In-flow evaporator

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(54) **In-flow evaporator**

(57) An evaporator for continuously evaporating a flowing liquid, comprising:
- an outer casing;
- an inner casing;
- an EM wave generator;
- a liquid supply;
- a gas collector; and
- a fluid barrier, impenetrable for fluids and penetrable for EM waves, dividing the evaporator in an EM inlet portion which includes an EM wave inlet and a fluid portion which includes a liquid inlet and a gas outlet,

wherein in use:
- a flow path of the EM inlet portion comprises a gaseous medium,
- a flow path of the fluid portion comprises a running flow of fluid, and
- the wave inlet allows EM waves to be introduced in the flow path of the EM inlet portion, through the fluid barrier, and ultimately in the flow path of the fluid portion, in which fluid portion the EM waves evaporate the liquid in said flow path.

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Title: In-flow evaporator

Description

The present invention relates to an evaporator for continuously evaporating a flowing liquid into a gas.

Traditionally, such evaporators comprise a flow tube through which a liquid flows. Walls of the flow tube are traditionally heated to temperatures (far) exceeding the boiling temperature of the liquid inside the flow tube. Many different ways of heating said walls are known. As a result of physical contact with the heated walls, the liquid inside the flow tube is heated and eventually evaporated.

One disadvantage of such evaporators is that they suffer from fouling. That is, unwanted material tends to accumulate on the hot inner walls of such evaporators, slowly reducing the flow area of the evaporator, and leading to a reduced functioning. Said unwanted material results from undesirable chemical reactions between the liquid and the hot inner walls of the evaporator. Therefore, such evaporators need to be cleaned periodically, which can be costly.

Hence, a further disadvantage of said evaporators is a degradation of the fluid, in the form of a contamination with unwanted material resulting from said reactions.

Further disadvantageously, heating of the walls typically costs a lot of energy (relative to the theoretical amount of energy needed to transform the liquid into a gas) and is relatively slow. The heating system is usually relatively large, often resulting in bulky evaporators, requiring considerable energy input and time before the system can be used to evaporate a liquid.

US 2013/0077943 in contrast relates to a liquid evaporator in which pulsed laser beams are used to intermittently evaporate small sample quantities of liquids. The described liquid evaporator is however not able to evaporate a continuous flow of liquid. Furthermore, the evaporator uses a laser, generating high-intensity radiation of a wavelength known to interfere with various types of intramolecular bonds, potentially causing even more degradation and contamination of the fluid..

It is an object of the present invention to provide an improved evaporator that is able to evaporate a continuous flow of liquid, without the need for heated walls. It is a further object to provide an evaporator that is fast. It is also an object to provide an evaporator that is energy-efficient.

This object is achieved with an evaporator for continuously evaporating a flowing liquid, comprising:

- an outer casing having a liquid inlet, a gas outlet, and an EM wave inlet;
- an inner casing, arranged inside the outer casing and defining flow paths between the inner casing and the outer casing;
- a wave generator, configured to generate EM waves and connected to the EM wave inlet to introduce EM waves in the flow path of the evaporator;
- a liquid supply, connected to the liquid inlet, for supplying a continuous stream of liquid into the flow path of the evaporator;
- a gas collector, connected to the gas outlet, for collecting the gas that results after evaporating said liquid in said flow path; and
- a fluid barrier, impenetrable for fluids and penetrable for EM waves, the fluid barrier being arranged in the flow path and dividing the evaporator in an EM inlet portion which includes the EM wave inlet and a fluid portion which includes the liquid inlet and the gas outlet, the fluid portion and the EM inlet portion being separated from each other by the fluid barrier,

wherein in use:

- the flow path of the EM inlet portion comprises a gaseous medium,
- the flow path of the fluid portion comprises a running flow of fluid, the fluid entering the fluid portion through the liquid inlet in its liquid state, the fluid being evaporated while flowing in said fluid portion, and the fluid exiting the fluid portion through the gas outlet in its gaseous state, and
- the wave inlet allows EM waves to be introduced in the flow path of the EM inlet portion, through the fluid barrier, and ultimately in the flow path of the fluid portion, in which fluid portion the EM waves evaporate the liquid in said flow path.

The evaporator according to the invention advantageously comprises an inner casing and an outer casing, with a flow path defined in between the inner casing and the outer casing and uses electromagnetic (EM) waves for heating of the liquid. As a result of the inner and outer casings the EM waves are contained (trapped) inside the evaporator, and the evaporator acts as a Faraday cage. This has two advantages. Firstly, the EM waves are trapped inside the flow path and can transfer their energy to the fluid very efficiently, because the closed nature of the cavity creates an electromagnetically resonant situation. Secondly, it provides shielding: no EM waves can escape the evaporator, such that persons in the surroundings of the evaporator are not exposed to said EM waves. The shielding also ensures that less energy is dissipated, resulting an increased efficiency. In a preferred embodiment the liquid inlet and the outlet have additional shielding, most preferably a conductive mesh.

The evaporator according to the invention advantageously comprises an EM inlet portion and a fluid portion, which are fluidically separated from each other by a fluid barrier. The fluid portion contains a liquid inlet and a gas outlet. The fluid barrier ensures that the fluid to be evaporated remains in the fluid portion, while any fluid present in the EM inlet portion remains in the EM inlet portion. The fluids in the EM inlet portion and the fluid portion may thus be different, but cannot mix as the fluid barrier is impenetrable for fluids. The EM wave inlet is arranged in the EM inlet portion, the EM inlet portion containing e.g. a fluid or comprising a vacuum. If the EM inlet portion contains a fluid, said fluid is transparent for the inserted EM waves and preferably is a single phase fluid. Typically a gaseous fluid is foreseen to be present in the EM inlet portion. By introducing the EM wave first in an EM inlet portion that contains a gaseous medium, and then in the fluid portion which contains a liquid medium, only a single seal or fluid barrier is needed to decouple the fluid part from the EM inlet part, thus reducing leakage risks. The reflection of the EM wave at the EM inlet can be properly minimized, since the EM wave inside the EM inlet portion has a well-defined shape not affected by the two phase flow boiling patterns in the fluid portion. Creating a separate EM inlet portion is favoured over feeding the EM radiation through or near the liquid inlet at which location the evaporating fluid will still be single phase. Similar reasoning holds for feeding the EM radiation through or near the gas outlet. Thus, EM radiation preferably does not heat the walls to a temperature above that of the fluid. This results in less degradation of the fluid and less fouling. On top of that, the evaporator is fast and relatively compact in size.

Therefore, the object of the invention is achieved.

The present invention relates to an evaporator for continuously evaporating a flowing liquid. In other words, the evaporator is able to evaporate a liquid / fluid while it is “in flow” or moving. The flow of liquid may in some embodiments be mixed with a gas.

The outer casing has a liquid inlet for letting liquids in the evaporator, a gas outlet for letting gasses flow out of the evaporator, and an EM wave inlet. As the invention relates to a liquid evaporator, liquid is introduced in the evaporator. Optionally, the introduced liquid is mixed with a gas. While flowing to the evaporator, the liquid is evaporated (i.e. transformed into a gas). Hence, when the fluid reaches the outlet of the evaporator, a phase transition from liquid to gas has occurred. The phase transition may be complete (i.e. all liquid is transitioned to gas) Therefore, the outlet of the evaporator is a gas outlet. A flow direction of the fluid is thus defined in the direction from the inlet to the outlet. As EM waves are used to evaporate the liquid, the evaporator further comprises an EM wave inlet.

It is noted that in the context of the present document, the wording “fluid” refers to a non-solid medium and may thus mean either a gas or a liquid. A “gas” is, in the context of the present document, a fluid in its gaseous state, and a “liquid” is, in the context of the present document, a fluid in its liquid state and encompasses “pure” liquid, a mixture of liquids, or a mixture of a liquid and a gas. For example, the liquid may be a solution or an emulsion. It is noted that this wording corresponds to the conventional use of these words in the patent literature. Hence, the fluid portion of the evaporator may e.g. contain a fluid in its liquid state only (e.g. just after turning the evaporator on), and/or may contain a fluid in both its liquid state and its gaseous state (e.g. when the evaporator has been in use for some time). The invention is not limited to any particular type of fluid. In principle, any fluid may be evaporated with the disclosed evaporator, as long as molecules in the fluid have an electric dipole moment or are polar(i.e. as long as the fluid is sensitive to EM waves in the sense that it can be heated / evaporated by EM waves).

A flow path for the fluid is defined between the inner casing and the outer casing of the evaporator. This may, as described, result in a Faraday cage when the proper materials are used. For example, the inner casing and the outer casing may be made from a metal that is a good electrical conductor, e.g. stainless steel. For example, the inner casing and the outer casing may be in a coaxial arrangement.

In principle, any type of wave generator may be used in accordance with the present invention. For example, the wave generator may be configured to generate continuous-wave or pulsed-wave EM waves up to a frequency of about 10 GHz. In embodiments, the wave generator is coupled with a power amplifier, which increases the power of the waves generated by the wave generator.

An advantage of the present evaporator, using EM waves to evaporate the liquid, is that it may be turned on and/or switched off immediately. There is no need to heat the walls before the evaporator fully functions, turning on the wave generator and supplying liquid results in output of gas after a relatively short time, in embodiments almost immediately. There is no need to cool the walls before the evaporator can be switched off, simply turning off the wave generator will stop the generation of gas. If fast cooling is not desired, the walls can be isolated. This can also reduce heat dissipation to the environment.

In principle, any type of liquid supply may be used in accordance with the present invention. In embodiments, the liquid supply may e.g. be configured to provide a constant stream of liquid into the liquid inlet of the evaporator. For example, the amount of liquid to be evaporated may range between 0.1 mg/h – 10 kg/h, preferably 0.1 g/h – 1 kg/h.

In principle, any type of gas collector may be used in accordance with the present invention. The gas collector may e.g. simply be a tube through which the gas flows to another device, the another device e.g. using the gas produced by the evaporator as input. The gas collector may e.g. be a gas collection chamber in which a certain quantity of gas can be stored.

The fluid barrier separates the EM inlet portion and the fluid portion of the evaporator and is impenetrable for fluids while it is penetrable for EM waves. A person skilled in the art knows many materials which have such properties, and may choose any of them. The fluid barrier may in embodiments be a solid material, such as a ceramic material (e.g. glass), a polymer, e.g. a dense rubber such as FKM or FFKM, Metal Oxides (e.g. Al_2O_3), or a plastic such as ABS, PEEK, EPDM, PC or Teflon(-like) plastics. The fluid barrier may in embodiments be a liquid material. For example, it is known that oil separates air (which may be present in the EM inlet portion) and water (which may be present in the fluid portion). In embodiments, the fluid barrier may be moved in an axial direction of the flow path, to change the lengths of the EM inlet portion and the fluid portion. Thus the fluid barrier should not be electrically conductive. In embodiments, the fluid barrier may have a thickness of less than 2 mm, e.g. about 1 mm.

In use of the evaporator, the fluid enters the evaporator on one side of the fluid barrier, the fluid being in its liquid state. The EM waves enter the evaporator on the other side of the fluid barrier. The EM waves first travel through the EM inlet portion, before travelling through the fluid barrier and being introduced in the fluid portion. In said fluid portion, the EM waves act on the fluid therein, increase the energy level of said fluid, and phase transition the liquid into a gas.

In embodiments, the gas outlet associated with the fluid portion is arranged near the fluid barrier and the liquid inlet associated with the fluid portion is arranged away from the fluid barrier. The EM waves then first reach the fluid in its gaseous state (i.e. in its hottest state) after passing through the fluid barrier, and reaches colder fluid as it travels towards the liquid inlet. In this embodiment, the propagation direction of the EM waves is thus substantially opposite to the flow direction of the fluid.

In an alternative embodiment, the gas outlet associated with the fluid portion is arranged away from the fluid barrier while the liquid inlet associated with the fluid portion is arranged near the fluid barrier. The EM waves then first reach the fluid in its coldest state (i.e. in its liquid state) after passing through the fluid barrier, and reaches hotter fluid and ultimately the gas as it travels towards the gas outlet. In this embodiment, the propagation direction of the EM waves is thus generally aligned with the flow direction of the fluid.

In an embodiment, the frequency of the used EM waves is below 10 GHz, e.g. between 10 kHz and 3 GHz, more in particular between 1 MHz and 3 GHz, such as between 100 MHz and 3 GHz, more in particular between 500 MHz and 1.5 GHz, e.g. between 700 MHz and 1.1 GHz. The EM wave may e.g. be in the microwave or the radio spectrum. By using these frequencies the fluid will be heated due to dielectric heating, inducing microfluidic flows and movements causing viscous friction dissipating the energy into the fluid, and intramolecular bonds will be minimally influenced. Higher frequencies in contrast may break or alter molecular bonds. This may be undesirable.

In an embodiment, a frequency bandwidth of the EM waves generated by the wave generator is smaller than 1 GHz. Preferably, the EM waves are generated with a small bandwidth, such that the dimensions of the evaporator may be optimized for said specific range of EM waves. However, as the liquid to be evaporated may always contain e.g. impurities (or as a result of other design considerations), it is preferred when a bandwidth of EM waves is generated and not just one particular frequency. For example, when the “design frequency” of the evaporator is 900 MHz, the EM waves may be generated in a range between 875 MHz – 925 MHz or preferably between 500 MHz – 1 GHz or more preferably between 400 MHz – 1.4 GHz, or alternatively between 1 GHz –2 GHz or in another alternative between 2 GHz –3 GHz. It is noted that the above example is only used to explain the concept of “bandwidth” and may analogously be used for other design frequencies even though they are not mentioned explicitly.

In an embodiment, a length of the EM inlet portion is about 0.5 times the wavelength of the mean EM wave in said EM inlet portion (or a multiple thereof, e.g. 1 times, 1.5 times, 2 times, etc.). . Continuing upon the previous (non-limiting) example, when the “design frequency” (i.e. the central frequency) is 900 MHz, the wavelength of the EM waves is about 33.3 cm, and the length of the EM inlet portion may be about 16.6 cm (or a multiple thereof). It is again stated that this example is non-limiting and only serves as a sample calculation. A person skilled in the art can derive the “optimal” length of the EM inlet portion according to this embodiment also when mean EM waves with another frequency are used.

Preferably a length of the EM inlet portion can be changed to make it compatible with different frequencies while a preferred length of 0.5 times the wavelength (or a multitude thereof) remains. For example, the length of the EM inlet portion may be changed by arranging it as an extendable rod and/or by providing screw thread of a substantial length so that the effective length of the EM inlet portion may be changed by screwing / unscrewing it.

In an embodiment, the EM-wave-transparent fluid in the flow path of the EM inlet portion contains air or consists of air. This gas is readily available and leads to a simple design of the evaporator as no precautions have to be made that the gas escapes the EM inlet portion. However, also other gasses may be present in the EM inlet portion.

In an embodiment, sensors are integrated in the design, for example in the outer casing or in the inner casing. The sensors may measure one or more gas properties. Exemplary sensors include temperature sensors, pressure sensors, humidity sensors, flow sensors, viscosity sensors, thermal conductivity sensors, void fraction sensors and chemical sensors such a sensors for determining the composition of a fluid mixture.

In an embodiment, the inner casing is hollow. This could allow sensors of all kinds to be inserted in the inner casing. For example, a temperature sensor may be inserted in or arranged in or provided inside the inner casing, e.g. near the liquid inlet and near the gas outlet. This has the advantage that said sensor does not have to be arranged at the exterior of the evaporator, resulting in a more compact and smaller design. A hollow inner casing would also permit alternative arrangements of inlets and outlets for the fluid, through the hollow casing.

In another embodiment, the inner casing is solid.

In an embodiment, the evaporator further comprises a heating element that is configured for heating the gas outlet to the boiling temperature or a temperature above the boiling temperature of the fluid in the fluid portion. While the EM waves are able to heat the fluid to such an extent that the liquid transforms into a gas, the EM waves would not heat the gas beyond the boiling temperature of the fluid efficiently. To prevent condensation of the fluid as soon as it enters the gas outlet, it is beneficial to heat said gas outlet.

In an embodiment a temperature of the outer casing of the fluid portion in use is approximately equal to or below a boiling temperature of the fluid in the fluid portion, wherein a temperature approximately equal to said boiling temperature is understood to have a margin of error of several Kelvin (K). Thus the outer casing or a part of the outer casing may be up to 1 K, up to 2 K, up to 3 K, up to 4 K or up to 5 K above or below the boiling temperature As the evaporator according to the invention does not make use of heated walls to evaporate the liquid but instead uses EM waves, the walls of the outer casing may beneficially remain at a relatively low temperature equal to or below the boiling temperature of the fluid in the fluid portion. In another embodiment, the part of the casing nearest to the fluid inlet is cooled to a temperature below said boiling temperature, for example 5 K or 10 K below said boiling temperature, or even more Kelvin below said boiling temperature.

A second aspect of the invention relates to a heater for continuously heating a flowing liquid, comprising:

- an outer casing having a liquid inlet, an outlet, and an EM wave inlet;

- an inner casing, arranged inside the outer casing and defining a flow path between the inner casing and the outer casing;
- a wave generator, configured to generate EM waves and connected to the EM wave inlet to introduce EM waves in the flow path of the evaporator;
- a liquid supply, connected to the liquid inlet, for supplying a continuous stream of relatively cold liquid into the flow path of the heater;
- a collector, connected to the outlet, for collecting the relatively hot liquid or the mixture of liquid and gas that results after heating said liquid in said flow path; and
- a fluid barrier, impenetrable for fluids and penetrable for EM waves, the fluid barrier being arranged in the flow path and dividing the heater in an EM inlet portion which includes the EM wave inlet and a fluid portion which includes the liquid inlet and the outlet, the fluid portion and the EM inlet portion being separated from each other by the fluid barrier,

wherein in use:

- the flow path of the EM inlet portion comprises a gaseous medium,
- the flow path of the fluid portion comprises a running flow of liquid, the liquid entering the fluid portion through the liquid inlet with a relatively low temperature, the liquid being heated while flowing in said fluid portion, and the liquid exiting the fluid portion through the outlet with a relatively high temperature, and
- the wave inlet allows EM waves to be introduced in the flow path of the EM inlet portion, through the fluid barrier, and ultimately in the flow path of the fluid portion, in which fluid portion the EM waves heats the liquid flowing in said flow path.

For the purpose of the second aspect, the liquid may be a “pure” liquid, a mixture of liquids, or a mixture of a liquid and a gas. For example, the liquid may be a solution, a suspension, an emulsion, a liquid sol, or an aerosol.

It is noted that, compared to the first aspect, with the heater according to the second aspect the liquid in the fluid portion is not evaporated but (merely) heated.

It is noted that the wording “cold liquid” and “hot liquid” are relative to each other. The same holds for the wording “low temperature” and “high temperature”. That is, the hot liquid is heated and has a higher temperature than the cold liquid. For example, the cold liquid may have a temperature of 25°C, whereas the hot liquid may has temperature higher than said temperature (higher than 25°C). For example, the hot liquid may have a temperature of 35°C or more, such as 60°C or more, more specifically 80°C or more, e.g. 90°C or more.

It is furthermore noted that advantages and embodiments discussed in relation to the first embodiment are equally applicable to the second embodiment.

These and other aspects of the invention will be elucidated further in the below, wherein reference is made to the following figures:

Figure 1 schematically shows a longitudinal cross-sectional view of a first embodiment of an evaporator according to the present invention,

Figure 2 schematically shows a longitudinal cross-sectional view of a second embodiment of an evaporator according to the present invention, and

Figure 3 schematically shows the EM wave 41 of Figure 2 as a stand-alone wave.

With reference to figure 1, an evaporator 1 is disclosed. The evaporator 1 comprises an outer casing 2 and inner casing 3 arranged inside the outer casing 2. A flow path 31, 32 is defined between the inner casing 3 and the outer casing 2. The evaporator 1 further comprises a wave generator 4 (see figure 2), a fluid supply 5 (see figure 2), a gas collector 6 (see figure 2) or a gas transporter and a fluid barrier 7.

The evaporator 1 is configured for evaporating a liquid into a gas while the liquid flows though the evaporation 1 in a direction from inlet 21 to outlet 22. The evaporator 1 is configured for evaporating said liquid continuously, i.e. while the fluid is flowing / while the fluid is in-flow. As is explained in more detail in the below, the evaporator uses EM waves to evaporate the liquid.

The fluid barrier 7 is arranged in the flow path 31, 32 of the evaporator 1 and divides said flow path 31, 32 (and hence divides the evaporator 1) in two separate portions. In figure 1 to the left of the fluid barrier 7 is an EM inlet portion 8, in figure 1 to the right of the fluid barrier 7 is a fluid portion 9. The fluid barrier 7 is impenetrable for fluids on both sides and completely seals the EM inlet portion 8 with respect to the fluid portion 9, such that no fluid from the EM inlet portion 8 can reach the fluid portion 9, and vice versa, such that the fluid portion 9 and the EM inlet portion 8 are fully separated from each other by the fluid barrier 7. It is however observed that, even though the fluid portion 9 and the EM inlet portion 8 are completely separated from each other, the outer casing 2 and the inner casing 3 may each be formed as a single component, having preferably a constant outer diameter D (see fig. 2) and optionally a constant wall thickness along their entire length. The inner casing 3 and the outer casing 2 may be attached to one another at the outer ends during the manufacturing process. Alternatively, the outer casing and/or the inner casing may be formed by two or more parts which are assembled together, e.g. near the fluid barrier 7, e.g. using screw thread or alternatively by welding, riveting, soldering or gluing. Even though it is not shown in Figure 1, the inner casing 3 may be hollow. In the embodiment of figure 1, a radius r of the flow path 31, 32 is constant along the entire length of the evaporator 1, but this is not required.

The inner casing 3 may in principle have any closed cross-sectional shape and is preferably round.

The outer casing 2 may in principle have any closed cross-sectional shape and is preferably round.

The inner casing 3 and the outer casing 2 are preferably concentric with respect to each other, i.e. the inner casing 3 is preferably arranged in the center of the outer casing 2.

The distance between inner casing 3 and outer casing 2 is preferably constant in the flow direction of the fluid.

The EM inlet portion 8 includes an EM wave inlet 23 and in use contains a gaseous medium, e.g. air. Connected to the EM wave inlet 23 is the wave generator 4 (see fig. 2). The wave generator 4 is configured to generate EM waves 41 (see figs. 2 and 3) and introduce said EM waves in the flow path 31, 32 of the evaporator 1.

The fluid portion 9 includes a liquid inlet 21 and a gas outlet 22. Connected to the liquid inlet 21 is the liquid supply 5 (see fig. 2), so that the liquid supply 5 may supply a constant stream of liquid into the flow path 31 of the EM inlet portion 21 of the evaporator 1. Connected to the gas outlet 22 is the gas collector 6 (see fig. 2), so that the gas collector 6 can collect the gas that results after evaporating the liquid. In use the fluid portion 9 comprises a running flow of fluid, the fluid entering the fluid portion 9 through the liquid inlet 21 in its liquid state. As the fluid moves from the inlet 21 to the outlet 22, it is being evaporated, such that by the time it reaches the gas outlet 22 it is in its gaseous state. At the gas outlet 22, the fluid exits the evaporator 1 through said gas outlet 22. It is alternatively conceivable to provide an intermittent (pulsed) flow of liquid.

In figure 1 the gas outlet 22 is arranged near the fluid barrier 7 while the liquid inlet 21 is arranged away from the fluid barrier 7. This may however be reversed in an alternative embodiment.

The working of the evaporator 1 is best shown with reference to figure 2. In this figure, it is schematically illustrated how EM waves 41 are introduced by EM feed 2 in the flow path 32 of the EM inlet portion 8 of the evaporator 1. The propagation direction of the EM waves 41 in Figure 2 is from left to right. After the EM wave 41 has travelled through the EM inlet portion 8, it passes the fluid barrier 7 (as the fluid barrier 7 is penetrable for EM wave 41) and enters the flow path 31 of the fluid portion 9 of the evaporator 1. The fluid in the flow path 31 of the fluid portion 9 may have different properties than the gas in the flow path 32 of the EM inlet portion 32. For example, the fluid in the flow path 31 of the fluid portion 9 may (initially) be in a liquid state. Therefore, as shown, the wavelength of the EM wave 41 may be different in the fluid portion 9 of the evaporator 1 compared to the EM inlet portion 8 of the evaporator 1. In the flow path 31 of the fluid portion 9 the EM waves 41 energize the liquid which is flowing therein, and evaporate said liquid. Advantageously a “standing wave” results in the EM inlet portion 8, and a resonant cavity results. This ensures an energy-efficient evaporator.

Figure 3 shows a better representation of EM wave 41, displaying only EM wave 41 of Figure 2 and not the other components of the evaporator.

The applicant has found that it is highly advantageous when a length L1 of the EM inlet portion 8 is, as shown, about equal to 0.5 times the wavelength of the EM wave 41 therein. The length L2 of the fluid portion 9 may however vary. For example, in Figure 1 the length of the fluid portion 9 is longer than the length of the EM inlet portion 8, whereas in Figure 2 the length of the fluid portion 9 is shorter than the length of the EM inlet portion 8.

A frequency of the used EM wave may vary between 10 GHz, e.g. between 10 kHz and 3 GHz, more in particular between 1 MHz and 3 GHz, such as between 100 MHz and 3 GHz, more in particular between 500 MHz and 1.5 GHz, e.g. between 700 MHz and 1.1 GHz. A frequency bandwidth of the EM waves 41 generated by the wave generator 4 may be smaller than 1 GHz, or 500 MHz.

Further visible in figure 2 is a heating element 10, arranged in communication with the gas outlet 22 and configured for heating the gas outlet 22 to a temperature above the boiling temperature of the fluid in the fluid portion 9.

Advantageously, the temperature of the outer casing 2 (and, less importantly, also the temperature of the inner casing 3) of the evaporator 1 in use is equal to or below a boiling temperature of the fluid in the fluid portion 9.

It is noted that, although the outer casing 2 and the inner casing 3 of the evaporator 1 are shown as straight tubes in both figure 1 and figure 2, this is not required. Other shapes of the outer casing 2 and the inner casing 3, such as a spiral shape or a conical shape, are very well possible.

LIST OF REFERENCE NUMERALS

1	evaporator	
2	outer casing	
	21	liquid inlet
	22	gas outlet
	23	EM wave inlet
3	inner casing	
	31	flow path
	32	flow path
4	EM wave generator	
	41	EM wave
5	liquid supply	
6	gas collector	
7	fluid barrier	
8	EM inlet portion	
9	fluid portion	
10	heating element	
D	diameter outer casing	
L1	length EM inlet portion	
L2	length fluid portion	
r	radius flow path	

CONCLUSIES

1. Een verdamper (1) voor het continue verdampen van een stromende vloeistof, omvattende:

- een buitenste behuizing (2) met een vloeistofinlaat (21), een gasuitlaat (22) en een EM-golf inlaat (23);

- een binnenste behuizing (3), aangebracht binnenin de buitenste behuizing (2) en stroompaden (31, 32) tussen de binnenste behuizing (3) en de buitenste behuizing (2) definiërend;

- een golfgenerator (4), ingericht om EM-golven te genereren (41) en verbonden met de EM-golf inlaat (23) om EM-golven (41) in het stroompad (31, 32) van de verdamper (1) te introduceren;

- een vloeistofvoorziening (5), verbonden met de vloeistofinlaat (21), voor het voorzien van een continue stroom van vloeistof in het stroompad (31) van de verdamper (1);

- een gasverzamelaar (6), verbonden met de gasuitlaat (22), voor het verzamelen van het gas dat resulteert na het verdampen van de vloeistof in het stroompad (31); en

- een fluïdumbarrière (7), ondoordringbaar voor een fluïdum en doordringbaar voor EM-golven (41), waarbij de fluïdum-barrière (7) is aangebracht in het stroompad (31, 32) en de verdamper (1) verdeelt in een EM-inlaatgedeelte (8) dat de EM-golf inlaat (23) omvat alsmede een fluïdumgedeelte (9) dat de vloeistofinlaat (21) en de gasuitlaat (22) omvat, waarbij het fluïdumgedeelte (9) en het EM-inlaatgedeelte (8) van elkaar gescheiden door de fluïdumbarrière (7),

waarbij in gebruik:

- het stroompad (32) van het EM-inlaatgedeelte (8) een gasvormig medium omvat,

- het stroompad (31) van het fluïdumgedeelte (9) een stromende fluïdumstroom omvat, waarbij het fluïdum het fluïdumgedeelte (9) door de vloeistofinlaat (21) in de vloeistofvorm binnentreedt, het fluïdum verdampt wordt terwijl deze in het fluïdumgedeelte (9) stroomt, en het fluïdum het fluïdumgedeelte (9) verlaat door de gasuitlaat (22) in de gasvorm, en

- de EM-golfinlaat (23) het mogelijk maakt voor EM-golven (41) om te worden geïntroduceerd in het stroompad (32) van het EM-inlaatgedeelte (8), door de fluïdumbarrière (7), en uiteindelijk in het stroompad (31) van het fluïdumgedeelte (9), in welk fluïdumgedeelte (9) de EM-goven (41) de vloeistof in het stroompad (31) verdampen.

2. De verdamper volgens conclusie 1, waarbij de gasuitlaat (22) nabij de fluïdumbarrière (7) aangebracht is en waarbij de vloeistofinlaat (21) weg van de fluïdumbarrière (7) aangebracht is.

3. De verdamper volgens conclusie 1, waarbij de vloeistofinlaat (21) nabij de fluïdumbarrière (7) aangebracht is en waarbij de gasuitlaat (22) weg van de fluïdumbarrière (7) aangebracht is.

4. De verdamper volgens een van de voorgaande conclusies, waarbij de frequentie van de gebruikte EM-golven (41) tussen 1 MHz en 3 GHz is, zoals tussen 100 MHz en 3 GHz, meer in het bijzonder tussen 500 MHz en 1.5 GHz, bij voorbeeld tussen 700 MHz en 1.1 GHz.

5. De verdamper volgens conclusie 4, waarbij een frequentiebandbreedte van de EM-golven (41) gegenereerd door de golfgenerator (4) kleiner is dan 1 GHz.

6. De verdamper volgens een van de voorgaande conclusies, waarbij een lengte (L1) van het EM-inlaatgedeelte (8) ongeveer 0,5 keer de golflengte (λ) van de gemiddelde EM-golf (41) in het EM-inlaatgedeelte (8) is, of een veelvoud daarvan.

7. De verdamper volgens een van de voorgaande conclusies, waarbij het stroompad (32) van het EM-inlaatgedeelte (8) een voor de ingelaten EM-golven transparant medium omvat en bij voorkeur een één-fase-gas of een vacuum.

8. De verdamper volgens een van de voorgaande conclusies, waarbij de binnenste behuizing (3) hol is.

9. De verdamper volgens een van de voorgaande conclusies, waarbij de verdamper (1) verder een verwarmingselement (10) omvat dat is ingericht voor het verwarmen van de gasuitlaat (22) tot een temperatuur boven de kooktemperatuur van het fluïdum in het fluïdumgedeelte (9).

10. De verdamper volgens een van de voorgaande conclusies, waarbij een temperatuur van de buitenste behuizing (2) van het fluïdumgedeelte (9) in gebruik gelijk is aan of lager is dan een kooktemperatuur van het fluïdum in het fluïdumgedeelte (9).

11. De verdamper volgens een van de voorgaande conclusies, waarbij de radiale afmeting (r) van het stroompad (31, 32) tussen 0,1 mm en 10 mm is.

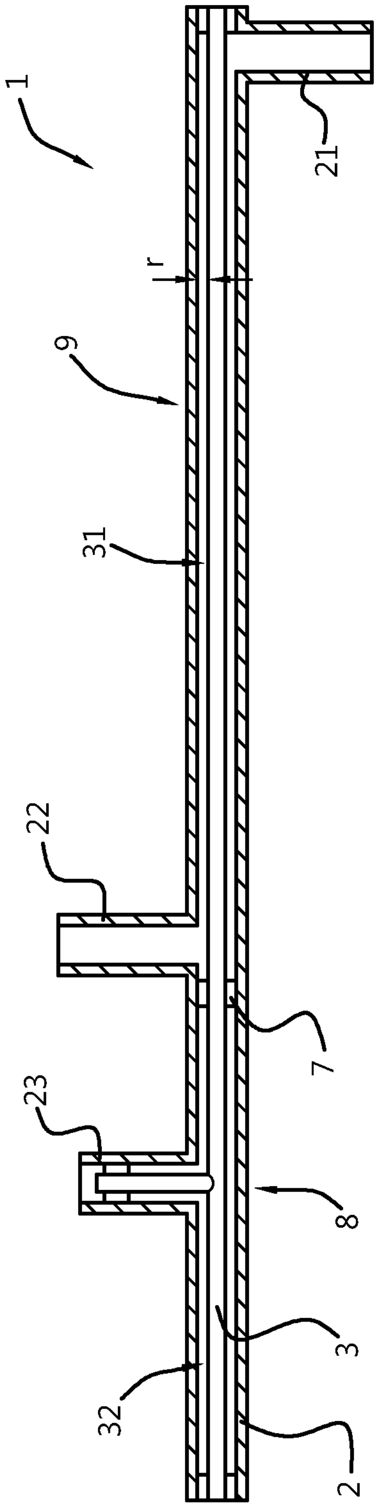

Fig. 1

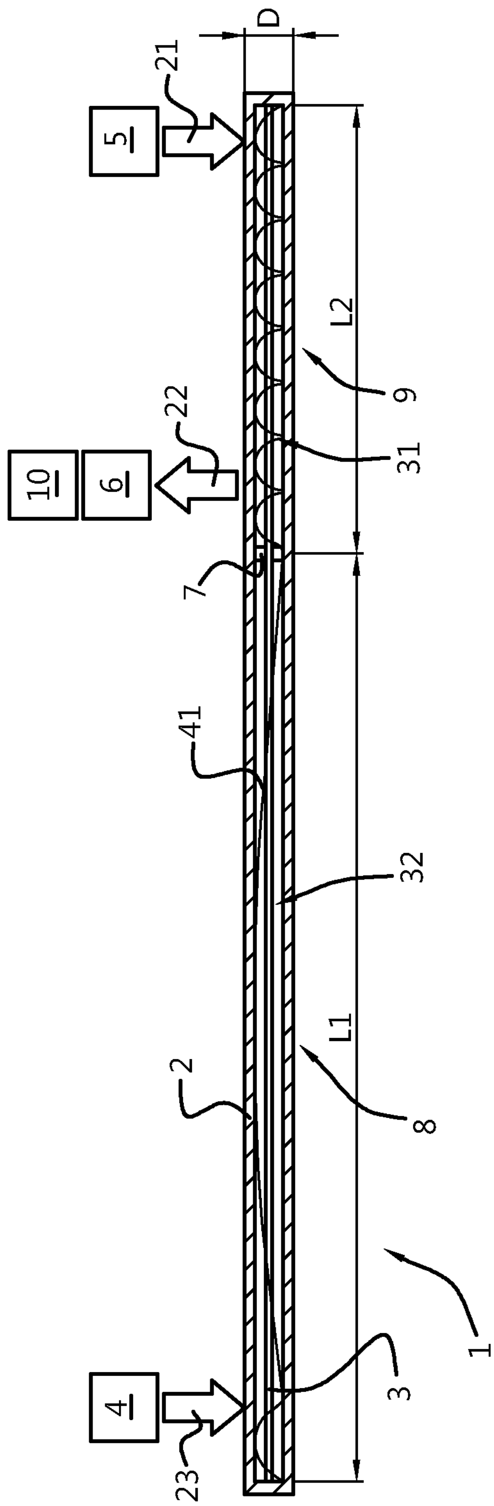

Fig. 2

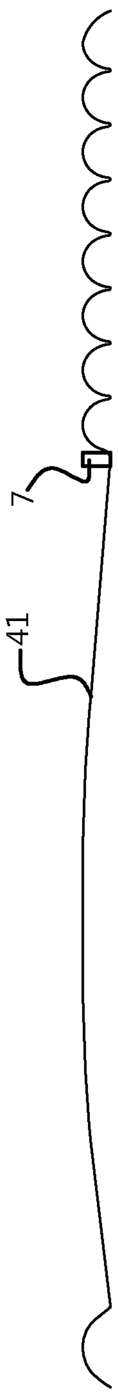

Fig. 3

SAMENWERKINGSVERDRAG (PCT)

RAPPORT BETREFFENDE NIEUWHEIDSONDERZOEK VAN INTERNATIONAAL TYPE

IDENTIFICATIE VAN DE NATIONALE AANVRAGE	**KENMERK VAN DE AANVRAGER OF VAN DE GEMACHTIGDE** **79355NL**
Nederlands aanvraag nr. **2023927**	Indieningsdatum **01-10-2019**
	Ingeroepen voorrangsdatum
Aanvrager (Naam) **Berkin B.V.**	
Datum van het verzoek voor een onderzoek van internationaal type **11-01-2020**	Door de Instantie voor Internationaal Onderzoek aan het verzoek voor een onderzoek van internationaal type toegekend nr. **SN75180**

I. CLASSIFICATIE VAN HET ONDERWERP (bij toepassing van verschillende classificaties, alle classificatiesymbolen opgeven)

Volgens de internationale classificatie (IPC)

Zie onderzoeksrapport

II. ONDERZOCHTE GEBIEDEN VAN DE TECHNIEK

Onderzochte minimumdocumentatie	
Classificatiesysteem	Classificatiesymbolen
IPC	**Zie onderzoeksrapport**

Onderzochte andere documentatie dan de minimum documentatie, voor zover dergelijke documenten in de onderzochte gebieden zijn opgenomen

III.	☐	**GEEN ONDERZOEK MOGELIJK VOOR BEPAALDE CONCLUSIES**	(opmerkingen op aanvullingsblad)
IV.	☐	**GEBREK AAN EENHEID VAN UITVINDING**	(opmerkingen op aanvullingsblad)

Form PCT/ISA 201 A (11/2000)

ONDERZOEKSRAPPORT BETREFFENDE HET RESULTAAT VAN HET ONDERZOEK NAAR DE STAND VAN DE TECHNIEK VAN HET INTERNATIONALE TYPE

Nummer van het verzoek om een onderzoek naar de stand van de techniek
NL 2023927

A. CLASSIFICATIE VAN HET ONDERWERP
INV. B01D1/00 H05B6/80
ADD.

Volgens de Internationale Classificatie van octrooien (IPC) of zowel volgens de nationale classificatie als volgens de IPC.

B. ONDERZOCHTE GEBIEDEN VAN DE TECHNIEK

Onderzochte miminum documentatie (classificatie gevolgd door classificatiesymbolen)
B01D H05B

Onderzochte andere documentatie dan de mimimum documentatie, voor dergelijke documenten, voor zover dergelijke documenten in de onderzochte gebieden zijn opgenomen

Tijdens het onderzoek geraadpleegde elektronische gegevensbestanden (naam van de gegevensbestanden en, waar uitvoerbaar, gebruikte trefwoorden)

EPO-Internal, WPI Data

C. VAN BELANG GEACHTE DOCUMENTEN

Categorie °	Geciteerde documenten, eventueel met aanduiding van speciaal van belang zijnde passages	Van belang voor conclusie nr.
X	EP 2 628 515 A1 (PLAZMATRONIKA NT SP Z O O [PL]) 21 augustus 2013 (2013-08-21) * fig.1, par.17-21 * -----	1-11
X	US 4 310 738 A (MORETTI MICHAEL ET AL) 12 januari 1982 (1982-01-12) * fig.1, col.2 line 36-68 * -----	1-11
A	CN 105 898 908 A (CHENGDU EN-SHAIN TECH INC; SICHUAN ROREI TECH CO LTD) 24 augustus 2016 (2016-08-24) * figuren 1,2 * -----	1-11
A	CA 2 504 159 A1 (HENDRIX HOLDING COMPANY INC [US]) 14 oktober 2006 (2006-10-14) * figuur 1 * -----	1-11
	-/--	

[X] Verdere documenten worden vermeld in het vervolg van vak C.

[X] Leden van dezelfde octrooifamilie zijn vermeld in een bijlage

° Speciale categorieën van aangehaalde documenten

"A" niet tot de categorie X of Y behorende literatuur die de stand van de techniek beschrijft

"D" in de octrooiaanvrage vermeld

"E" eerdere octrooi(aanvrage), gepubliceerd op of na de indieningsdatum, waarin dezelfde uitvinding wordt beschreven

"L" om andere redenen vermelde literatuur

"O" niet-schriftelijke stand van de techniek

"P" tussen de voorrangsdatum en de indieningsdatum gepubliceerde literatuur

"T" na de indieningsdatum of de voorrangsdatum gepubliceerde literatuur die niet bezwarend is voor de octrooiaanvrage, maar wordt vermeld ter verheldering van de theorie of het principe dat ten grondslag ligt aan de uitvinding

"X" de conclusie wordt als niet nieuw of niet inventief beschouwd ten opzichte van deze literatuur

"Y" de conclusie wordt als niet inventief beschouwd ten opzichte van de combinatie van deze literatuur met andere geciteerde literatuur van dezelfde categorie, waarbij de combinatie voor de vakman voor de hand liggend wordt geacht

"&" lid van dezelfde octrooifamilie of overeenkomstige octrooipublicatie

Datum waarop het onderzoek naar de stand van de techniek van internationaal type werd voltooid	Verzenddatum van het rapport van het onderzoek naar de stand van de techniek van internationaal type
18 februari 2020	

Naam en adres van de instantie	De bevoegde ambtenaar
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Weber, Christian

1

ONDERZOEKSRAPPORT BETREFFENDE HET RESULTAAT VAN HET ONDERZOEK NAAR DE STAND VAN DE TECHNIEK VAN HET INTERNATIONALE TYPE

Nummer van het verzoek om een onderzoek naar de stand van de techniek
NL 2023927

C.(Vervolg). VAN BELANG GEACHTE DOCUMENTEN

Categorie °	Geciteerde documenten, eventueel met aanduiding van speciaal van belang zijnde passages	Van belang voor conclusie nr.
A	US 6 044 661 A (PFISTER DENNIS M [US] ET AL) 4 april 2000 (2000-04-04) * figuur 8 * -----	1-11
A,D	US 2013/077943 A1 (MUELLER JOERG [DE] ET AL) 28 maart 2013 (2013-03-28) in de aanvraag genoemd * figuren 1,3 * -----	1-11

1

ONDERZOEKSRAPPORT BETREFFENDE HET RESULTAAT VAN HET ONDERZOEK NAAR DE STAND VAN DE TECHNIEK VAN HET INTERNATIONALE TYPE

Informatie over leden van dezelfde octrooifamilie

Nummer van het verzoek om een onderzoek naar de stand van de techniek

NL 2023927

In het rapport genoemd octrooigeschrift		Datum van publicatie	Overeenkomend(e) geschrift(en)			Datum van publicatie
EP 2628515	A1	21-08-2013	AU	2013220981	A1	02-10-2014
			CA	2850493	A1	22-08-2013
			CN	103987430	A	13-08-2014
			EA	201490511	A1	31-03-2015
			EP	2628515	A1	21-08-2013
			KR	20140147801	A	30-12-2014
			US	2013206582	A1	15-08-2013
			WO	2013122490	A1	22-08-2013
US 4310738	A	12-01-1982	GEEN			
CN 105898908	A	24-08-2016	GEEN			
CA 2504159	A1	14-10-2006	GEEN			
US 6044661	A	04-04-2000	AU	750482	B2	18-07-2002
			CA	2284907	A1	24-09-1998
			EP	0970334	A1	12-01-2000
			JP	2002515964	A	28-05-2002
			US	5916259	A	29-06-1999
			US	6044661	A	04-04-2000
			US	6125650	A	03-10-2000
			US	6263697	B1	24-07-2001
			US	6415626	B1	09-07-2002
			US	6415627	B1	09-07-2002
			WO	9841800	A1	24-09-1998
US 2013077943	A1	28-03-2013	CA	2797608	A1	03-11-2011
			CN	103108682	A	15-05-2013
			DE	102010018830	A1	03-11-2011
			EP	2563490	A1	06-03-2013
			JP	2013527443	A	27-06-2013
			US	2013077943	A1	28-03-2013
			WO	2011134968	A1	03-11-2011

WRITTEN OPINION

File No.	Filing date *(day/month/year)*	Priority date *(day/month/year)*	Application No.
SN75180	01.10.2019		NL2023927

International Patent Classification (IPC)
INV. B01D1/00 H05B6/80

Applicant
Berkin B.V.

This opinion contains indications relating to the following items:

- ☒ Box No. I — Basis of the opinion
- ☐ Box No. II — Priority
- ☐ Box No. III — Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- ☐ Box No. IV — Lack of unity of invention
- ☒ Box No. V — Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- ☐ Box No. VI — Certain documents cited
- ☐ Box No. VII — Certain defects in the application
- ☒ Box No. VIII — Certain observations on the application

	Examiner
	Weber, Christian

WRITTEN OPINION

Box No. I Basis of this opinion

1. This opinion has been established on the basis of the latest set of claims filed before the start of the search.

2. With regard to any **nucleotide and/or amino acid sequence** disclosed in the application and necessary to the claimed invention, this opinion has been established on the basis of:

   a. type of material:

   ☐ a sequence listing

   ☐ table(s) related to the sequence listing

   b. format of material:

   ☐ on paper

   ☐ in electronic form

   c. time of filing/furnishing:

   ☐ contained in the application as filed.

   ☐ filed together with the application in electronic form.

   ☐ furnished subsequently for the purposes of search.

3. ☐ In addition, in the case that more than one version or copy of a sequence listing and/or table relating thereto has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

4. Additional comments:

Box No. V Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty	Yes:	Claims	3, 9, 11
	No:	Claims	1, 2, 4-8, 10
Inventive step	Yes:	Claims	
	No:	Claims	1-11
Industrial applicability	Yes:	Claims	1-11
	No:	Claims	

2. Citations and explanations

   see separate sheet

Application number

WRITTEN OPINION

NL2023927

Box No. VIII Certain observations on the application

see separate sheet

Re Item V

Reference is made to the following documents:

D1 EP 2 628 515 A1 (PLAZMATRONIKA NT SP Z O O [PL]) 21 augustus 2013 (2013-08-21)

D2 US 4 310 738 A (MORETTI MICHAEL ET AL) 12 januari 1982 (1982-01-12)

1.INDEPENDENT CLAIM

The present application does not meet the criteria of patentability, because the subject-matter of claim 1 is not new.

Document D1 discloses (fig.1, par.17-21):

An evaporator (fig.1) comprising

-an outer casing (around chamber 102) having a liquid inlet (112), a gas outlet (to separator 120) and an EM wave inlet (110);

-an inner casing (106), arranged inside the outer casing and defining flow paths between the inner casing and the outer casing and defining flow paths between the inner casing and outer casing;

- a wave generator (104), configured to generate EM waves and connected to the EM wave inlet to introduce EM waves in the flow path of the evaporator;

-a liquid supply (112 upstream), connected to the liquid inlet, for supplying a continuous stream of liquid into the flow path of the evaporator;

-a gas collector (120), connected to the gas outlet, for collecting the gas that results after the evaporating said liquid in said flow path; and

-a fluid barrier (122), impenetrable for fluids and penetrable for EM waves, the fluid barrier being arranged in the flow path and dividing the evaporator in an EM inlet portion which includes the EM wave inlet and a fluid portion which includes the liquid inlet and the gas outlet, the fluid portion and the EM inlet portion being separated from each other by the fluid barrier.

Document D2 discloses (fig.1, col.2 line 36-68):

An evaporator (10) comprising

-an outer casing (12 and around chamber 16) having a liquid inlet (48), a gas outlet (50) and an EM wave inlet (38);

-an inner casing (walls 42), arranged inside the outer casing and defining flow paths between the inner casing and the outer casing and defining flow paths between the inner casing and outer casing;

- a wave generator (32), configured to generate EM waves and connected to the EM wave inlet to introduce EM waves in the flow path of the evaporator;

-a liquid supply (upstream 48), connected to the liquid inlet, for supplying a continuous stream of liquid into the flow path of the evaporator;

-a gas collector (outer portion 16), connected to the gas outlet, for collecting the gas that results after the evaporating said liquid in said flow path; and

-a fluid barrier (30), impenetrable for fluids and penetrable for EM waves, the fluid barrier being arranged in the flow path and dividing the evaporator in an EM inlet portion which includes the EM wave inlet and a fluid portion which includes the liquid inlet and the gas outlet, the fluid portion and the EM inlet portion being separated from each other by the fluid barrier.

Hence, the subject-matter of claim 1 is not novel.

2.DEPENDENT CLAIMS

Dependent claims do not appear to contain any additional features which, in combination with the features of any claim to which they refer, meet the requirements of novelty and/or inventive step.

-claim 2,3: In both D1 and D2 the gas outlet is somewhat closer to the barrier. It is however not clear from the application what configuration would be best (claim 2 or 3 as both are claimed).

-claim 4-6: See clarity issues below.

-claim 7: In D1 PTFE or glass plate (122) and in D2 clear plastic (30).

-claim 8: In both D1 and D2 the inner casing as indicated for claim 1 are hollow.

-claim 9: The additional heating of the gas outlet is not indicated in D1 or D2 however it is a feature the skilled person would readily contemplate when confronted with the problem of with the problem of condensation.

-claim 10: See clarity below.

-claim 11: It is not clear what special surprising technical effect is obtained from these specific sizes defined.

Re Item VIII

Claims are not clear.

As explained below, some of the features in the apparatus claims 1,4-7,10 relate to a method of using the apparatus rather than clearly defining the apparatus in terms of its technical features. The intended limitations are therefore not clear from these claims:

-claim 1,7: the fluids such as liquids or gas flowed or contained in parts of the apparatus are not apparatus feature and will thus therefore not be considered limiting for the claim. Thus also in claim 1the entire portion below is trying to define the apparatus through its use:

wherein use:

-the flow path of the EM inlet portion comprises a gaseous medium;

-the flow path of the fluid portion comprises a running flow of the fluid, the fluid entering the fluid portion through the liquid inlet in its liquid state, the fluid being evaporated while flowing in said portion, and the fluid exiting the fluid portion through the gas outlet in its gaseous state, and

-the wave inlet allows EM waves to be introduced in the flow path of the EM inlet portion, through the fluid barrier, and ultimately in the flow path of the fluid portion, in which fluid portion the EM waves evaporate the liquid in said flow path.

-claims 4-6: the frequency of the waves generated is also not an apparatus feature so that these claims do not define any further concrete apparatus features.

-claim 10: the temperature is also not an apparatus feature.

The relative terms "close" or distant" ("nabij" and "weg") used in claims 2,3 have no well-recognized meaning and leaves the reader in doubt as to the meaning of the technical features to which it refers, thereby rendering the definition of the subject-matter of said claims unclear.