetres) + (0.3362 x weight in kilograms) = total body water (TBW) in liters

Women: –2.097 + (0.1069 x height in centimetres) + (0.2466 x weight in kilograms) = total body water (TBW) in litres

Because of these variations, the reduction in water content achieved during drying, as well as the water content after drying will vary as well.

“Waveguides” as used in the present description means: a structure that guides waves, such as electromagnetic waves, with minimal loss of energy by restricting the transmission of energy to one direction. Without the physical constraint of a waveguide, wave amplitudes decrease according to the inverse square law as they expand into three dimensional space. There are different types of waveguides for different types of waves. The original and most common meaning is a hollow conductive metal pipe used to carry high frequency radio waves, particularly microwaves.

"Susceptor" as used in the present description means: a material used for its ability to absorb electromagnetic energy and convert it to heat. Suitable susceptor materials include silicon carbide, graphite, metal oxides such as zirconium dioxide or magnetite, ferrite, and conductive metals (on glass or ceramic plates). A ferrite is a ceramic material made by mixing and firing large proportions of iron(III) oxide (Fe_2O_3, rust) blended with small proportions of one or more additional metallic elements, such as barium, manganese, nickel, and zinc.

"Silicon carbide" as used in the present description means: a semiconductor containing silicon and carbon. Silicon carbide (SiC) is also known as carborundum. Silicon carbide exists in about 250 crystalline forms. The major polytypes are 3C (β), 4H, and 6H (α).

BRIEF DESCRIPTION OF DRAWINGS

The present invention is described hereinafter with reference to the accompanying drawings in which embodiments of the present invention are shown and in which like reference numbers indicate the same or similar elements.

Figure 1 is a schematic view of a chamber 1 with four waveguides 2. In the chamber biological material 3 is present in the form of a human body. The biological material is resting on a microwave absorbing susceptor 4, which is present in the shape of a tile – as indicated by the sub-figure of the tile in close-up.

Figure 2 shows the temperature evolution in a meat sample placed undergoing microwave radiation.

DESCRIPTION OF INVENTION AND EMBODIMENTS

The invention relates to a method for combustion of a biological material by means of microwave radiation. In a first aspect, the method comprises two steps. In a first step the method comprises providing: a) a biological material to be combusted; b) a microwave absorbing susceptor; and c) an apparatus comprising a chamber and a source of microwave radiation. The biological material and the susceptor should be provided in such a manner that they are both present inside the chamber of said apparatus. The biological material and the susceptor are provided in such a manner that the biological material at least partly occludes said susceptor from said radiation. In that case, the susceptor is at least partly blocked from direct irradiation by the presence of the biological material which is in the line of sight between the susceptor and the source of microwave radiation. In a second step of the method, microwave radiation is directed from the source of microwave radiation to the biological material and the, optionally at least partly occluded, susceptor to combust said biological material.

The method according to the present invention may comprise in step ii) a two-phase process comprising as a first phase the evaporation of water from said biological material to a (partially) dried biological material, and as a second phase the ignition of said (partly) dried biological material. Both phases take place in the same chamber. Hence, the chamber can –according to this two-phase system - be seen as a dual action chamber: a first action being heating to reach a drying temperature for the biological material to release water, i.e. to at least partially dry the biological material, and a second action being heating of the microwave adsorbing susceptor to reach an ignition temperature to achieve combustion of the (partially) dried biologically material.

The biological material has a higher level of interaction with the microwave radiation than the partly dried biological material. As the biological material releases water due to microwave radiation, its dielectric properties change and its molecules are less polarisable. This means that as the biological material releases water due to the microwave radiation, it becomes more transparent to the microwave radiation.

The biological material at least partly occludes the microwave absorbing susceptor by being present between the susceptor and said source of microwave radiation by the opaque nature of said biological material. A non-limiting example thereof is that human remains that are positioned on a plurality of tiles of the susceptor which are e.g. located on a tray resting on the base/bottom of the chamber whereas the source of microwave radiation is located near the top/ceiling or at the sides of said chamber.

The opaque nature of said biological material is related to the water content thereof: as the water content decreases (due to drying) the opaque level decreases and the transparency to microwave radiation increases, thereby decreasing the occlusion, or attenuation, of the directed energy. As the water content of the biological material decreases, more microwave radiation is able to penetrate the body in order to reach the susceptor that is present underneath. The occlusion is gradually decreased during a first phase of drying said biological material. During this first phase the main effect of said microwave radiation is heating said biological material (since the susceptor is hardly reached by the radiation because it is at least partly occluded by said biological material). During a second phase the main effects of said microwave radiation are irradiating said susceptor and said partly dried biological material (since the susceptor is now reached by the radiation because it is less occluded by said biological material; however since the biological material is still present, that is also still irradiated). These first and second phases overlap as the opaque level gradually decreases during the drying. This means that the irradiation of the susceptor will increase proportionally with the drying of the biological material.

The effect of irradiating said biological material with microwave radiation is heating of said biological material; leading first to evaporation of at least part of the water of said biological material (called volumetric heating) and then to thermal decomposition of said biological material providing flammable gasses.

The effect of irradiating said susceptor with microwave radiation is that the susceptor absorb this radiation energy and convert it to heat which is re-emitted as thermal radiation; this radiation provides thermal decomposition of said biological material providing flammable gasses and in addition provides a sufficiently high temperature to ignite said flammable gasses leading to combustion. The mere irradiation of biological material without the presence of a susceptor may lead to ignition; but the present inventors have observed that the susceptor helps in achieving that effect in a shorter time span and with a decreased energy consumption.In the embodiment where the susceptor is at least partly occluded from microwave radiation, the susceptor is not activated (fully) until at least part of the water has evaporated thereby avoiding a too high a temperature too early in the process, leading to heat-scorching of the biological material and thereby preventing evaporation of water.

According to the invention, drying and combustion of the biological material take place in the same chamber as a consequence of directing microwave radiation to the biological material and at least partly to the susceptor. The chamber may be closed. Since the method according to the present invention can take place under atmospheric pressure, there is no need for a complete air-tight seal of the chamber. However, the chamber may be sealed air-tight.

In an embodiment, the source of microwave radiation is a single magnetron. In an embodiment, the source of microwave radiation comprises multiple magnetrons.

In general, the temperature to dry the biological material may be below 200°C, preferably between 100 and 150 °C. This is to avoid (skin) scorching. In general, the biological material will combust when an ignition temperature of between 400 and 500°C is reached, preferably between 440 and 460 °C, such as 450 °C.

In the present invention, no preheating of the chamber or the biological material is necessary, the combustion process of the present invention can start from room temperature (20-25°C). If the temperature in the chamber is above room temperature but below the drying temperature of 200°C, for instance from a recent use of the chamber, there is no need to cool the chamber prior to the combustion process of the present invention. The biological material may have been cooled prior to the combustion process. There is no need for the biological material to be heated until room temperature before initiating the combustion process of the present invention.

In an embodiment, the microwave absorbing susceptor comprises a susceptor material. Suitable susceptor materials include silicon carbide, graphite, metal oxides such as zirconium dioxide or magnetite, ferrite, and conductive metals (on glass or ceramic plates). In a preferred embodiment, the susceptor material is silicon carbide.

In an embodiment, the microwave absorbing susceptor is in the form of tiles or powder. The susceptor may expand upon heating. Hence, when the susceptor is in the form of tiles, it is preferable that the tiles are not fixed in their location, but that each tile has room to expand upon being heated.

The susceptor may be present in the chamber before introduction of the biological material, or the susceptor may be introduced into the chamber simultaneously with the biological material, or the susceptor may be introduced into the chamber after introduction of the biological material. Preferably, the susceptor is present in the chamber before introduction of the biological material, or introduced into the chamber simultaneously with the biological material.

The standard procedure for cremation is often as follows. The biological material (e.g. coffin with human or animal remains) is introduced into the chamber manually or by a mechanical pusher. After combustion of the biological material, the combusted biological material after combustion (ashes, burned bone fragments etc.) is removed from the oven chamber and transported to another room for further handling thereof (e.g. cooling and reduction in particle size of the combusted biological material and packaging thereof (“ashes”)). The combusted biological material, is also referred to as “cremains” or “ashes”. It is not actual ash but unburnt fragments of bone mineral, which are commonly ground down into powder in a cremulator. The terms “cremains” and “ash” may refer to the combusted biological material as well as to the cremulated combusted biological material. The product obtained from the method and process according the present invention are cremains or ashes.

According to the present invention, the biological material (e.g. coffin with human or animal remains) may be placed on top a tray, for instance a metal tray, outside of the oven chamber, after which the tray is introduced into the chamber.The susceptor may be present on the tray beneath the biological material or may be provided within a container for holding the biological material, positioned below said material, e.g. within the base of a coffin. After combustion of the biological material, the tray including the combusted biological material after combustion may be removed from the oven chamber and transported to another room for further handling thereof. The trays are then cleaned and ready for use again. Several trays are in use simultaneous for a single cremator oven.

In an embodiment, the source of microwave radiation is connected to at least one waveguide. Waveguides direct the microwaves towards to the biological material and the susceptor. This assures that the reflection of microwaves back to the microwave source is minimalised. In a preferred embodiment, the source of microwave radiation is connected to a number of waveguide which allows the maximum energy absorption and limits the reflection to the minimum. For example, the source of microwave radiation is connected to one to six waveguides. For instance, the source of microwave radiation may be connected to one, two, three, four, five or six waveguides. Preferably it is connected to four waveguides. These waveguides can be directed to different parts of the biological material, e.g. when the biological material is a human body or large animal the waveguides can be directed to the head, chest and legs, for instance with two of the waveguides directed to the chest, one to the head and one to the legs in case of a human body or to the head, chest/front legs and back side/back legs in case of a large animal (e.g. horse or large dog). In case the body is small (e.g. an infant body or a small animal, such as a cat or small dog), it is preferred to use only two waveguides. Each of the wave guides present in the apparatus may be individually switched off and on as needed.

The geometry of a waveguide reflects its function. The frequency of the transmitted wave also dictates the size of a waveguide: each waveguide has a cutoff wavelength determined by its size and will not conduct waves of greater wavelength. The waveguides should thus be selected or modified based on the applied frequency / wavelength of microwaves by the source of microwave radiation.

The microwave absorbing susceptor may be in line-of-sight with the source of microwave radiation or the waveguides, such that the biological material partially occludes energy from reaching the susceptor.

A (microwave) stirrer may be present in the chamber. The stirrer distributes the (reflections of the) microwave radiation more homogeneously throughout the chamber. Although likely full homogeneity cannot be expected, the stirrer may help to avoid certain 'hot spots' of microwave radiation (reflections). The presence of such a stirrer will ensure a more even (uniform) heating of the biological material.

In an embodiment, the microwave radiation directed from the source of microwave radiation to the biological material is of a single frequency. This means that – in this embodiment - during the time that the source of microwave radiation is active, the frequency of the radiation remains the same; the frequency is not changed during the time of application of the radiation.

In an embodiment, the microwave radiation has a frequency between 1 MHz and 3 GHz, such as between 100 MHz and 3 GHz, more in particular between 500 MHz and 1.5 GHz. In a preferred embodiment, the microwave radiation has a frequency between 700 MHz and 1.1 GHz, such as 915 MHz. A longer wavelength (corresponding to a lower frequency) allows for a higher level of penetration of the radiation into the biological material. The microwave frequencies used in microwave ovens are chosen based on regulatory and cost constraints. One regulatory constraint is that they should be in one of the industrial, scientific, and medical (ISM) frequency bands set aside for unlicensed purposes. Consumer microwave ovens work around a nominal 2.45 GHz, corresponding to a wavelength of 12.2 cm, in the 2.4 GHz to 2.5 GHz ISM band, while large industrial/commercial ovens often use 915 MHz, corresponding to a wavelength of 32.8 cm.

In an embodiment, the method comprises in step ii) a two-phase combustion process, wherein in a first phase of said combustion process said radiation heats said biological material to evaporate water from the biological material and obtain a dried biological material, and wherein in a second phase of said combustion process said radiation heats the microwave absorbing susceptor to an ignition temperature, to combust said dried biological material and obtain combusted biological material. In this embodiment, the two phases may overlap. In an embodiment, in the first phase the heating takes place at a drying temperature (or until such a drying temperature is reached which is then maintained). In an embodiment, in the second phase the heating takes place at an ignition temperature (or until such an ignition temperature is reached). In a specific embodiment the power of the source of microwave radiation is between 10 and 30 kW in the first phase of step ii) of the method according to the invention. In another specific embodiment, that may be combined with the above specific embodiment, the power of the source of microwave radiation is between 30 and 100 kW in the second phase of step ii) of the method according to the invention. The increase of power between the first and the second phase may be gradually or may be at once.

In an embodiment, the microwave radiation is applied from (source of microwave radiation turned on at) the beginning of step ii) and are applied at least until the point of ignition (at which point the source of microwave radiation is turned off). The microwave radiation may be applied non-intermittently (in other words, constantly) from the beginning of the first phase at least until the point of ignition. The microwave radiation may however also be applied until combustion is complete, however this is not necessary. Combustion is an exothermic reaction, and while sufficient energy is required to overcome the so-called activation energy for combustion in order to initiate combustion, the heat produced by the combustion reaction itself will provide enough energy to make the reaction self-sustaining.

A significant high temperature (ignition temperature) is required to start combustion. Combustion can also be initiated by the use of a spark to ignite the flammable gasses. However, by use of the microwave absorbing susceptor according to the present invention a temperature can be reached that is above the ignition point of the flammable gasses produced during thermal decomposition of the biological material. By use of the susceptor according to the invention, a temperature of between 400 and 500°C can be reached, which is sufficient to ignite the flammable gasses.

In an embodiment, the method according to the present invention takes place under atmospheric pressure (atm), defined as 101,325 Pa.

In an embodiment, the method according to the present invention takes place in the presence of oxygen. This may be atmospheric oxygen, i.e. the method may take place in the presence of air, which comprises oxygen. The amount of oxygen in air is approximately 21 vol.%. The method of the present invention does not require a vacuum or an inert (oxygen free) atmosphere. This is difference from pyrolysis, since pyrolysis requires an inert atmosphere. The product obtained is different with combustion versus pyrolysis since the chemical reaction is different.

In an embodiment, the combustion process of the invention includes a step of determining the starting weight of the biological material to determine the energy level of the microwave radiation and/or the duration for direction of microwave radiation. The weight of the biological material may be for instance determined by the use of scales, or calculations based on estimated or measured volume of the biological material. The weight of a container (e.g. coffin) may be included in the determined weight of the biological material. It may also be possible to subtract the weight of the container (which may be known from e.g. a catalogue) from the measured weight of the container including the biological material to determine the weight of the biological material without the container.

In general, a cremation process includes a step of cooling the combusted biological material, for instance to room temperature (20-25°C). This cooling may be active or passive cooling. The cremation process may also include a step of collecting the combusted biological material. The collected combusted biological material may be transferred to a grinder, called cremulator, where it is powdered into a fine grey-white material, ashes. The ashes may then be collected e.g. into an urn.

The microwave absorbing susceptor does not combust during the combustion process of the invention. If the susceptor is in the form of powder, the susceptor may be collected together with the combusted biological material. The susceptor may thus also be present together with the ashes, e.g. in an urn. In case the susceptor is in the form of tiles or other shapes, the combusted biological material may be separated from the susceptor prior to grinding and transfer of the ashes e.g. into an urn. The susceptor can be reused.

In an embodiment, the biological material includes a human or animal body or body part, and optionally a container. With “human or animal body or body part” is meant a (deceased) human body, an animal body, one or more human body parts, or one or more animal body parts. The container is preferably selected from the group consisting of a coffin, a casket, a basket, a shroud. More preferably, the container is a coffin.

The container must be at least partially transparent to microwave radiation. The container may be a conventional coffin, as long as it allows microwave radiation to enter the container, and water vapour to exit the container.

In an embodiment, the container comprises the microwave absorbing susceptor, preferably below the biological material.

In an embodiment, the biological material is resided on a tray. The biological material may be in a container, which container then is resided on the tray.

In an embodiment, the chamber has a base, wherein – during use – there is a spacing in between the biological material and the base of the chamber to avoid electrical arcing. In case a tray is used, and the tray is in physical contact with the chamber floor (i.e. electrically neutral with the chamber floor), the spacing in this embodiment is between the biological material and the tray. The arcing phenomena can cause unwanted thermal runaway inside the chamber, leading to disruption and malfunctioning of the system. To avoid arcing it is required that the field strength (300 kV/m) needed for arcing will not be reached all along the arcing path. Arcing can occur when the spacing is very small, e.g. between 8 mm and 3 cm.The preferred spacing depends on the system, but it may be for instancepreferably at least 3 cm, more preferably at least 5 cm. In a specific embodiment, the microwave absorbing susceptor is present in the spacing between the biological material and the base of the chamber. This spacing may for example be realised by a false floor (adding a bottom compartment) in the container to raise the biological material within said container from the base of the chamber. The susceptor may for example be present in a bottom compartment of the container. For instance, the container (e.g. a coffin) may have a double bottom dividing the container in two compartments, where the susceptor is present in the bottom compartment and the biological material is present in the top compartment.

In an embodiment, there is a thermal insulation provided between the tray and the susceptor. This serves to protect the tray from conduction heating. This thermal insulation may be from a ceramic material with thermal insulation properties. in the form of a tile, e.g. of silicon nitride.

Upon heating, the biological material produces gaseous products due to thermal decomposition. Any gasses that leave the chamber may be analyzed, e.g. for oxygen, e.g. at the outlet of the chamber, and/or they may be trapped by chemical reaction or physical transformation.

The present invention relates in a specific embodiment to a method for combustion of a biological material which includes a human or animal body or body part, and optionally a container, by means of microwave radiation, said method comprising the steps of:

i) providing said biological material to be combusted, a microwave absorbing susceptor and an apparatus comprising a chamber and a source of microwave radiation, in such a manner that said biological material and said susceptor are present in said chamber such that said biological material at least partly occludes said susceptor from microwave radiation; and

ii) directing microwave radiation having a frequency between 1 MHz and 3 GHz from said source of microwave radiation to said biological material and said at least partly occluded susceptor in a two-phase combustion process in the presence of oxygen, wherein in a first phase of said combustion process said radiation heats said biological material to a drying temperature of below 200 °C to evaporate water from the biological material and obtain a dried biological material, and wherein in a second phase of said combustion process said radiation heats the microwave absorbing susceptor to an ignition temperature of between 400 and 500° C, to combust said dried biological material and obtain combusted biological material.

The present invention relates in a specific embodiment to a method for combustion of a biological material which includes a human or animal body or body part, and optionally a container, by means of microwave radiation, said method comprising the steps of:

i) providing said biological material to be combusted, a microwave absorbing susceptor and an apparatus comprising a chamber and a source of microwave radiation, in such a manner that said biological material and said susceptor are present in said chamber such that said biological material at least partly occludes said susceptor from microwave radiation; and

ii) directing microwave radiation having a frequency between 1 MHz and 3 GHz from said source of microwave radiation to said biological material and said at least partly occluded susceptor in a two-phase combustion process in the presence of oxygen, wherein in a first phase of said combustion process said radiation heats said biological material to a drying temperature to evaporate water from the biological material and obtain a dried biological material, and wherein in a second phase of said combustion process said radiation heats the microwave absorbing susceptor to an ignition temperature, to combust said dried biological material and obtain combusted biological material.

Other variations to the disclosed embodiments can be understood and effected by those skilled in the art in practicing the claimed invention, from a study of the drawings, the disclosure, and the appended claims. In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. A single processor or other unit may fulfil the functions of several items recited in the claims. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measured cannot be used to advantage. Any reference signs in the claims should not be construed as limiting the scope thereof.

The scope of the present invention is defined by the appended claims. One or more of the objects of the invention are achieved by the appended claims.

EXAMPLE

The present invention is further elucidated based on the Example below which is illustrative only and not considered limiting to the present invention.

The experiments for this example were conducted in a small-scale microwave (maximum power input 1.8 kW) on samples of pork meat. The example shows the temperature evolution of a pork meat sample when subjected to microwave radiation. Figure 2 shows the results. The temperature was measured using a thermocouple. The thick line in **Fout! Verwijzingsbron niet gevonden.** shows the temperature evolution of the meat when the thermocouple is placed inside the meat sample (approximately in the centre of the sample).

It was observed that after 1 minute the temperature in the centre reached 100°C and the surface water evaporated. The chamber was full of vapour and the meat was well-cooked. The temperature remained constant for 3 minutes and 30 seconds before starting to increase again to allow vaporisation.

After approximately 2 minutes the sample centre reaches 120°C. It was not possible to evaporate all the water at 100°C and higher temperature and a longer timeframe were required. Without wishing to be bound by theory, the inventors believe that this is due to the high-water content, the limited diffusivity in the meat pores and the lockage due to scorching.

After 5 minutes the centre of the meat reached approximately 150°C. The meat looked well cooked and the temperature remained constant for 3 minutes.

After 8 minutes the sample reached 200°C and the meat started to melt in a dense and viscous black liquid. The complex molecules of the meat, for instance the amino acids, started to decompose in less complex compounds.

After approximately 15 minutes the sample reached 300°C and continued the melting phase, but it was not fully carbonized.

By increasing the temperature and the experimental time, it was possible to observe ignition at approximately 400°C (not shown Figure 2). The combustion afterwards was sustained by the high calorific value of the fats present.

CONCLUSIES

1. Werkwijze voor het verbranden van biologisch material door middel van microgolfstraling, waarbij de werkwijze de stappen omvat van:

i) het verschaffen van een te verbranden biologisch materiaal, een microgolf-absorberende susceptor en een inrichting omvattende een kamer en een bron van microgolfstraling;

waarbij het biologische materiaal een menselijk of dierlijk lichaam of lichaamsdeel omvat en optioneel een container;

waarbij in stap i) het biologische materiaal en de susceptor aanwezig zijn in de kamer op een zodanige wijze dat het biologische materiaal de susceptor ten minste gedeeltelijk occludeert van microgolfstraling; en

ii) het richten van microgolfstraling met een kracht van tussen 10 kW en 100 kW vanaf de bron van microgolfstraling naar het biologische materiaal en de susceptor om het biologische materiaal te verbranden.

2. Werkwijze volgens een of meer van de voorafgaande conclusies, waarbij de microgolf absorberende susceptor een susceptormateriaal omvat; bij voorkeur waarbij het susceptormateriaal siliciumcarbide is.

3. Werkwijze volgens een of meer van de voorafgaande conclusies, waarbij de microgolf-absorberende susceptor in de vorm van tegels is.

4. Werkwijze volgens een of meer van de voorafgaande conclusies, waarbij de bron van microgolfstraling is verbonden aan ten minste een golfgeleider gericht naar het biologische materiaal.

5. Werkwijze volgens een of meer van de voorafgaande conclusies, waarbij de microgolfstraling gericht vanaf de bron van microgolfstraling naar het biologische materiaal van een enkele frequentie is.

6. Werkwijze volgens een of meer van de voorafgaande conclusies, waarbij de microgolfstraling een frequentie heeft van tussen 1 MHz en 3 GHz, bij voorkeur tussen 100 MHz en 3 GHz, meer bij voorkeur tussen 500 MHz en 1.5 GHz, met name tussen 700 MHz en 1.1 GHz.

7. Werkwijze volgens een of meer van de voorafgaande conclusies, waarbij de werkwijze in stap ii) een verbrandingsproces in twee stadia omvat, waarbij in een eerste stadium van het verbrandingsproces de straling het biologische materiaal

verwarmt totdat water verdampt uit het biologische materiaal en een gedroogd biologische materiaal wordt verkregen, en waarbij in een tweede stadium van het verbrandingsproces de straling de microgolf-absorberende susceptor verhit tot een ontbrandingstemperatuur, om het gedroogde biologische materiaal te verbranden en verbrand biologische materiaal te verkrijgen.

8. Werkwijze volgens een of meer van de voorafgaande conclusies, waarbij de microgolfstraling wordt toegepast vanaf het begin van stap ii) ten minste tot het ontbrandingspunt van het biologische materiaal.

9. Werkwijze volgens een of meer van de voorafgaande conclusies, waarbij de werkwijze onder atmosferische druk plaats heeft.

10. Werkwijze volgens een of meer van de voorafgaande conclusies, waarbij de werkwijze onder aanwezigheid van zuurstof, bij voorkeur lucht, plaatsvindt.

11. Werkwijze volgens een of meer van de voorafgaande conclusies, omvattende een stap van het bepalen van het uitgangsgewicht van het biologische materiaal om het energieniveau te bepalen van de microgolfstraling en/of de duur van het richten van de microgolfstraling.

12. Werkwijze voor het verbranding van een biologisch materiaal volgens een of meer van de voorafgaande conclusies waarbij het biologische materiaal een menselijk of dierlijk lichaam of lichaamsdeel omvat, en optioneel een container, door middel van microgolfstraling, waarbij de werkwijze de stappen omvat van:

i) het verschaffen van het te verbranden biologische materiaal, een microgolf-absorberende susceptor en een inrichting omvattende een kamer en een bron van microgolfstraling; op een zodanige wijze dat zowel het biologische materiaal als de suscepter aanwezig zijn in de kamer zodadig dat het biologische materiaal de susceptor ten minste gedeeltelijk occludeert van microgolfstraling; en

ii) het richten van microgolfstraling met een frequentie tussen 1 MHz en 3 GHz vanaf de bron van microgolfstraling naar het biologische materiaal en de ten minste gedeeltelijk geoccludeerde susceptor in een verbrandingsproces in twee stadia in aanwezigheid van zuurstof, waarbij in een eerste stadium van het verbrandingsproces de straling het biologische materiaal wordt verwarmd tot een droogtemperatuur van minder dan 200 °C om water te verdampen uit het biologische materiaal en een gedroogd biologisch materiaal te verkrijgen, en waarbij in een tweede stadium van het verbrandingsproces de straling de microgolf-absorberende susceptor verhit tot een ontbrandingstemperatuur van tussen 400 en 500° C, om het gedroogde biologische materiaal te verbranden en verbrand biologisch materiaal te verkrijgen.

13. Proces voor het cremeren van een menselijk of dierlijk lichaam of lichaasdeel omvattende de werkwijze volgens een of meer van de voorafgaande conclusies.

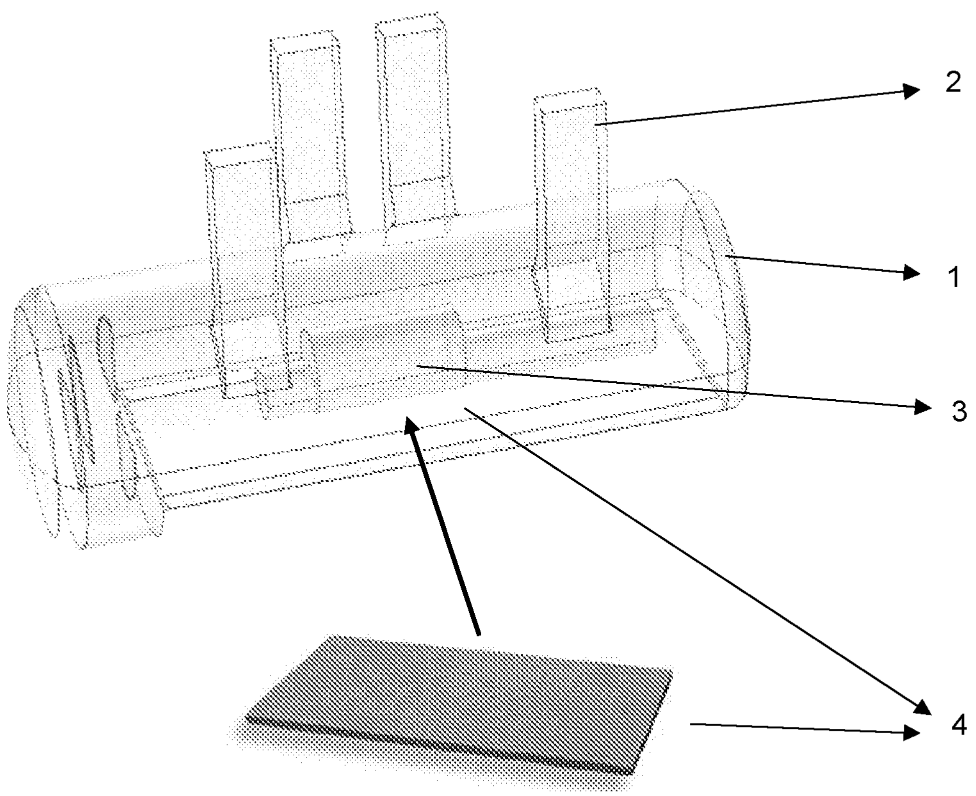
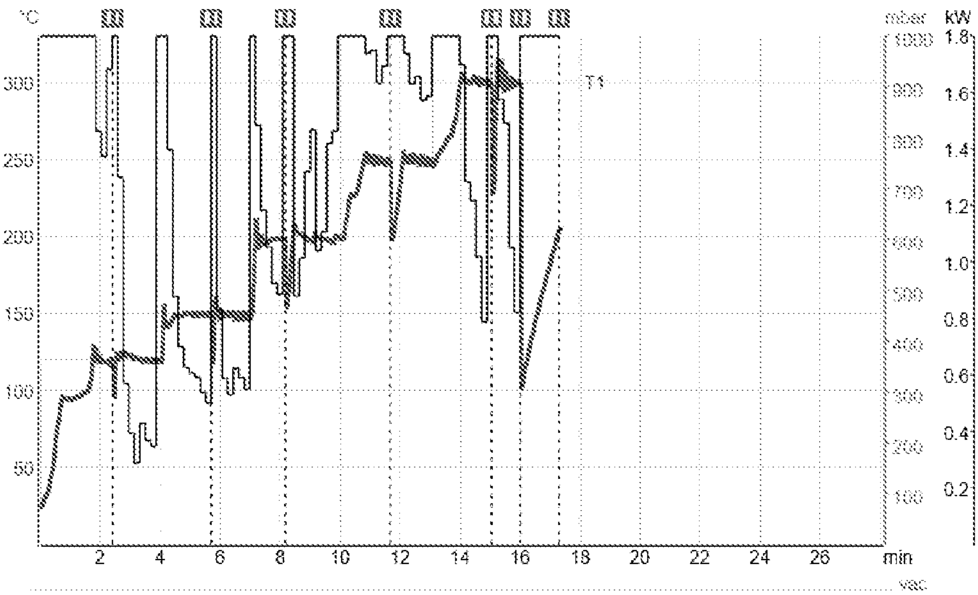


Fig. 1



°C
mbar
kW
T1
300
250
200
150
100
50
1000
900
800
700
600
500
400
300
200
100
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
2
4
6
8
10
12
14
16
18
20
22
24
26
min
vac

Fig. 2

Rijksdienst voor Ondernemend Nederland

RAPPORT BETREFFENDE HET ONDERZOEK NAAR DE STAND VAN DE TECHNIEK

Octrooiaanvrage 2026692

Classificatie van het onderwerp[1]: F23G1/00	Onderzochte gebieden van de techniek[1]: F23G
Computerbestanden: EPODOC, WPI	Omvang van het onderzoek: Volledig
Datum van de onderzochte conclusies: 13 november 2020	Niet onderzochte conclusies: -

Van belang zijnde literatuur

Categorie[2]	**Vermelding van literatuur met aanduiding, voor zover nodig, van speciaal van belang zijnde tekstgedeelten of figuren**	**Van belang voor conclusie(s)**
X, D	US 5886326 A (THERMOTREX CORP) 23 maart 1999 * zie gehele document * – – –	1, 3, 5-9, 11-13, 15
X	KR 101381245 B (PKF CO LTD) 4 april 2014 & machinevertaling [online], [opgehaald op 17 september 2021] via <http://www.espacenet.com> * zie figuur 11; machinevertaling * – – –	1, 3, 5-9, 11-13, 15
X	JP H01-123911 A (CHUBU ELECTRIC POWER) 16 mei 1989 & machinevertaling [online], [opgehaald op 17 september 2021] via <http://www.espacenet.com> * zie figuur 1 en machinevertaling * – – –	1-12
X	JP H01-142312 A (MATSUSHITA ELECTRIC IND CO LTD) 5 juni 1989 & machinevertaling [online], [opgehaald op 17 september 2021] via <http://www.espacenet.com> * zie figuur 1 en machinevertaling * – – –	1-12
A	CN 110285426 A (UNIV DONGGUAN TECHNOLOGY) 27 september 2019 & machinevertaling [online], [opgehaald op 17 september 2021] via <http://www.espacenet.com> * zie figuur 2; machinevertaling * – – – – –	1-15

Datum waarop het onderzoek werd voltooid: 17 september 2021	De bevoegde ambtenaar: mr.dr.ir. J.W. Meewisse **Octrooicentrum Nederland** **onderdeel van Rijksdienst voor Ondernemend Nederland**

1, 2 Zie toelichting volgend blad.

Toelichting:

[1] Classificatie gebieden van de techniek:
gedefinieerd volgens International Patent Classification (IPC).

[2] Categorie van de vermelde literatuur:

X: op zichzelf van bijzonder belang zijnde stand van de techniek

Y: in samenhang met andere geciteerde literatuur van bijzonder belang zijnde stand van de techniek

A: niet tot de categorie X of Y behorende van belang zijnde stand van de techniek

O: verwijzend naar niet op schrift gestelde stand van de techniek

P: literatuur gepubliceerd tussen voorrangs- en indieningsdatum

T: niet tijdig gepubliceerde literatuur over theorie of principe ten grondslag liggend aan de uitvinding

E: octrooiliteratuur gepubliceerd op of na de indieningsdatum van de onderhavige aanvrage en waarvan de indieningsdatum of de voorrangsdatum ligt voor de indieningsdatum van de onderhavige aanvrage

D: in de aanvrage genoemd

L: om andere redenen vermelde literatuur

&: lid van dezelfde octrooifamilie; corresponderende literatuur

Rijksdienst voor Ondernemend
Nederland

AANHANGSEL

Behorende bij het Rapport betreffende het Onderzoek naar de Stand van de Techniek

Octrooiaanvrage 2026692

Het aanhangsel bevat een opgave van elders gepubliceerde octrooiaanvragen of octrooien (zogenaamde leden van dezelfde octrooifamilie), die overeenkomen met octrooigeschriften genoemd in het rapport. De opgave is samengesteld aan de hand van gegevens uit het computerbestand van het Europees Octrooibureau per 16 september 2021. De juistheid en volledigheid van deze opgave wordt noch door het Europees Octrooibureau, noch door Octrooicentrum Nederland gegarandeerd; de gegevens worden verstrekt voor informatiedoeleinden.

In het rapport genoemd octrooigeschrift		Datum van publicatie	Overeenkomende octrooigeschriften		Datum van publicatie
US 5886326	A	23-03-1999	(geen)		
KR 101381245	B1	04-04-2014	(geen)		
JP H01123911	A	16-05-1989	JP 2624267	B2	25-06-1997
CN 110285426	A	27-09-2019	(geen)		
JP H01142312	A	05-06-1989	JP H0523326	B2	02-04-1993

Rijksdienst voor Ondernemend
Nederland

SCHRIFTELIJKE OPINIE

Octrooiaanvrage 2026692

Indieningsdatum: 16 oktober 2020	Voorrangsdatum:
Classificatie van het onderwerp [1]: F23G1/00	Aanvrager: Neo Joule B.V.

Deze schriftelijke opinie bevat een toelichting op de volgende onderdelen:

☒	Onderdeel I	Basis van de schriftelijke opinie
☐	Onderdeel II	Voorrang
☐	Onderdeel III	Vaststelling nieuwheid, inventiviteit en industriële toepasbaarheid niet mogelijk
☐	Onderdeel IV	De aanvrage heeft betrekking op meer dan één uitvinding
☒	Onderdeel V	Gemotiveerde verklaring ten aanzien van nieuwheid, inventiviteit en industriële toepasbaarheid
☐	Onderdeel VI	Andere geciteerde documenten
☐	Onderdeel VII	Overige gebreken
☐	Onderdeel VIII	Overige opmerkingen

De bevoegde ambtenaar:
mr.dr.ir. J.W. Meewisse

Octrooicentrum Nederland
onderdeel van Rijksdienst voor Ondernemend Nederland

1 Gedefinieerd volgens International Patent Classification (IPC).

Schriftelijke Opinie

Octrooiaanvrage 2026692

Onderdeel I	**Basis van de schriftelijke opinie**

Deze schriftelijke opinie is opgesteld op basis van de op 13 november 2020 ingediende conclusies.

Onderdeel V	**Gemotiveerde verklaring ten aanzien van nieuwheid, inventiviteit en industriële toepasbaarheid**

1. Verklaring

Nieuwheid	Ja: conclusie(s)	4, 14
	Nee: conclusie(s)	1-3, 5-13, 15
Inventiviteit	Ja: conclusie(s)	14
	Nee: conclusie(s)	4
Industriële toepasbaarheid	Ja: conclusie(s)	1-15
	Nee: conclusie(s)	-

2. Literatuur en toelichting

In het rapport betreffende het onderzoek naar de stand van de techniek worden de volgende publicaties genoemd:

D1: US 5886326 A (THERMOTREX CORP) 23 maart 1999
D2: KR 101381245 B (PKF CO LTD) 4 april 2014
D3: JP H01-123911 A (CHUBU ELECTRIC POWER) 16 mei 1989
D5: JP H01-142312 A (MATSUSHITA ELECTRIC IND CO LTD) 5 juni 1989
D4: CN 110285426 A (UNIV DONGGUAN TECHNOLOGY) 27 september 2019

D1

Uit document D1 is een werkwijze bekend voor het verbranden van biologisch materiaal (waaronder 'pets' en ook 'human cremation device', zie kolom 5, regels 53-56) door middel van microgolfstraling, zie o.a. het abstract. De werkwijze omvat de stappen van i) het verschaffen van een te verbranden biologisch materiaal ('garbage tray 8 with garbage 10', zie kolom 2, regel 23), een microgolf-absorberende susceptor ('shroud 6') en een inrichting omvattende een kamer en een bron van microgolfstraling ('Microwave generators 16A, 16B en 16C) en van ii) het richten van microgolfstraling vanaf de bron van microgolfstraling naar het biologische materiaal en de susceptor om het biologische materiaal te verbranden, zie kolom 2, vanaf regel 63 t/m kolom 3, regel 9.
Alle maatregelen van conclusies 1, 13 en 15 zijn daarmee bekend uit D1 en deze conclusies zijn niet nieuw.
Figuur 3 van D1 toont een andere configuratie van 'shroud 6'. Aangezien er drie bronnen van microgolfstraling zijn (16A, 16B en 16C) die vanaf drie zijden op het te verbranden materiaal gericht zijn, kan niet gesteld worden dat het biologisch materiaal in die configuratie de susceptor ten minste gedeeltelijk occludeert. Conclusie 2 is derhalve nieuw ten opzichte van D1. Om deze reden is ook conclusie 14 nieuw.
'Shroud 6' volgens D1 omvat silicium carbide, zie kolom 2, regel 22. Conclusie 3 is niet nieuw.

Schriftelijke Opinie

Octrooiaanvrage 2026692

De maatregel van conclusie 5 met betrekking tot een golfgeleider, is algemeen bekend en voor de hand liggend voor de gemiddelde vakman. Conclusie 5 is niet inventief.
D1 openbaart een enkele frequentie van 800 MHz, zie kolom 2, regel 37, waarmee conclusies 6 en 7 niet nieuw zijn.
De werkwijze volgens D1 omvat de stappen 'evaporation phase' en 'incineration phase', zie kolom 2. Conclusie 8 is niet nieuw.
Uit kolom 3, regels 9-11, blijkt dat de microgolfstraling wordt aangehouden tot na het begin van de verbranding, waarmee conclusie 9 niet nieuw is. Uit kolom 3, regels 4-8, volgt dat lucht wordt toegelaten voor de verbranding. Conclusie 11 is niet nieuw.
Conclusie 12 betreft een voor de hand liggende maatregel voor de gemiddelde vakman om de werkwijze adequaat te kunnen controleren. Deze conclusie is niet inventief.

D2
Uit document D2 is eveneens een werkwijze bekend voor het verbranden van biologisch materiaal, waaronder een dierlijk lichaam, zie de eerste alinea van de machinevertaling. Het materiaal wordt geplaatst in een houder van silicium carbide (820) en verhit door middel van bronnen van microgolfstraling (830) teneinde het biologische materiaal te verbranden. Hiermee zijn alle maatregelen van conclusies 1 en 3 bekend uit D2. Ook conclusies 13 en 15 zijn niet nieuw.
Het biologisch materiaal is in D2 reeds in een eerdere stap gedroogd, met microgolfbron 150, en wordt daarna gemalen en in houder 820 gebracht. Er is daarmee geen sprake van occluderen zoals bedoeld in conclusie 2. Ook conclusie 14 is daarmee nieuw. Wel is conclusie 8 daarmee bekend uit D2. Conclusies 5-7, 9, 11 en 12 worden niet inventief geacht ten opzichte van D2.

D3 en D4
Zowel document D3 als document D4 openbaart een werkwijze voor het verbranden van biologisch materiaal door middel van microgolfstraling. Dat het gaat om biologisch materiaal is impliciet bekend, omdat het gaat om huishoudelijk afval dat vocht bevat. In beide gevallen is sprake van een susceptor van siliciumcarbide die wordt geoccludeerd door het biologische materiaal. Zie D3, figuur 1, 'microwave absorbing heating element' en zie D4, figuur 1, 'radio wave absorber 4'. Conclusies 1 t/m 12 worden niet nieuw of althans niet inventief geacht ten opzichte van zowel D3 als D4.
D3 en D4 suggereren geen geschiktheid voor het verbranden van een menselijk of dierlijk lichaam. Voorts wordt het effect van de occlusie zoals toegelicht in de beschrijving van de aanvrage, zie blz. 7, regel 18 t/m blz. 8, regel 13, niet inzichtelijk gemaakt in D3 of D4. Een gemiddelde vakman die uitgaande van D1, een van de documenten D3 of D4 zou raadplegen, komt daarmee niet op een werkwijze volgens conclusie 14 van de aanvrage.

D5
Uit D5 is een werkwijze bekend voor het verbranden van afval met behulp van microgolfstraling en een susceptor van silicium carbide (17). De werkwijze wordt in twee stappen uitgevoerd, zie de laatste twee alinea's van de machinevertaling. D5 suggereert echter geen biologisch materiaal.