(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
19 July 2007 (19.07.2007)

PCT

(10) International Publication Number
WO 2007/079774 A1

(51) International Patent Classification:
A01G 9/14 (2006.01) *A01G 9/24* (2006.01)

(21) International Application Number:
PCT/EP2006/000219

(22) International Filing Date: 12 January 2006 (12.01.2006)

(25) Filing Language: English

(26) Publication Language: English

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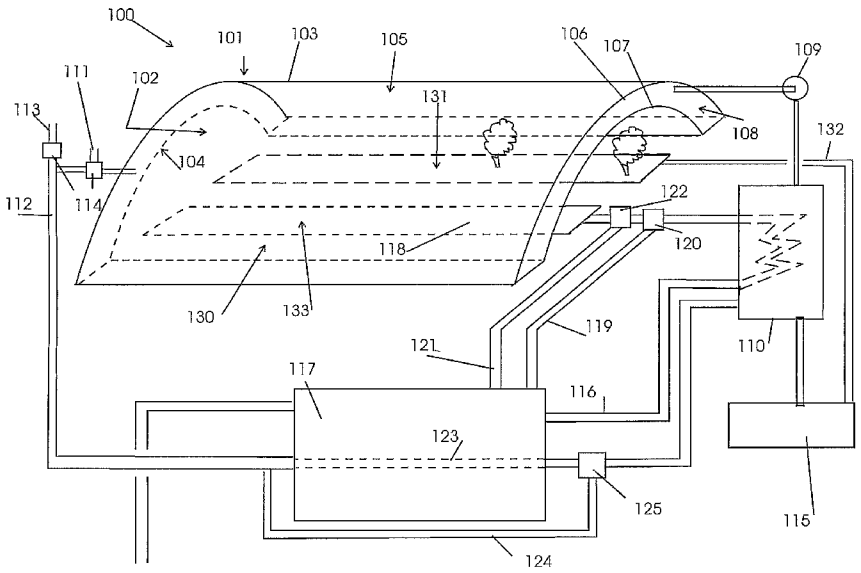
(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, LY, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: CLOSED GREENHOUSE WITH CONTROLLED HUMIDITY



(57) Abstract: A greenhouse as subject of the present invention comprises a floor surface and a building structure. The floor structure and said building structure delimit an inner space. The building structure comprising at least one light- transmitting architectural element, which light transmitting architectural element is a double layered element comprising an outer layer of light-transmitting material and an inner layer of light-transmitting material. A void space is provided between the inner layer and the outer layer. The greenhouse comprises means for extracting air from the void space. The inner layer is a water vapour permeable but water impermeable membrane.

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CLOSED GREENHOUSE WITH CONTROLLED HUMIDITY

Technical field of the invention

The present invention relates to greenhouses and more in particular closed greenhouses. The invention relates also to the use of such greenhouses for growing plants, distillation of seawater or brackish water, drying of goods or energy output. The invention relates further to a method to provide a closed greenhouse and a method for controlling the humidity and/or temperature in a greenhouse.

Background of the invention

Greenhouses for cultivation of plants are well known nowadays. It was already noticed that it is more economic to use closed greenhouses for growing crops or plants. Closed greenhouses in general can provide higher yields in growing plants and crops per surface unit. It was found that optimal conditions for growing plants are obtained when the relative humidity, temperature and CO_2-content of the atmosphere in the cultivation environment are set to about 18 to 24°C, an air humidity of about 70% to 90% and a CO_2-content of about 1000ppm.

In US6705043, EP517432, WO2004/049783 and EP1464218, several means to provide a closed greenhouse, as well as means to control the above-mentioned conditions of temperature, CO_2-content and humidity are suggested.

However, the equipment to control such conditions are very complex and large, and require significant investment and operational costs. This is especially the case when an existing open greenhouse is to be modified into a closed greenhouse. Possibly it is not even feasible to make such modifications.

Apart from the above-mentioned advantage of closed greenhouses, greenhouses in very dry and arid environments usually lack sufficient fresh water for irrigating the crops and plants. Usually salt seawater or brackish water is evaporated and condensed again, in order to provide fresh water. As

an example, US4383891 or WO98/04231 describes such installations. Also these installations require significant investment and operational costs.

Open greenhouses have been provided with systems to control the humidity and/or the temperature of the inner environment. Especially, much interest is shown in the control of the humidity of the inner environment of the greenhouse. Often temperature and humidity is controlled and adjusted by ventilating the greenhouse. But during ventilation, the CO_2-content is not under control, especially not in the range being optimal for plant or crop growth.

As an alternative for ventilation, air conditioning systems, conditioning the total volume of air present in the greenhouse, are used for controlling the humidity and/or temperature. Such air conditioning systems however require again significant installation and consume a serious amount of energy. This causes significant operational costs during use of the greenhouse.

Summary of the invention

It is a first object of the present invention to provide an alternative greenhouse, more particular a closed greenhouse as well as a method of operating the same.

It is an advantage of some of the embodiments of the present invention to provide a greenhouse, which can be installed and used in a more economical way, requiring equal or less investment costs to be made, and which can be used at equal or lower operational costs. It is an advantage of some of the embodiments of the present invention to provide a greenhouse, which may be used in both cold and warm regions. It is an advantage of some of the embodiments of the present invention to provide a greenhouse, which can control two or more of the humidity, temperature and CO_2-content of the inner space of the greenhouse without the need of treating the whole volume of air present in the greenhouse. It is an advantage of some of the embodiments of the present invention to provide a greenhouse, which consumes an amount of water, being equal or less then existing greenhouses.

It is an advantage of some of the embodiments of the present invention to provide a greenhouse, which has relatively low operating costs, still having a good, or even improved yield of crop and plant growth. It is an advantage of

some of the embodiments of the present invention to provide a greenhouse, which requires a limited amount of energy, or which can be used as a source of energy.

It is an advantage of some of the embodiments of the present invention to provide a greenhouse, which may be used to distillate seawater or brackish water into fresh water. It is an advantage of some of the embodiments of the present invention to provide a greenhouse, which may be used to distillate seawater or brackish water, which distillate is water to be used for growing crops or plants present at the inner space of the greenhouse.

According to embodiments of the invention, the greenhouses may be used for several purposes, such as crop and plant growing, growing of aqueous plants such as seawater plants, or for providing fresh water from brackish or seawater, or for drying goods.

It is a further object of the present invention to provide method to modify a greenhouse, e.g. to modify an existing open greenhouse, into a greenhouse that solves the first object of the present invention.

It is an advantage of some embodiments of the present invention that this modification can be conducted at relatively low investment costs.

It is yet a further object of the present invention to provide a method for controlling the humidity and/or temperature in a greenhouse according to the first object of the present invention. It is an advantage of some of the embodiments of the present invention that the method enables to control the humidity, temperature and CO_2-content of the inner space of the greenhouse without the need of treating the whole volume of air present in the greenhouse.

The above objectives are accomplished by a greenhouse having a linking technical feature, namely that being the use of a water vapour permeable membrane as an additional layer in a solar still arrangement.

According to embodiments of the first object of the present invention, a greenhouse comprises a floor surface and a building structure located above the floor surface. The floor structure and the building structure delimit an inner volumetric space. The building structure comprises at least one light-transmitting architectural element, which light transmitting architectural element is a double layered element comprising an outer layer of light-transmitting

material and an inner layer of light-transmitting material, whereby a void space is provided between the inner layer and the outer layer. The greenhouse comprises means for extracting air from the void space. The inner layer is a water vapour permeable but water impermeable membrane, e.g. a polymer membrane.

The light-transmitting architectural elements may be self-supporting or non-self-supporting elements. They may be rigid or flexible. These elements may be parts of or comprise architectural elements such as walls, roofs, windows, skylights. According to embodiments of the present invention, the building structure may consist of light-transmitting structural elements.

According to embodiments of the present invention, a support fabric, which is preferably mechanically coupled to the membrane, may be provided to support the membrane.

According to embodiments of the present invention, the greenhouse further may comprise means for measuring the temperature and/or humidity of the inner space.

According to embodiments of the present invention, the greenhouse further may comprise means for providing a gas such as ambient air to the void space.

According to embodiments of the present invention, the greenhouse further may comprise means for heating and/or evaporating liquid in the inner space.

According to embodiments of the present invention, this means for heating and/or evaporating liquid in the inner space may comprise liquid channels and/or liquid basins for exposing liquid to the environment in the inner space. Such means may be mounted on the floor of the greenhouse, or may be provided as channels or basins or alike, hanging in the inner space of the greenhouse. The environment includes sunlight. According to embodiments of the present invention, the means for heating and/or evaporating liquid in said inner space may comprise an irrigation system for irrigating the soil. The soil may be a part of the floor surface, or may be present in e.g. containers located in the inner space of the greenhouse. The greenhouse may be provided with a basin, which basin provides the floor

surface of the greenhouse and functions as a means for heating and/or evaporating liquid in the inner space. The cultivation containers are mounted elevated from the floor surface in the inner space of the greenhouse.

According to embodiments of the present invention, the greenhouse may comprise a heat exchanging means, the means for extracting air from the void space being coupled to this heat exchanging means for cooling the extracted air.

According to embodiments of the present invention, the greenhouse further may comprise means for conducting at least part of this cooled air to the void space.

According to embodiments of the present invention, the heat exchanging means may be a condenser for converting the air being extracted from the void space into condensate and dehumidified air.

According to embodiments of the present invention, the greenhouse further may comprise means for conducting at least part of this condensate to the means for heating and/or evaporating liquid in the inner space.

According to embodiments of the present invention, at least part of the condensate may be provided to the irrigating system.

According to embodiments of the present invention, the greenhouse further may comprise means for providing secondary water to the heat exchanging means for converting the air being extracted from the void space into condensate and dehumidified air.

According to embodiments of the present invention, this secondary water for exchanging heat with the air extracted from the void space may be stored in a water buffering means.

According to embodiments of the present invention, the greenhouse further may comprise means for conducting at least part of the secondary water used for exchanging heat with the air extracted from the void space, to the means for heating and/or evaporating liquid in the inner space.

According to embodiments of the present invention, the greenhouse may be a closed greenhouse.

According to embodiments of the present invention, the greenhouse may be used for growing or cultivating plants, such as aqueous plants, e.g.

aqueous plants which are grown in seawater. According to embodiments of the present invention, the greenhouse may be used for distillation of fresh water from secondary water such as seawater or brackish water, or may be used for drying goods and products.

According to embodiments of a second object of the present invention, a method to modify a greenhouse comprising structural elements, a floor surface and at least one light transmitting member is provided. The method comprises:

- providing at the inner side of the greenhouse, a water vapour permeable but water impermeable membrane, e.g. a polymer membrane, for creating a double layered light transmitting architectural element, which comprises an outer layer comprising the at least one light transmitting member, and an inner layer being the membrane. The double-layered light transmitting architectural element defines a void space between the inner and the outer layer. The double layered light transmitting architectural element and the floor surface encompasses an inner space; and
- providing a means for extracting air from the void space

The light-transmitting architectural elements may be self-supporting or non-self-supporting elements. They may be rigid or flexible. These elements may be parts of or comprise architectural elements such as walls, roofs, windows, skylights.

According to embodiments of the present invention, additional means as set out above are provided to further modify the existing greenhouse.

According to embodiments of a third object of the present invention, a method for controlling the humidity and/or temperature in a greenhouse is provided. The method comprises the steps of:

- providing a greenhouse comprising a floor surface and a building structure. The floor structure and the building structure delimit an inner space. The building structure comprises at least one light-transmitting architectural element, which light transmitting architectural element is a double layered architectural element comprising an outer layer of light-transmitting material and an

inner layer of light-transmitting material, whereby a void space is provided between the inner layer and the outer layer. The greenhouse as subject of the present invention comprises means for extracting air from the void space. The inner layer is a water vapour permeable but water impermeable membrane, e.g. a polymer membrane;

- defining a temperature set value and/or humidity set value for temperature and humidity of the inner space;
- providing means for measuring the temperature and/or humidity at inner space;
- adjusting the amount of air extracted from the void space and/or adjusting the amount of water evaporated at the inner space in function of the measured temperature and/or humidity at said inner space as compared to said temperature set value and/or humidity set value.

According to embodiments of the present invention, the method may comprise the steps of:

- monitoring the temperature and/or humidity of the air displaced in the void space; and
- changing the amount of air extracted from the void space in function of the monitored temperature and/or humidity of the air displaced in the void space.

According to embodiments of the present invention, the greenhouse further may comprise a heat exchanging means. The void space is coupled to this heat exchanging means for cooling the extracted air. The method may comprise the step of providing at least part of the cooled air to the void space for adjusting the temperature and/or humidity of the air displaced in the void space in function of the monitored temperature and/or humidity of the air displaced in the void space.

According to embodiments of the present invention, the method may comprise the step of mixing ambient air with this at least part of the cooled air to be provided to the void space according to a mixing ratio. The ratio may be

adjustable in function of the monitored temperature and/or humidity of the air displaced in said void space.

According to embodiments of the present invention, the heat exchanging means may be a condenser for converting the air extracted from the void space into condensate and dehumidified air. The greenhouse further may comprise means for conducting at least part of the condensate to the inner space of the greenhouse, e.g. for irrigating the plants and crops or for irrigating the soil in which the plants or crops are cultivated. The method may comprise the step of conducting at least part of this condensate to the inner space of the greenhouse for adjusting the temperature and/or humidity in the inner space in function of the measured temperature and/or humidity at the inner space as compared to the temperature set value and/or humidity set value.

According to embodiments of the present invention, the greenhouse further may comprise means for heating and/or evaporating liquid in the inner space. The method may comprise the step of heating and/or evaporating secondary water in the inner space for adjusting the temperature and/or humidity in the inner space in function of the measured temperature and/or humidity at the inner space as compared to the temperature set value and/or humidity set value

According to embodiments of the present invention, the greenhouse further may comprise means for providing secondary water to the heat exchanging means for cooling the extracted air from the void space. The method may comprise the step of providing at least part of this secondary water used for cooling the extracted air to the means for heating and/or evaporating liquid in the inner space. This in order to adjust the temperature and/or humidity of the air in the inner space in function of the measured temperature and/or humidity at the inner space as compared to the temperature set value and/or humidity set value.

Particular and preferred aspects of the invention are set out in the accompanying independent and dependent claims. Features from the dependent claims may be combined with features of the independent claims

and with features of other dependent claims as appropriate and not merely as explicitly set out in the claims.

Although there has been constant improvement, change and evolution of devices in this field, the present concepts are believed to represent substantial new and novel improvements, including departures from prior practices, resulting in the provision of more efficient, stable and reliable devices of this nature.

The above and other characteristics, features and advantages of the present invention will become apparent from the following detailed description, taken in conjunction with the accompanying drawings, which illustrate, by way of example, the principles of the invention. This description is given for the sake of example only, without limiting the scope of the invention. The reference figures quoted below refer to the attached drawings.

Brief description of the drawings

Fig. 1 is a schematically view of a first embodiment of a greenhouse as subject of the present invention;

Fig. 2 and Fig. 3 are schematically views of a second and a third greenhouse as subject of the present invention, which is provided by modifying a greenhouse according to a method of the present invention.

In the different figures, the same reference signs refer to the same or analogous elements.

Definitions

According to the present invention, the term "water vapour permeable but water impermeable membrane" is to be understood as a membrane, e.g. a polymer membrane, possibly a perforated membrane, which is permeable to water vapour, but which is substantially impermeable to water such as water droplets. The membrane may be permeable to water vapour due to osmosis effects, for example.

According to the present invention, the term "secondary water" is to be understood as any kind of water-based liquids such as seawater, brackish water, groundwater, waist water or even ordinary fresh or potable water. The secondary water is not necessarily useful directly for crop or plant cultivation.

Description of illustrative embodiments

The present invention will be described with respect to particular embodiments and with reference to certain drawings but the invention is not limited thereto but only by the claims. The drawings described are only schematic and are non-limiting. In the drawings, the size of some of the elements may be exaggerated and not drawn on scale for illustrative purposes. The dimensions and the relative dimensions do not correspond to actual reductions to practice of the invention.

Furthermore, the terms first, second, third and the like in the description and in the claims, are used for distinguishing between similar elements and not necessarily for describing a sequential or chronological order. It is to be understood that the terms so used are interchangeable under appropriate circumstances and that the embodiments of the invention described herein are capable of operation in other sequences than described or illustrated herein.

Moreover, the terms top, bottom, over, under and the like in the description and the claims are used for descriptive purposes and not necessarily for describing relative positions. It is to be understood that the terms so used are interchangeable under appropriate circumstances and that the embodiments of the invention described herein are capable of operation in other orientations than described or illustrated herein.

It is to be noticed that the term "comprising", used in the claims, should not be interpreted as being restricted to the means listed thereafter; it does not exclude other elements or steps. It is thus to be interpreted as specifying the presence of the stated features, integers, steps or components as referred to, but does not preclude the presence or addition of one or more other features, integers, steps or components, or groups thereof. Thus, the scope of the expression "a device comprising means A and B" should not be limited to devices consisting only of components A and B. It means that with respect to the present invention, the only relevant components of the device are A and B.

Similarly, it is to be noticed that the term "coupled", also used in the claims, should not be interpreted as being restricted to direct connections only. Thus, the scope of the expression "a device A coupled to a device B" should not be limited to devices or systems wherein an output of device A is directly

connected to an input of device B. It means that there exists a path between an output of A and an input of B which may be a path including other devices or means.

The invention will now be described by a detailed description of several embodiments of the invention. It is clear that other embodiments of the invention can be configured according to the knowledge of persons skilled in the art without departing from the true spirit or technical teaching of the invention, the invention being limited only by the terms of the appended claims.

A first embodiment of a closed or semi-closed greenhouse according to the present invention is shown in Fig. 1. A greenhouse 100 comprises a floor surface 130 and a building structure 101 located above the floor surface and delimiting an inner space 102. The building structure comprises, and in this particular embodiment consists, of a light-transmitting structural element 103. The light light-transmitting structural element 103 has an inner surface 104 and an outer surface 105. The light light-transmitting structural element 103 is double layered, comprising an outer layer 106, e.g. being a water impermeable layer of bent plastic or glass, e.g. provided from polyester. The inner layer 107 is a water vapour permeable but water impermeable membrane, e.g. a polymer membrane, e.g. an Osmofilm® membrane from the company ALYZEE (FR). Alternatively a water vapour permeable membrane like Techpack membranes or Flecron membranes. It is preferred to use a membrane, which has a high permeability to water vapour. The permeability to water vapour is preferably more than 2 l/m²/24h, more preferred in the range of 7 to 20 l/m²/24h. The light-transmitting elements may be self-supporting or non-self-supporting elements. They may be rigid or flexible. These elements may be parts of or comprise architectural elements such as walls, roofs, windows, skylights.

Between the two layers 106 and 107, a void space 108 is created. A means 109 for extracting air from the void space 108, e.g. a ventilator or a venturi-driven air mover, coupled to the void space by means of appropriate ducting system, is provided as shown in Fig. 1. This means 109 for extracting air is coupled to a heat exchanging means 110, e.g. condenser, for cooling the air being extracted from the void space 108 by means of means 109 for

extracting air. The presence of a void space between the water vapour permeable membrane and the outer layer, and the means for extracting air from this void space, enables to adjust and control two or more of the humidity, temperature and CO_2-content of the inner space of the greenhouse.

The greenhouse further comprises a means 111 to provide ambient air into the void space 108, and means 112 to provide at least a part of the cooled and optionally dehumidified air, from the heat exchanging means 110 back to the void pace 108. Optionally, a means 113 for discharging at least part of the air from said heat exchanging means to the ambient is provided. Optionally, appropriate valve-like systems 114 are provided to control the amount of cooled air and/or the amount of ambient air and/or the ratio of ambient air and cooled air to the void space. It is understood that also only fresh air or only cooled air may be directed or redirected to the void space by these valve-like systems 114. Air, either fresh ambient air or cooled or dehumidified air is to be provided to the void space, in order to avoid a too large a sub-pressure in the void space 108. Such significant sub-pressure could harm the membrane 107

In case, as not illustrated in the drawings, the means 109 for displacing air in the void space 108 is not coupled to a heat exchanging means, the means 109 for displacing air may discharge its air taken from the void space to the ambient. It is understood that in such case, sufficient fresh ambient air will have to be provided to the void space 108 by means of means 111 to provide ambient air into the void space 108, in order to avoid e.g. a significant sub-pressure in the void space 108 as compared to the pressure in the inner space 102.

In case the heat exchanging means 110 is a condenser, as shown in Fig. 1, the cooled air will be dehumidified air. The condensate, this is the condensed water from the condenser, is fresh water and may be stored in a buffer unit 115. It may be brought back, at least partially, to the inner space 102 of the greenhouse 100, e.g. to irrigate the soil 131 onto which the crops and plants are grown in the inner space 102 of the greenhouse. At least part of the condensate can be used to provide water to an irrigation system 132, which irrigation system 132 forms part of a means for heating and/or evaporating liquid in the inner space 102.

Alternatively or additionally, the greenhouse may be seen as a source to provide fresh, e.g. potable, water. At least a part of the condensate, which is not used to irrigate the soil, may be used to provide potable water or fresh water. The provision of such fresh water is an advantage when the greenhouse is located in regions where there is a shortage of fresh water.

In case a heat exchanging means 110, such as a condenser, is used to cool or dehumidify the air taken from the void space, several possible fluids may be used to cool the air. As an example, secondary water, such as seawater, brackish water or ground water may be used. As shown in Fig. 1, means 116 to provide secondary water to the heat exchanging means 110 is provided. This means 116 may comprise a buffer volume 117. The secondary water, or at least a part of this secondary water, being heated by the heat exchanging means 110 can be provided to either a means 118 for heating and evaporating this secondary water in the inner space 102 of the greenhouse 100. Alternatively, the water, or at least a part of this water, being heated by the heat exchanging means 110 may be conducted back to said buffer volume 117 via appropriate conducting means 119, or may be discharged back to the ambient (not shown in Fig. 1). It is understood that appropriate valve-like systems 120 may be provided to adjust the volumes of water to be conducted to various directions.

In case the water used for evaporation in the inner space of the greenhouse, has been used to cool the extracted air in the heat exchanging means, this water is so-to-say preheated in the heat exchanging means. This results in a higher yield of fresh water obtainable from the greenhouse. For this purpose, the means 118 for heating and/or evaporating liquid in the inner space 102 may comprise liquid channels 133 or liquid buffers, which expose the liquid to the environment of the inner space.

In alternative embodiments, not illustrated in the drawings, separate buffers may be used, one for cold water to be used for cooling the extracted air in the heat exchanging means, and another one for recovering the water which is pre-heated in the heat exchanging means. This pre-heated water may be used to cool the air introduced into the void space.

As one may adjust the amount of air being extracted in the void space, the amount of air being extracted over night can be reduced. This may create an insulating air layer, which prevent the inner space to cool down too quick or too much during night. The void space functions as a thermal insulating layer. The water, or at least a part of this water, being heated by the heat exchanging means 110 and being conducted back to said buffer volume 117 may be used to keep the water in the buffer volume at a constant or increased temperature. This may be an advantage during nighttime, when no sunlight is available for heating the air in the void space 108. As the ambient air may cool down too much, the buffer volume may be used during this period to keep the air circulated in the void space 108 at the temperature above the ambient. The water in the buffer volume 117 can be used as a source of thermal energy. This thermal energy may be provided to the air extracted from the void space by e.g. the heat exchanging means, when being used in a reverse way: the air being heated by the water, instead of air being cooled by the water. Such a layer of warmer air between the cold ambient outside the greenhouse and the inner space may prevent the inner space cooling down too much or too quickly. Alternatively or additionally, for the purpose of increasing the temperature of the air extracted from the void space, the means 112 to provide cooled air from the heat exchanging means 110 back to the void pace 108 may have an extra heat exchanging region 123 in the buffer volume 117, as well as a bypass 124 to bypass this extra heat exchanging region 123. It is understood that a valve-like system 125 may be provided to adjust the amount of air being provided to either the extra heat exchanging region 123 or the bypass 124.

Optionally, means 121 for conducting secondary water directly to the means 118 for heating and evaporating liquid in the inner space 102 of the greenhouse 100 is provided. It is understood that appropriate valve-like systems 122 may be provided to adjust the volumes of water conducted to the inner space 102 by means 121.

In order to increase the lifetime of the water vapour permeable but water impermeable membrane, e.g. polymer membrane, and/or its mechanical properties, the membrane may be provided with a support fabric, which is

sufficiently light transmitting in order not to cause a negative effect on the ratio of illumination of the crops or plants being grown in the inner space102, and/or to avoid too much negative effect on the yield of water being evaporated or heated in the inner space. As an example, a woven, non-woven or knitted fabric, e.g. from polymer such as transparent polymer filaments, may be mounted under the membrane. Alternatively a fabric may e.g. be mechanically coupled to the membrane, such as by laminating the fabric to the membrane.

In case the greenhouse is constructed in regions where there is too much light energy available, which may endanger the growing of crops, it is understood that a support fabric may be provided which shields a part of the light. As an example a black woven or non-woven fabric may be used as support fabric. As a further example, in the space between the crops and the inner surface of the membrane, a semi-transparent fabric may be provided, e.g. a black gauze woven or non-woven fabric, which fabric shields the crops and plants form at least a part of the illumination. This fabric located between inner side of membrane and crops, prevent the crops to be subjected to too high degree of illumination, meanwhile allowing the light energy to heat the air of the inner space above the fabric. The fabric may be provided with a selectively light reflecting coating, reflecting light back to the space above the fabric and into the void space. This reflected light might further heat the air in the inner space above the fabric and the void space.

The means 118 for heating and/or evaporating liquid may be provided as liquid channels or basins. Optionally, means for increasing the temperature of the liquid and to increase the yield of evaporation may be provided, such as e.g. the inner surface of the channel or basin may be coloured black. As another example, waves may be created in the liquid present in the basins or channels. As a further example, means to create and guide air bubbles through the liquid may be provided. As a further example, means to create liquid movement or fountains in the liquid may be provided.

In case there is a risk that the liquid would cause fragrance embarrassment in the inner space or could cause contamination of the inner space by crop endangering bacteria, the liquid basin or channel may be

covered with a water vapour permeable membrane, similar or identical to the membrane of the inner layer 107.

Fig. 2 shows an alternative embodiment of the present invention. The greenhouse 200 is based on an existing conventional greenhouse structure. The existing greenhouse comprises structural elements 203, e.g. brick walls, on which a construction of light transmitting members is provided, e.g. made of glass or plastic. It is understood that the existing greenhouse structure will further comprise supporting means, frame work for holding the glass, plastic or any other useful light transmitting structure, such as profiled metal bars and many more structural elements to provide a firm greenhouse structure.

Such an existing greenhouse structure can be modified, according to an object of the present invention, into a greenhouse 200 as subject of the present invention.

According to this second object of the present invention, a method is provided to modify a greenhouse comprising structural elements 203, a floor surface and at least one light-transmitting member, comprising the steps of

- providing at the inner side of the greenhouse, a water vapour permeable but water impermeable membrane, e.g. a polymer membrane, for creating a double layered light transmitting architectural element 103, which comprises an outer layer 106 comprising at least one light transmitting member, and an inner layer 107 being said membrane. The double-layered light-transmitting architectural element 103 defines a void space between the inner and the outer layer. The double layered light transmitting architectural element 103, the floor surface 204 encompasses an inner space.
- providing a means 109 for extracting air from the void space.

Optionally, additional means as already set out for the greenhouse of Fig. 1 may be provided, in order to create an alternative greenhouse 200 as subject of the present invention. Identical reference numbers for means shown in Fig. 2 refer to identical means as described and explained in Fig. 1, and have the same function and provide the same advantages as was explained for the features in Fig. 1.

Fig. 3 shows an alternative for the greenhouse as shown in Fig. 2. The greenhouse is provided with an additional discharging means 301 for discharging secondary water being used by the heat exchanging means 110. The greenhouse comprises also an additional means 302 for guiding cooled air through the heat exchanging means. The means 302 provides the possibility to cool the extracted air to even lower temperatures. The conducting means 119 and 121 are provided as one duct 303. The valve-like systems 120 and 122 are provided as a mixing valve 304.

In the space between the crops and the inner surface of the membrane, the greenhouse is provided with a semi-transparent fabric 310, e.g. a black gauze woven or non-woven fabric, which fabric shields the crops and plants form at least a part of the illumination.

Further means 311 are provided to introduce additional water vapour or water in the void space, to further lower the temperature of the air in the void space and thus in the inner space. As an example, this means 311 comprises a sprinkler 312 system.

The buffer unit 115 is provided with a discharging means 313 for allowing condensate to be discharged from the water circuit. This condensate discharged via means 313 may be used for other applications, e.g. to produce potable water or alike.

Identical reference numbers for additional means shown in Fig. 3 refer to identical means as described and explained in Fig. 1 and Fig. 2, and have the same function and provide the same advantages as was explained for the features in Fig. 1 and Fig. 2.

As compared to existing closed greenhouses, the devices for conditioning, e.g. cooling or dehumidifying the air, e.g. the heat exchanging means, need not to be dimensioned to treat the whole inner air volume of the greenhouse. As the dimensions need not to be so large, the modification of an existing greenhouse can be made at relatively low investment costs. The devices, which are to be provided to modify the existing greenhouse, are fairly easy in use and can easily be adjusted and controlled.

The modifications of the existing greenhouse into a greenhouse as subject of the present invention provide significant advantages. Whereas the existing greenhouse may have to be ventilated completely when the temperature in the inner side of the greenhouse was increased too much, the inner space of the modified greenhouse 200 is not to be ventilated. The temperature and humidity of the inner space can be set and controlled to a given level in such a way that even when too much light or solar energy is provided to the greenhouse, the CO_2-content, humidity and temperature conditions in the inner space can be kept in optimal conditions to have the largest yields of crop or plant growing. Optionally, the additional solar energy available can be converted into fresh water of thermal energy stored for use over night or during periods where less solar energy is available.

The modification of the existing greenhouse according to the present invention has as an advantage that the amount of light, which can be used to grow the crops or plants, is not to be significantly reduced.

Optionally, but not shown in Fig. 1 or Fig. 2, the greenhouse comprises a means for heating the environment in the inner space in case the temperature is too low, and the amount of illumination by solar energy is not sufficient to heat the inner space sufficiently. In such case, the void space between the inner and outer layer of the light transmitting structure element can still be used to evacuate superfluous vapour, and/or can function as a thermal buffer between ambient and inner space, avoiding to some extent thermal losses of energy.

The greenhouses 100 and 200 as shown in Fig. 1 and Fig. 2 can be used as a closed greenhouse. According to the third object of the present invention, a method for controlling the humidity and/or temperature in a greenhouse as subject of the present invention is provided.

In a greenhouse as subject of the present invention the temperature, humidity and CO_2-content present in the inner space can be controlled without the need to ventilate the whole inner space e.g. to control the temperature. As compared to closed greenhouses using an air conditioning system to adjust temperature and humidity, the whole volume of air present in the inner space of the greenhouse as subject of the present invention is not to be displaced

and treated, e.g. cooled or heated, to adjust its temperature, humidified or condensed to adjust its humidity.

In a greenhouse as subject of the present invention, the water vapour permeable but water impermeable membrane, e.g. a polymer membrane, will keep substantially all CO_2 in the inner space. This means that the CO_2-content of the inner space can easily be controlled by providing once a sufficient amount of CO_2 to create a given concentration of CO_2, and thereafter only adding the amount of CO_2, which is consumed by the crops or plants being grown. Optionally, the amount of CO_2 may be provided by composting of e.g. wet peat in the inner space.

According to a method of the present invention, the temperature and humidity of the air in the inner space of the greenhouse can be controlled by

- defining a temperature set value and/or humidity set value for temperature and humidity of the inner space;
- providing means for measuring the temperature and/or humidity at inner space;
- adjusting the amount of air extracted from the void space and/or adjusting the amount of water evaporated at the inner space in function of the measured temperature and/or humidity at inner space as compared to .said temperature set value and/or humidity set value.

Optionally, the temperature and/or humidity of the air being displaced in the void space is monitored, and the amount of air extracted from the void space is changed in function of the monitored temperature and/or humidity of said air displaced in said void space.

The additional means as disclosed and described in Fig. 1 and Fig. 2 may be provided. The greenhouse may comprise a heat exchanging means, e.g. a condenser, which is coupled to the void space for cooling the extracted air, or in case of a condenser, converting the extracted air into condensate and dehumidified air. The cooled or dehumidified air may be provided again to the void space for adjusting the temperature and humidity of the air displaced in the void space.

Optionally, the method comprises the step of mixing ambient air with at least part of the cooled air or dehumidified air to be provided to the void space

according to a mixing ratio, which ratio being adjustable in function of the monitored temperature and/or humidity of the air displaced in the void space.

In case the heat exchanging means is a condenser, the greenhouse further may comprise means for conducting at least part of the condensate to the inner space of the greenhouse The method as subject of the present invention may comprise the step of conducting at least part of the condensate to the inner space of the greenhouse for adjusting the temperature and/or humidity in the inner space in function of the measured temperature and/or humidity at the inner space as compared to the temperature set value and/or humidity set value.

Optionally, the greenhouse further comprises means for heating and/or evaporating liquid in said inner space. The method may comprise the step of heating and/or evaporating secondary water in the inner space for adjusting the temperature and/or humidity in the inner space in function of the measured temperature and/or humidity at the inner space as compared to the temperature set value and/or humidity set value.

Optionally, the greenhouse further comprises means for providing secondary water to the heat exchanging means for cooling the extracted air from the void space. The method may comprise the step of providing at least part of the secondary water used for cooling the extracted air to the means for heating and/or evaporating liquid in the inner space for adjusting the temperature and/or humidity of the air in the inner space in function of the measured temperature and/or humidity at the inner space as compared to the temperature set value and/or humidity set value.

The humidity at the inner space can be controlled by controlling the water vapour pressure of the air in the void space, in function of the water vapour pressure in the inner space. Due to the osmosis effect of the membrane, the difference between these two water vapour pressures at both sides of the membrane defines the amount of vapour being transferred between the two sides of the membrane, taking the surface area of the membrane into account. This is because the water vapour passes through the membrane from the side at with there is a higher water vapour pressure to the side where a lower water vapour pressure is present. In the greenhouse as

subject of the present invention, the water vapour pressure at the inner space will be higher as compared to the water vapour pressure in the void space, which two spaces are separated by the water vapour permeable membrane. So water vapour will pass from the inner space to the void space.

The illumination of the greenhouse by means of sunlight increases the temperature of the inner space and the void space. Crops or plants present in the inner space will provide water vapour to the inner space. Also water evaporated from the soil will provide water vapour to the inner space. Other liquids such as secondary water present in the inner space, such as by means of liquid channels or basins will partially or fully evaporate providing water vapour in the inner space. The surface and the temperature of the liquid such as secondary water will influence the amount of water vapour provided in the inner space.

Hence the water vapour pressure at the inner space will be higher as compared to the void space. Water vapour will pass from the inner space to the void space through the membrane. The amount of air extracted from the void space, the amount of plants and crops, the amount of water in the soil, and the amount and optionally the temperature of water evaporating at the inner space allow to adjust the water vapour pressure present over the membrane, and thus the amount of vapour to be extracted from or provided to the inner space. The humidity, and to some extent the temperature, of the inner space will be controlled by the water being evaporated in the inner space.

The temperature of the inner space, which is influenced by the amount of solar illumination provided to and through the light transiting structure elements, can be controlled by several parameters, dependent on the means provided to the greenhouse as subject of the present invention.

The temperature of the inner space can be controlled by varying and adjusting the amount and temperature of the air extracted from the void space It may as well be influenced by controlling the amount and temperature of the liquid, either condensate or secondary water, either from the heat exchanging means, from the buffer volume and/or from the ambient, being provided to the inner space for evaporation.

The temperature of the air in the void space can be controlled by controlling and adjusting the temperature and volume of air being provided to the void space, either ambient air or cooled and/or dehumidified air. It may also be controlled and adjusted by changing the amount of air extracted from the void.

In case the temperature is to decrease in the inner space, e.g. when too much sunlight is provided to the greenhouse, more water may be evaporated, as the evaporation consumes thermal energy, being provided to the inner space via the illumination. The amount of thermal energy consumed can be further increased e.g. by enlarging the water surface present in the inner space, or by creating water movement or fountains in the water to be evaporated or similar actions, which increase the amount of liquid which is evaporated. In case condensate is used to irrigate the soil of the greenhouse, more condensate may be provided to increase the amount of condensate that is evaporated. In order to decrease the temperature of the inner space, also the temperature of the air circulating in the void space can be reduced, e.g. by cooling the air in the heat exchanging means to a lower temperature by using more or colder water at the cold side of the heat exchanging means, or by changing the ratio of ambient air and cooled air from the heat exchanging means to provide air entering in the void space at a lower temperature. The amount of air extracted from the void space can be increased as well.

Optionally, means are provided in the void space to introduce additional water vapour or water in the void space, to further lower the temperature of the air in the void space and thus in the inner space. As an example, a sprinkler system or alike may be provided. If the air extracted from the void space is condensed to condensate in the heat exchanging means, which condensate is used to provide fresh or even potable water, it is understood that the water vapour provided by such system in the void space is to be fresh water.

In case the temperature is too low and has to be increased, the liquid to be evaporated in the inner space may be provided on a higher temperature, this is especially the case when substantially no illumination is provided, e.g. over night. To increase the temperature when illumination is present, the amount of liquid to be evaporated may be decreased, or the temperature of the

air in the void space may be increased. Alternatively, the amount of air extracted from the void space may be reduced.

In order to control the temperatures, humidity and volumes in the different means of the greenhouse as subject of the present invention, it is understood that appropriate measuring means are to be provided.

The greenhouses as subject of the present invention, and especially closed green houses as subject of the present invention have further advantages.

As the membrane is vapour permeable, there is a very low risk to create condensate at the inner side of the membrane.

Preferably, the membrane is impermeable for bacteria. The bacterial content present in the inner space can then be easily controlled. This is advantageous because the crops and plants can be shielded from endangering bacteria.

The energy sources such as motors for driving different means for displacing fluids such as the water of the air, can be generated by using solar energy. The buffer unit storing the condensate may be positioned higher than the ground level in the inner space of the greenhouse, in order to facilitate an easy irrigation, using a minimum of energy. Because the humidity of the inner space can be kept high, there is less irrigation water needed to grow crops or plants.

The secondary water may be subjected to evaporation to such an extent that only a dry residue, e.g. salt in case of seawater, remains, or a means for discharging water from the means for heating and/or evaporating liquid in said inner space to the ambient or to the buffer volume may be provided. The latter to discharge the partially evaporated liquid

In case there is a risk that too much solar energy may be provided to the greenhouse as subject of the present invention, a protective means such a as a semitransparent or not transparent cover or shield may be provided to prevent a part of the solar energy to illuminate the greenhouse.

It was found that the greenhouse as subject of the present invention may provide a significant reduction of energy consumption. A reduction of about 60% as compared to the presently known greenhouses may be

obtained. There is in general no need for external heat sources. On the contrary, the greenhouse may create energy which can be used, as set out above, to distillate seawater or brackish water. The greenhouse can hence be seen as a collector of solar energy, which converts substantially all solar energy being provided to the greenhouse. In the first place it converts solar energy to provide an increased yield of crop growth by controlling the temperature, humidity and CO_2-content of the inner space of the greenhouse. The surplus of solar energy is used either to provide fresh water, e.g. for irrigation of the crops, or is buffered and stored for use when insufficient solar energy is available, or for other uses.

The optimal control of temperature, humidity and CO_2-content according to the present invention doesn't need the whole air volume of inner environment of the greenhouse to be circulated, which circulation itself may influence or even endanger the cultivation of certain crops or plants.

It is understood that the temperature, humidity and CO_2-content may be varied in time, in order to influence the moment of harvest of crops in the greenhouse.

Further, as the crops and plants are shielded from endangering bacteria by the membrane being impermeable for such bacteria, the use of herbicide or pesticide can be reduced. This is also due to the fact that the total volume of air in the inner environment of the greenhouse which is not to be ventilated or treated.

It is understood that if necessary, fresh air could be provided to the inner space as well, although this could be reduced to a minimum. Appropriate filter systems may be used when air is circulated, also in the circulation of air of the void space. In such a way, also elements, which should not be in the air system, may be removed.

The greenhouses as subject of the present invention may be used for several applications. The greenhouses as shown in Fig. 1 and Fig. 2 may be used for growing crops and plants. Optionally, when means for evaporating and/or heating water are provided, in the inner space, the greenhouse may be used to grow aqueous plants, such as e.g. plants grown in seawater, when seawater is evaporated and/or heated.

Alternatively the greenhouses may be used to dry products, such as fruit, vegetables, grains, organic waist, sludge or any other water-containing substrate.

In case the greenhouse is to be used for drying goods, the means to means for heating and/or evaporating secondary water in the inner space of the greenhouse are not necessarily to be provided. In case the ambient air is sufficient to provide a sufficient water vapour pressure over the two surfaces of the membrane, the heat exchanging means is not necessary either. The air taken from the void space, which is replaced by fresh ambient air, can be discharged to the ambient.

It is to be understood that although preferred embodiments, specific constructions and configurations, as well as materials, have been discussed herein for devices according to the present invention, various changes or modifications in form and detail may be made without departing from the scope and spirit of this invention. The actual placement of parts of a greenhouse with respect to each other, as in the different embodiments, is illustrative only. In real implementations the placement of the parts may be adapted so as to use the available energy in an as optimal way as possible. This may include the volume of the void space, defining the distance between the outer and inner layer of light-transmitting material, and/or the rate of extraction of air from the void space.

CLAIMS

1.- A greenhouse comprising a floor surface and a building structure, said floor structure and said building structure delimiting an inner space, said building structure comprising at least one light-transmitting architectural element, said light transmitting architectural element being a double layered element comprising an outer layer of light-transmitting material and an inner layer of light-transmitting material, whereby a void space is provided between the inner layer and the outer layer, said greenhouse comprising means for extracting air from said void space, wherein said inner layer is a water vapour permeable but water impermeable membrane.

2.- A greenhouse according to claim 1, wherein building structure comprises light-transmitting structural elements.

3.- A greenhouse according to any one of the claims 1 to 2, wherein said membrane is supported by a support fabric, which support fabric is preferably mechanically coupled to said membrane.

4.- A greenhouse according to any one of the claims 1 to 3, wherein said greenhouse further comprises means for measuring the temperature and/or humidity at said inner space.

5.- A greenhouse according to any one of the claims 1 to 4, wherein said greenhouse further comprises means for providing ambient air to said void space.

6.- A greenhouse according to any one of the claims 1 to 5, wherein said greenhouse further comprises means for heating and/or evaporating liquid in said inner space.

7.- A greenhouse according to claim 6, wherein said means for heating and/or evaporating liquid in said inner space comprises liquid channels and/or liquid basins for exposing liquid to the environment in said inner space.

8.- A greenhouse according to any one of the claims 6 to 7, wherein said means for heating and/or evaporating liquid in said inner space comprises an irrigation system for irrigating the soil, said soil possibly being part of said floor surface.

9.- A greenhouse according to any one of the claims 1 to 8, wherein said greenhouse comprises a heat exchanging means, said means for extracting air from said void space being coupled to said heat exchanging means for cooling said extracted air.

10.- A greenhouse according to claim 9, wherein said greenhouse further comprises means for conducting at least part of said cooled air to said void space.

11.- A greenhouse according to any one of the claims 9 to 10, wherein said heat exchanging means is a condenser for converting said air being extracted from said void space into condensate and dehumidified air.

12.- A greenhouse according to claim 11, wherein said greenhouse further comprises means for conducting at least part of said condensate to said means for heating and/or evaporating liquid in said inner space.

13.- A greenhouse according to claim 12 as far as dependent on claim 8, wherein at least part of said condensate is provided to said irrigating system.

14.- A greenhouse according to any one of the claims 9 to 13, wherein said greenhouse further comprises means for providing secondary water to

said heat exchanging means for converting said air being extracted from said void space into condensate and dehumidified air.

15.- A greenhouse according to claim 14, wherein said secondary water for exchanging heat with said air extracted from said void space, is stored in a water buffering means.

16.- A greenhouse according to any one of the claims 14 to 15, wherein said greenhouse further comprises means for conducting at least part of said secondary water used for exchanging heat with said air extracted from said void space, to said means for heating and/or evaporating liquid in said inner space.

17.- A greenhouse according to any one of the preceding claims, said greenhouse is a closed greenhouse.

18.- A greenhouse according to any one of the preceding claims, wherein said water vapour permeable but water impermeable membrane is a polymer membrane.

19.- The use of a greenhouse as in any one of the claims 1 to 18 for growing of plants.

20.- The use of a greenhouse as in claim 19, wherein said plants are aqueous plants.

21.- The use of a greenhouse as in claim 20, wherein said aqueous plants are grown in seawater.

22.- The use of a greenhouse as in any one of the claims 1 to 18 for distillation of fresh water from secondary water.

23.- The use of a greenhouse as in any one of the claims 1 to 18, for drying of products.

24.- A method to modify a greenhouse comprising structural elements, a floor surface and at least one light transmitting member, said method comprising the steps of

- providing at the inner side of the greenhouse, a water vapour permeable but water impermeable membrane, for creating a double layered light transmitting architectural element, which comprises an outer layer comprising the at least one light transmitting member, and an inner layer being said membrane, said double layered light transmitting architectural element having a void space between said inner and said outer layer; said double layered light transmitting architectural element, and the floor surface encompassing an inner space; and
- providing a means for extracting air from the void space.

25.- A method for controlling the humidity and/or temperature in a greenhouse, comprising the steps of:

- providing a greenhouse comprising a floor surface and a building structure, said floor structure and said building structure delimiting an inner space, said building structure comprising at least one light-transmitting architectural element, said light transmitting architectural element being a double layered structure comprising an outer layer of light-transmitting material and an inner layer of light-transmitting material, whereby a void space is provided between the inner layer and the outer layer, said greenhouse comprising means for extracting air from said void space, wherein said inner layer is a water vapour permeable but water impermeable membrane;
- defining a temperature set value and/or humidity set value for temperature and humidity of the inner space;
- providing means for measuring the temperature and/or humidity at inner space; and

- adjusting the amount of air extracted from said void space and/or adjusting the amount of water evaporated at the inner space in function of the measured temperature and/or humidity at said inner space as compared to said temperature set value and/or humidity set value.

26.- A method according to claim 25, wherein said method comprises the steps of

- monitoring the temperature and/or humidity of said air displaced in said void space; and
- changing the amount of air extracted from said void space in function of the monitored temperature and/or humidity of said air displaced in said void space.

27.- A method according to any one of the claims 25 to 26, wherein said greenhouse further comprises a heat exchanging means, said void space being coupled to said heat exchanging means for cooling said extracted air, said method comprises the steps of providing at least part of said cooled air to said void space for adjusting the temperature and/or humidity of the air displaced in said void space in function of said monitored temperature and/or humidity of said air displaced in said void space.

28.- A method according to claim 27, wherein said method comprises the step of mixing ambient air with said at least part of said cooled air to be provided to said void space according to a mixing ratio, said ratio being adjustable in function of said monitored temperature and/or humidity of said air displaced in said void space.

29.- A method according to any one of the claims 27 to 28, wherein said heat exchanging means is a condenser for converting said air extracted from said void space into condensate and dehumidified air, said greenhouse further comprises means for conducting at least part of said condensate

to the inner space of said greenhouse, said method comprising the step of conducting at least part of said condensate to the inner space of said greenhouse for adjusting the temperature and/or humidity in said inner space in function of the measured temperature and/or humidity at said inner space as compared to said temperature set value and/or humidity set value.

30.- A method according to any one of the claims 27 to 29, wherein said greenhouse further comprises means for heating and/or evaporating liquid in said inner space, said method comprises the step of heating and/or evaporating secondary water in said inner space for adjusting the temperature and/or humidity in said inner space in function of the measured temperature and/or humidity at said inner space as compared to said temperature set value and/or humidity set value

31.- A method according to claim 30, wherein said greenhouse further comprises means for providing secondary water to said heat exchanging means for cooling said extracted air from said void space, said method comprises the step of providing at least part of said secondary water used for cooling said extracted air to said means for heating and/or evaporating liquid in said inner space for adjusting the temperature and/or humidity of the air in said inner space in function of the measured temperature and/or humidity at said inner space as compared to said temperature set value and/or humidity set value.

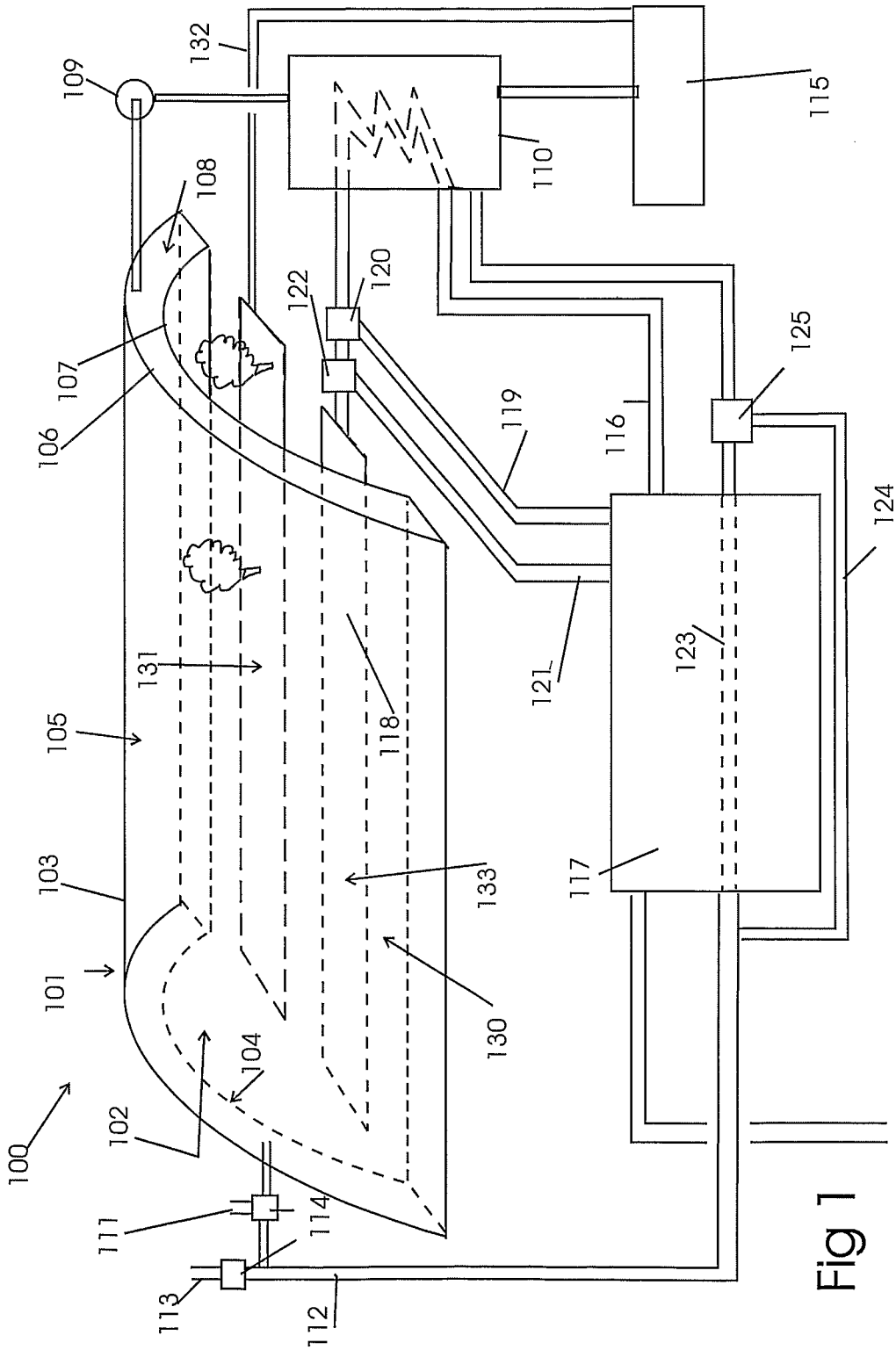
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Fig 1

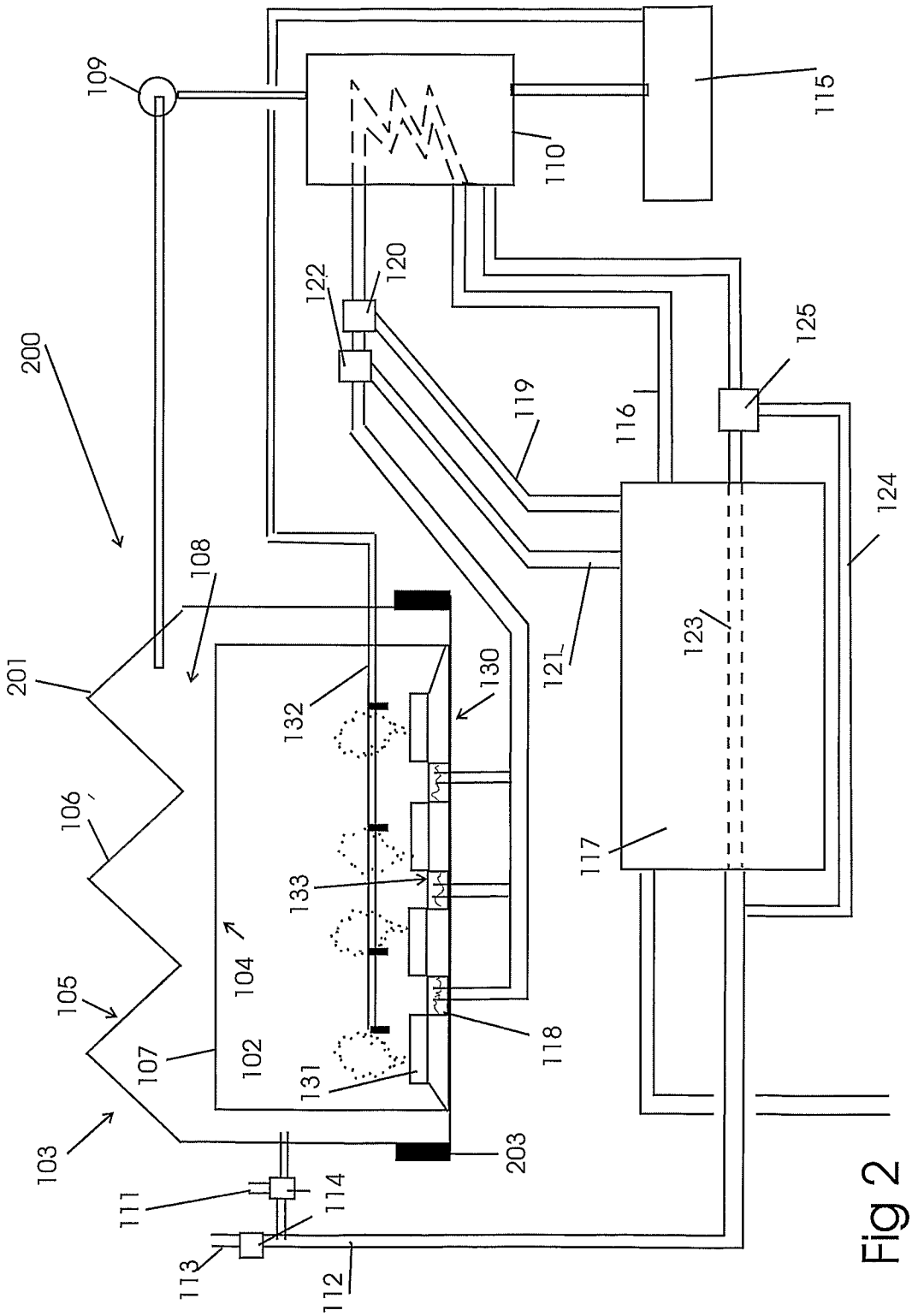
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Fig 2

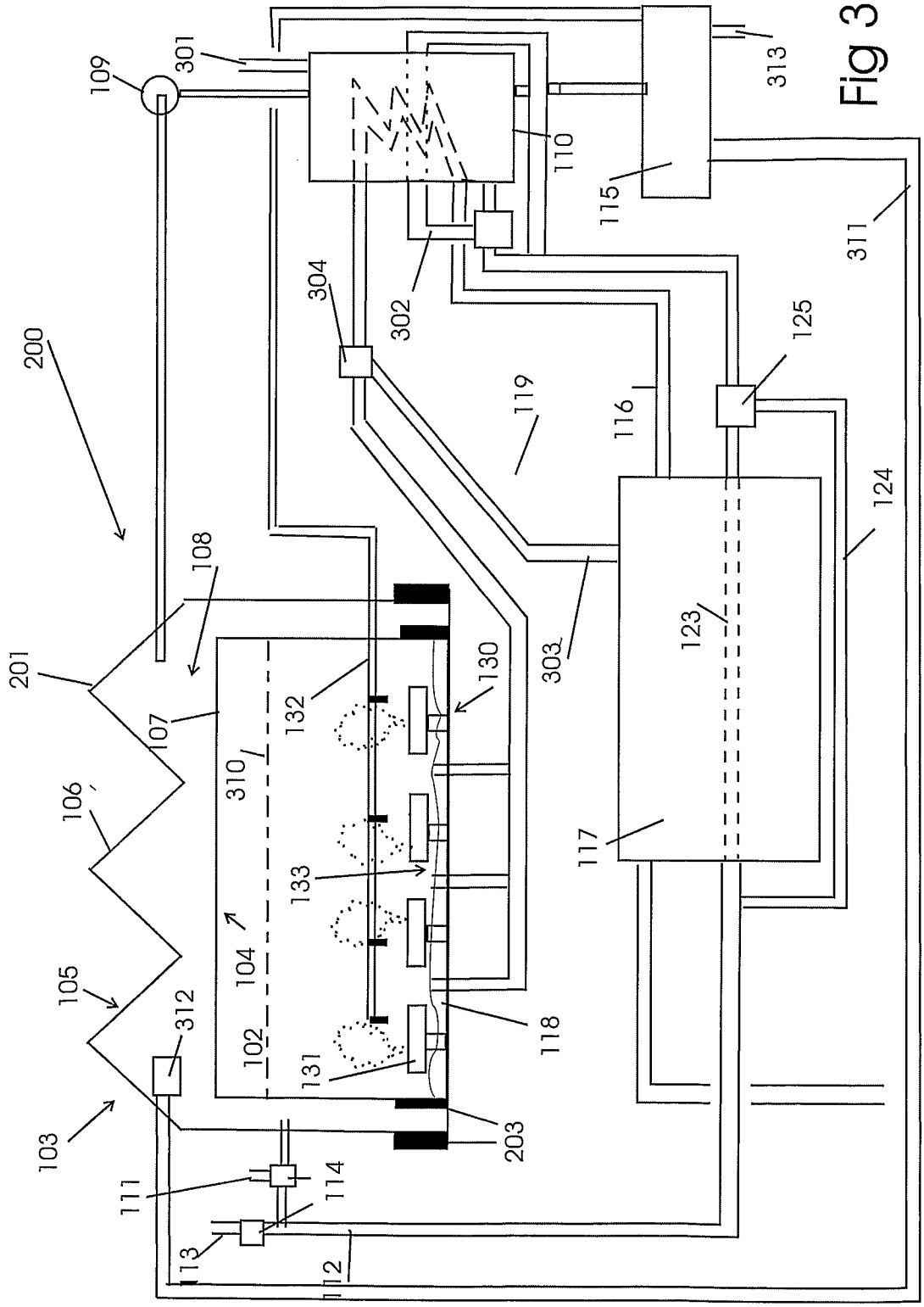
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Fig 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2006/000219

A. CLASSIFICATION OF SUBJECT MATTER
INV. A01G9/14 A01G9/24

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A01G

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

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	FR 2 600 230 A (UTILAIR) 24 December 1987 (1987-12-24) the whole document	1,24,25
A	FR 2 475 850 A (ELECTRICITE DE FRANCE) 21 August 1981 (1981-08-21) the whole document	1
A	DE 30 26 845 A1 (KIESEL,GEB. ROTHKEGEL,VERA) 11 February 1982 (1982-02-11) page 5, paragraph 4 - page 14, paragraph 2; figures 1-4	1

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
7 September 2006	14/09/2006

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	CALDENTEY POZO, F

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2006/000219

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
FR 2600230	A	24-12-1987	NONE	
FR 2475850	A	21-08-1981	NONE	
DE 3026845	A1	11-02-1982	NONE	