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(54) Title: ASSEMBLY FOR COMBINED ELECTRICAL POWER AND DISTILLED WATER GENERATION

(57) Abstract: Electrical power and distilled water generator comprising: - a combustion device (22) for driving an electrical power generator (21); - a membrane distillation system (3) comprising a heat transfer module for providing heat to a distillation module which comprises an evaporation part provided in a feed water flow passage, a condensation part provided adjacent to said evaporation part, and a hydrophobic porous membrane interposed between these parts, and a condenser unit fluidly connected to said condensation part, which condenser unit is coupled to a first cooling circuit, wherein said condensation part and/or said condenser unit are connected to a distillate flow passage; and - a cooling system (4) comprising an accumulator, and a condenser/ evaporator which is coupled to a second cooling circuit (42), - wherein said first and second cooling circuit are thermally coupled, and - wherein the assembly is provided with a primary heating circuit (5), which is coupled to the combustion device, the heat transfer module, and the accumulator.
ASSEMBLY FOR COMBINED ELECTRICAL POWER AND DISTILLED WATER GENERATION

BACKGROUND

The invention relates to an assembly for combined electrical power and distilled water generation. In particular, the invention relates to a mobile electrical power generator and water treatment device, which is able to be deployed as a fully stand-alone system.

An assembly for combined electrical power and distilled water generation, is, for example, disclosed in United States Patent Application Publication 2006/0130487. The assembly for electric power generation with distilled water output employs a combined cycle gas turbine power generation system for electrical power generation. A multistage evaporator uses steam drawn from the gas turbine as a heating medium to power the multistage evaporator for the production of distilled water. Residual steam output from the multistage evaporator is used as an energy source for an absorption refrigeration unit. The absorption refrigeration unit simultaneously preheats wastewater supplied to the multistage evaporator and provides chilled water to cool intake air for the combined cycle gas turbine power generation system. Thus, the system's efficiency is increased because the preheating of the wastewater supply to the multistage evaporator improves efficiency of the distillation process, while cooling of the gas turbine intake air increases power generated by the gas turbine, increasing both power and steam output from the combined cycle gas turbine power generation system.
However, a disadvantage of this known system is, that it operates at high temperatures, in particular using the steam from a gas turbine power generation system, which makes it difficult to employ such a system in a mobile electrical power generator and water treatment device, which is able to be deployed as a fully stand-alone system.

It is an object of the present invention to provide an assembly for efficiently generating electrical power and distilled water generation, in particular an assembly suitable for use in a mobile electrical power generator and water treatment device, which is able to be deployed as a fully stand-alone system.

SUMMARY OF THE INVENTION

According to a first aspect, the invention provides an assembly for combined electrical power and distilled water generation comprising:

- an electrical power generator and a combustion device for driving the electrical power generator;
- a membrane distillation system comprising a heat transfer module for providing heat to a distillation module, wherein the distillation module comprises an evaporation part provided in a feed water flow passage, a condensation part provided adjacent to said evaporation part, and a substantially fluid-impermeable, vapor permeable membrane interposed between said evaporation part and said condensation part, and a condenser unit which is arranged in fluid connection with said condensation part, wherein said condenser unit is coupled to a first cooling circuit, wherein said condensation part and/or said condenser unit are connected to a distillate flow passage; and
- an adsorption cooling system comprising an accumulator comprising solid adsorption material, a condenser and an evaporator, wherein the evaporator and/or the condenser are coupled to a second cooling circuit,
wherein said second cooling circuit is coupled to said first cooling circuit, and
wherein the assembly is provided with a primary heating circuit, which primary heating circuit is coupled to
the combustion device, the heat transfer module of the membrane distillation system, and the accumulator of the absorption cooling system.

In the assembly of the present invention the combustion device, the membrane distillation system and the absorption cooling system are all coupled to one primary heating circuit. This allows to use the heat generated by the combustion device, for heating the feed water for the membrane distillation system, and for generating cooling in the absorption cooling system, which cooling is used in the condenser unit of the membrane distillation system.

Providing one primary heating circuit, which takes up heat from the combustion device and delivers this heat to the membrane distillation system and the absorption cooling system, makes the assembly according to the invention particularly suitable for use in a mobile electrical power generator and water treatment device, in particular when the primary heating circuit is a closed circuit.

In an embodiment, the primary heating circuit comprises a heat transfer fluid and a pump for circulating said heat transfer fluid through the primary heating circuit. In an embodiment, the heat transfer fluid comprises a liquid. Preferably the heat transfer fluid comprises glycol or a water/glycol mixture. The heat transfer fluid takes up heat from the combustion device and thus provides the necessary cooling of the combustion device. When the temperature of the heat transfer fluid in the primary heating circuit is high enough, preferably in a range between 80 and 90 degrees Celsius, more preferably approximately 85 degrees Celsius, the membrane distillation system can process the feed water into a distilled water portion and brine. In addition, also the absorption cooling system can operate when the temperature of the heat transfer
fluid in the primary heating circuit is high enough, and no external cooling is necessary.

In an embodiment, the first cooling circuit and the second cooling circuit are coupled to form one single cooling circuit, preferably a closed cooling circuit.

In an alternative embodiment, the second cooling circuit and the first cooling circuit are thermally coupled via a first heat exchange unit. By providing a separated first and second cooling circuit, one of the cooling circuits, preferably the second cooling circuit, can be provided with an additional input/output for coupling this cooling circuit to an external supply of cooling medium, when available. Accordingly, the assembly according to this embodiment can use an external supply of cooling medium, when available, and allows to feed said external cooling medium in one of the substantially separate first or second cooling circuits, without the external cooling medium is introduced into the other one of the substantially separate first or second cooling circuits.

In an embodiment, the combustion device comprises a third cooling circuit for removing thermal energy from the combustion device, wherein the third cooling circuit and the primary heating circuit are thermally coupled via a second heat exchange unit. By providing a separated third cooling circuit which is arranged to take up heat from the combustion device and to deliver this heat to the primary heating circuit, the heat transfer fluid of the primary heating circuit is physically separated from the combustion device. Accordingly, in the assembly according to this embodiment a contamination of the heat transfer fluid of the primary heating circuit by possible contaminants from the combustion device, such as lubricants, oil or diesel, can be circumvented.

In an embodiment, the heat transfer module of the membrane distillation system comprises a second heating circuit for providing thermal energy to the heat transfer module, wherein the second heating circuit and the primary
heating circuit are thermally coupled via a third heat exchange unit. By providing a separated second heating circuit which is arranged to take up heat from the primary heating circuit and to deliver this heat to the heat transfer module of the membrane distillation system, the heat transfer fluid of the primary heating circuit is physically separated from the membrane distillation system. Accordingly, in the assembly according to this embodiment a contamination of the membrane distillation system by possible contaminants in the primary heating system can be circumvented.

In an embodiment, the accumulator of the absorption cooling system comprises a third heating circuit for providing thermal energy to the accumulator, wherein the third heating circuit and the primary heating circuit are thermally coupled via a fourth heat exchange unit. By providing a separated third heating circuit which is arranged to take up heat from the primary heating circuit and to deliver this heat to the accumulator of the absorption cooling system, the heat transfer fluid of the primary heating circuit is physically separated from the absorption cooling system. Accordingly, in the assembly according to this embodiment a contamination of the absorption cooling system by possible contaminants in the primary heating system can be circumvented.

In an embodiment, the assembly comprises one or more boilers, wherein the one or more boilers are arranged in fluid connection with the primary heating circuit for providing thermal energy to the primary heating circuit. An advantage of the assembly according to this embodiment is, that the production of distilled water can be continued even when the combustion device produces not enough heat energy for driving the membrane distillation system and/or the adsorption cooling system. When the combustion device produces not enough heat energy, for example when the demand for external electrical power is very low or even nil, the one or more boilers can act as a heat source for heating the
heat transfer fluid in the primary heating circuit to a level that the membrane distillation system can process the feed water into a distilled water portion and brine, and/or to operate the absorption cooling system. Accordingly, the assembly according to this embodiment can produce distilled water substantially independent from the production of external electrical power by the electrical power generator.

In an embodiment, the electrical power generator is electrically connected to the one or more boilers for providing electrical power to the one or more boilers. Although the one or more boilers may comprise a combustion unit for generating heat, it is preferred that the one or more boilers comprise electrical heat generators, which are preferably arranged to use electrical power from the electrical power generator for heating the heat transfer fluid in the primary heating circuit. Accordingly, the heat generated by the combustion device which is arranged to drive the electrical power generator for providing, inter alia, internal electrical power for supplying to the one or more boilers, also provides some heating of the heat transfer fluid. Thus, the heating capacity of the one or more boilers can be lower in comparison to the case where all heating of the heat transfer fluid is done by the one or more boilers, thus without any heating by the combustion device.

In an embodiment, the assembly comprises a sun boiler, wherein the sun boiler are arranged in fluid connection with the primary heating circuit for providing thermal energy to the primary heating circuit. In addition to or instead of the one or more boilers for providing thermal energy to the primary heating circuit, the assembly according to this embodiment further comprises a sun boiler for collecting the heat of the sun for heating the heat transfer fluid of the primary heating circuit.

In an embodiment, the membrane distillation system comprises a vacuum pump which is arranged for reducing an air pressure in at least the distillation module. The
specific boiling temperature of the feed water, in particular in the evaporation part of the distillation module, can be lowered by lowering the air pressure in said evaporation part using said vacuum pump. This allows to operate the membrane distillation system at temperatures well below the boiling temperature of water at atmospheric pressure, in particular well below 100 degrees Celsius.

In an embodiment, the electrical power generator is electrically connected to the membrane distillation system and the adsorption cooling system for providing electrical power to the membrane distillation system and the adsorption cooling system. In addition to providing external electrical power, the electrical power generator also provides the internal electrical power for operating the various systems of the assembly, in particular the membrane distillation system and the absorption cooling system. No external electrical power is required, and the assembly can be deployed as a fully stand-alone system.

In an embodiment, the assembly comprises a feed water input and a filter unit which is arranged between the feed water input and the membrane distillation system. In an embodiment, the filter unit comprises a disk filter. Preferably said disk filter is arranged filtering the feed input water in order to retain particles larger than approximately 20 micron in the filtering element. Preferably the disk filter is arranged for providing a cleaning cycle by means of a back-flush, preferably in such a way that the discs separate during the cleaning cycle. The filter unit provides a course filtering of the feed water, in particular to filter out course particles from the feed water, which course particles may adversely affect the operating of the membrane distillation system.

In an embodiment, the assembly comprises a feed water tank. Due to the feed water tank, the assembly can be employed at locations where there is no feed water supply available. Only when the feed water tank is close to empty, the assembly needs to be refilled by either moving the
assembly to a location with feed water supply or by bringing feed water to the assembly.

In an embodiment, the first cooling circuit is arranged in fluid connection with said feed water tank. Accordingly, the feed water from the feed water tank is used as a cooling liquid in the first cooling circuit to provide cooling to the condenser unit. The heat that is taken up by the feed water can be removed from the feed water by means of the absorption cooling system.

When the assembly is arranged at a location with feed water, the heated feed water from the condenser unit can be discharged out of the assembly, and fresh cool feed water can be taken in, in order to replenish the feed water. Accordingly the external feed water can be used for cooling the condenser unit of the membrane distillation system, and the absorption cooling system may at least partially be shut down.

According to a second aspect, the invention provides a use of an assembly or an embodiment as described above for the generation of electrical power and/or distilled water.

The various aspects and features described and shown in the specification can be applied, individually, wherever possible. These individual aspects, in particular the aspects and features described in the attached dependent claims, can be made subject of divisional patent applications.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be elucidated on the basis of an exemplary embodiment shown in the attached drawings, in which:

Figure 1 shows a schematic diagram of a first example of an assembly according to the invention,

Figure 2 shows a schematic diagram of a second
example of an assembly according to the invention,
Figure 3 shows a schematic diagram of the process control of the example of figure 2,
Figure 4 shows a schematic diagram of the water processing in the examples of figure 1 and 2,
Figure 5 shows a schematic diagram of a membrane distillation system for use in the assembly of the invention,
Figure 6 shows a schematic diagram of an absorption cooling system for use in the assembly of the invention, and
Figure 7 shows schematically an assembly according to the invention arranged inside a mobile container.

It is noted that equal reference numerals in different figures refer to equal or corresponding parts.

DETAILED DESCRIPTION OF THE INVENTION

Figure 1 shows a schematic diagram of an example of an assembly 1 for combined electrical power and distilled water generation. The assembly 1 combines an engine-generator system 2, a membrane distillation system 3 and an absorption cooling system 4, which are all coupled to a primary heating circuit 5. The primary heating circuit 5 comprises a heat transfer fluid and a pump 51 for circulating said heat transfer fluid through the primary heating circuit 5. In this example, the heat transfer fluid preferably comprises glycol or a water/glycol mixture.

The engine-generator system 2 comprises an electrical power generator and a combustion device for driving the electrical power generator. In this example, the engine-generator system 2 comprises a diesel generator which is a combination of a diesel engine 22 with an electrical generator 21 to generate electrical energy. The generated electrical energy is used as an internal power supply 26 to power the various components of the assembly 1 as described in more detail below, and as an external power supply 27 for
powering various appliances and/or equipment outside said assembly 1.

The combustion device, in this example the diesel engine 22, comprises a diesel engine cooling circuit 23 for removing thermal energy from the diesel engine 22. This diesel engine cooling circuit 23 corresponds to the 'third cooling circuit' as mentioned in the claims.

The thermal energy removed from the diesel engine 22 is transferred to the heat transfer fluid of the primary heating circuit 5 via a heat exchange unit 52 which corresponds to the 'Second heat exchange unit' as mentioned in the claims.

In case the primary heating circuit 5 is not able to take up enough thermal energy from the diesel engine cooling circuit 23, any excess of thermal energy can be removed from the diesel engine cooling circuit 23 using a radiator/fan unit 24 in the diesel engine cooling circuit 23 which is arranged to remove the excess thermal energy via the expelled air 25.

Preferably, the radiator/fan unit 24 is provided with a fan comprising an adaptable fan speed. If the primary heating circuit 5 cannot take up any thermal energy from the diesel engine cooling circuit 23, the fan is operated at high speed in order to provide enough cooling to the diesel engine 22. However in case that the primary heating circuit 5 takes up substantially all excess thermal energy from the diesel engine, the fan can be switched off in order to save energy. In case the primary heating circuit 5 can only take up part of the excess thermal energy generated by the diesel engine, the fan speed is adapted to a lower speed in order to provide enough cooling and to save energy.

The membrane distillation system 3 comprises for example a system as described in EP 2606953 from Aquaver B.V. which is fully incorporated herein by reference. The membrane distillation system 3 is described in more detail further on in the description with reference to figure 5.

The membrane distillation system 3 comprises a
heat transfer module for heating the feed water. The heat transfer module of the membrane distillation system is coupled to the primary heating circuit 5 in order to take thermal energy from the primary heating circuit 5 for operating the membrane distillation system 3. In particular, the heat transfer module of the membrane distillation system comprises a second heating circuit 31 for providing thermal energy to the heat transfer module. The second heating circuit 31 and the primary heating circuit 5 are thermally coupled via a heat exchange unit 53 which corresponds to the 'third heat exchange unit' as mentioned in the claims. In addition, the membrane distillation system 3 comprises a condenser unit which is coupled to a first cooling circuit 32.

The adsorption cooling system 4 comprises an accumulator comprising solid adsorption material, for example silica gel. The adsorption cooling system 4 is described in more detail further on in the description with reference to figure 6.

The accumulator of the absorption cooling system 4 is coupled to the primary heating circuit 5 in order to take thermal energy from the primary heating circuit 5 for operating the adsorption cooling system 4. In particular, the accumulator of the absorption cooling system 4 comprises a third heating circuit 41 for providing thermal energy to the accumulator, wherein the third heating circuit 41 and the primary heating circuit 5 are thermally coupled via heat exchange unit 54 which corresponds to the 'fourth heat exchange unit' as mentioned in the claims.

Furthermore, the adsorption cooling system 4 comprises a condenser and an evaporator, wherein the evaporator and/or the condenser are coupled to a second cooling circuit 42. As shown in figure 1, the second cooling circuit 42 is coupled to said first cooling circuit 32. In particular, the second cooling circuit 42 and the first cooling circuit 32 are thermally coupled via a heat exchange unit 34 which correspond to the 'first heat exchange unit'
as mentioned in the claims. Thus the adsorption cooling system 4 is used for cooling the condenser unit of the membrane distillation system 3.

The arrangement of the adsorption cooling system 4 makes the assembly independent from external cooling facilities. However, when in use, the adsorption cooling system 4 is powered by the electrical generator 21. Thus, when cooling facilities are present at the location of the assembly, these facilities can be used instead of the adsorption cooling system 4, and the adsorption cooling system 4 can be switched off in order to save energy. In order to couple external cooling facilities to the assembly 1, the second cooling circuit 42 is provided with an input/output connector 8 for connecting an optional external cooling facility to the assembly 1.

The absorption cooling system 4 is further provided with a heat discharge unit 43 to remove the excess thermal energy from the adsorption cooling system 4. Preferably, the heat discharge unit 43 comprises a radiator and fan which is arranged to remove the excess thermal energy via the expelled air 44.

In the assembly according to the first example as described above, the 'waste' heat from an electrical power generator 2 is used in a membrane distillation system 3 for the production of distilled water, and in an absorption cooling system 4 to provide cooling to the membrane distillation system 3.

In the second example as shown in figure 2, the assembly 10 is further provided with one or more boilers 61, 62, wherein the one or more boilers 61, 62 are arranged in fluid connection with the primary heating circuit 5 for providing thermal energy to the primary heating circuit, in case the demand for thermal energy from the membrane distillation system 3 and/or the adsorption cooling system 4 is larger than the amount of thermal energy delivered to the primary heating circuit 5 by the diesel engine 22.
advantage of the system according to this second example is, that the production of distilled water can be continued even when the diesel engine 22 produces not enough heat energy for driving the membrane distillation system 3 and/or the adsorption cooling system 4. When the diesel engine 22 produces not enough heat energy, the boilers 61, 62 act as heat source for:
- the membrane distillation system 3 and the adsorption cooling system 4, when no external cooling facilities are available, or
- the membrane distillation system 3, when external cooling facilities are available.
In the system according to this second example, the generation of distilled water is substantially independent from the generation of electrical power, in particular the generation of electrical power for external power supply 27.
Although the boilers may use a combustion process for heating the heat transfer fluid of the primary heating circuit 5, it is preferred that the electrical power generator 2 is electrically connected to the one or more boilers 61, 62 for providing electrical power to the one or more boilers 61, 62 for electrically heating the heat transfer fluid. The use of electrical boilers 61, 62 is in particular advantageous because they provide a load to the electrical power generator 2, at least when starting the assembly 10. Due to this applied load, the diesel engine 22 produces thermal energy which is used for heating the heat transfer fluid of the primary heating circuit 5, and the one or more electrical boilers 61, 62 are also used for heating the heat transfer fluid. When the temperature of the heat transfer fluid in the primary heating circuit 5 is high enough, for example in a range between 80 and 90 degrees Celsius, preferably approximately 85 degrees Celsius, the membrane distillation system 3 starts operating to process the feed water into a distilled water and brine. In addition, when no external cooling is applied, also the absorption cooling system 4 starts operating when the
temperature of the heat transfer fluid in the primary heating circuit 5 is high enough.

In an embodiment one or more of said boilers 61, 62 may comprise a sun boiler in order to use the heat of the sun for heating the heat transfer fluid of the primary heating circuit 5 and to save energy, in particular when the demand for external electrical power is low and the production of distilled water needs to be sustained.

Figure 3 shows a schematic diagram of the process control of the example of figure 2. As shown in figure 3, the assembly may be provided with an input terminal 71, which is used by an operator to select whether there is external cooling available 72 or not 73. The input terminal 71 transmits 74 this input to a controller 7.

When at the input terminal 71 it is selected that external cooling is available 72, the controller 7 activates 75 the valves 81 in order to fluidly connect the input/output connector 8 to the first heat exchange unit 34. In addition, the controller is coupled 76 to the absorption cooling system 4, and shuts down the absorption cooling system 4.

When at the input terminal 71 it is selected that no external cooling is available 73, the controller activates 75 the valves 81 to fluidly connect the absorption cooling system 4 with the first heat exchange unit 34, and activates the absorption cooling system 4.

In both situations, the controller 7 is arranged for controlling the boilers 61, 62 as follows: The electrical power generator 2 is also connected to the controller 7 and provides a load signal 77 representative for the total load or external load on the electrical power generator 2. The controller 7 is also connected to the boilers 61, 62 and is arranged for activating one or more of said boilers 61, 62 in dependence of the load signal 77 from the electrical power generator 2. In particular, when the total load on the electrical power generator 2 is low or the
external load on the electrical power generator 2 is substantially zero, the controller 7 activates the boilers 61, 62 for heating the heat transfer fluid of the primary heating circuit 5. When the total load or the external load on the electrical power generator 2 is maximum, the controller 7 shuts down the boilers 61, 62. When the total load or the external load on the electrical power generator 2 is intermediate - between low and maximum - the controller 7 adjust the activation of one or more of said boilers 61, 62 so that the heat transfer fluid is heated both by the combustion device 22 and one or more of said boilers 61, 62 to a predetermined temperature, which predetermined temperature is adjusted to a level that at least the membrane distillation system 3, and also the absorption cooling system 4 when no external cooling is available, can operate for distillation of the feed water. The controller 7 is for example arranged to provide a temperature of the heating fluid inside the primary heating circuit 5 of approximately 85 degrees Celsius at the entrance of the heat exchange unit 53 for the membrane distillation system 3.

In addition, in case no feed water needs to be distilled, the membrane distillation system 3 may be shut down. In this situation the membrane distillation system 3 does not take away the heat from the heat transfer fluid of the primary heating circuit 5, and the heat of the combustion device 22 cannot be dissipated to the primary heating circuit 5. Accordingly, the controller 7 is arranged to provide a signal 77' to the radiator/fan unit 24, to activate and/or control the speed of the radiator/fan unit 24 to remove the excess of thermal energy from the combustion device 22 using the radiator/fan unit 24 in the cooling circuit 23 of the combustion device 22, which is arranged to remove the excess thermal energy via the expelled air 25.

Figure 4 shows a schematic diagram of the water processing in an assembly according to the invention, which
water processing may be used in the examples of figure 1 and 2. It is remarked that the assembly according to the invention is preferably arranged inside a module, in particular in a mobile container 9 as for example shown in figure 7.

Inside the mobile container 9, a feed water tank 95 is arranged. Due to the feed water tank 95, the assembly is provided with its own feed water supply, and can be employed at locations where there is no feed water source available. When the feed water tank 95 needs to be refilled, the feed water tank 95 can be refilled by either moving the mobile container 9 to a location with a feed water source or by bringing feed water to the mobile container 9.

When the mobile container 9 is arranged near a feed water source 100, the assembly can take-in feed water by coupling a pipe or a hose to a feed water input connector 101, which pipe or hose is provided with an intake filter 91, for example a filter basket, to substantially prevent large debris to be sucked-up into the pipe or hose and end-up in the feed water pump 92. The feed water from the feed water source is pumped by the feed water pump 92 through a filter unit 93 which is arranged between the feed water input 101 and the feed water tank 95. Preferably, the filter unit 93 comprises a disk filter which is arranged for filtering the input feed water in order to retain particles larger than approximately 20 micron in its filtering element(s). Preferably the disk filter is arranged for providing a cleaning cycle by means of a back-flush 102, preferably in such a way that the discs separate during the cleaning cycle. In the example shown in figure 4, feed water from the feed water tank 95 is used for this back-flush 102, which back-flushed feed water is guided 103 towards a back-flush output 104, and is expelled out of the mobile container 9 and may be directed back to the feed water source 100.

For processing the feed water in the assembly 1, 10 of the invention, the feed water from the feed water tank
95 is directed 105 to the membrane distillation system 3, which will be described in more detail below with reference to figure 5. Before the feed water enters the membrane distillation system 3 an anti-scalant agent from an anti-sealant tank 106 may be added to the feed water by means of an anti-scalant pump 107.

Inside the membrane distillation system 3, part of the feed water is evaporated, separated from the feed water by means of a membrane, and condensed to form distilled water. The distilled water is directed 108 to a distilled water tank 98, which is connected to a distilled water output connector 99. The distilled water can be re-mineralized and is then available as drinking water. The membrane distillation system 3 is a very flexible system with respect to the feed water; it can use fresh, brackish or salt water for the production of distilled water. The remaining, non-evaporated feed water, also denoted as 'Brine' is directed 109 to a brine water tank 96, which is connected to a brine water output connector 97. The brine may be used for flushing toilets for example.

As shown in figure 4, the assembly may be provided with a chlorine tank 110 and a chlorine pump 111 for adding an amount of chlorine into the distilled water tank 98 and/or the brine water tank 96.

As discussed above, the membrane distillation system 3 receives thermal energy from the primary heating circuit 5, which thermal energy is transferred to the membrane distillation system 3 via a second heating circuit 31 which is thermally coupled to the primary heating circuit 5 via a heat exchange unit 53. In addition, the membrane distillation system 3 comprises a condenser unit which is coupled to a first cooling circuit 32.

The example as depicted in figure 4, shows a second example of a cooling circuit 112, 113, 114, in which the feed water from the feed water tank 95 is used as a cooling fluid. When the assembly 9 is arranged at a feed
water source 100 and the feed water temperature is suitably low to act as a cooling fluid for the membrane distillation system 3, feed water from the feed water tank 95 is introduced into the cooling circuit 112 by opening a first valve 115 in the cooling circuit. The feed water is provided to the condenser unit of the membrane distillation system 3 via a suitable tubing 112, 113. After having flown through the membrane distillation system 3, in particular the condenser unit thereof, the feed water is directed 114 to an cooling water output connector 116 and is expelled out of the mobile container 9 and may be directed back to the feed water source 100.

When no feed water source 100 is available or the temperature of the feed water is too high to be usable as a cooling fluid, the absorption cooling system 4 is activated for cooling the feed water from the feed water tank 95 before it is provided 113 to the membrane distillation system 3, in particular the condenser unit thereof. When the assembly 9 is operated remote from a feed water source 100, and/or as a fully stand-alone system, the feed water that has flown through the membrane distillation system 3, in particular the condenser unit thereof, is directed 114' back to the feed water tank 95, by activating the valve unit 117. In this situation, the cooling water circuit 112, 113, 114, 114' is a substantially closed circuit comprising the feed water tank 95.

It is noted that in the example shown in figure 4, the feed water used as cooling liquid is arranged to flow through the membrane distillation system 3, in particular the condenser unit thereof. However, as an alternative, the feed water used as cooling liquid may also be provided to the heat exchanged unit 34 of the first cooling circuit 32 as shown in figures 1, 2 and 3.

Figure 5 shows a schematic diagram of a membrane distillation system 3 for use in the assembly of the invention. The membrane distillation system 3 comprises a
heat transfer module 301 for providing a heat flux 302 to a distillation module 303. In particular, the heat transfer module 301 of the membrane distillation system is connected to the second heating circuit 31 for providing thermal energy to the heat transfer module 301. The second heating circuit 31 is coupled to the primary heating circuit via the heat exchange unit 53, as described above with reference to figures 1-4.

The distillation module 303 comprises a feed water flow passage 304 for providing a flow of feed water 305 through said distillation module 303. The feed water flow passage 304 comprises an evaporation part 304' inside said distillation module 303. In the example shown in figure 5, the evaporation part 304' of the feed water flow passage 304 is provided with a spacer 306. Due to the heat flux 302, part of the feed water 305 in the evaporation part 304' of the feed water flow passage 304 will evaporate, and the resulting water vapor 307 can pass the substantially fluid-impermeable, vapor permeable membrane 308 into a condensation part 309 provided adjacent to said evaporation part 304'. In said condensation part 309, the water vapor 307 can condensate to form distilled liquid 310.

As schematically indicated in figure 5, the combination of an evaporation part 304', an condensation part 309 and the interposed vapor permeable membrane 308 forms one stage in the distillation module 303 which may be preceded by a preceding stage PS and may be followed by a next stage NS, in order to provide multiple stages in order to increase the yield of the distilled liquid 310.

At the end of the multiple stages, the distillation module 303 comprises a condenser unit 311 which is arranged in fluid connection with said condensation part 309, wherein said condenser unit 311 comprising a condenser 312 which is coupled to the first cooling circuit 32; 112, 113, 114. At the condenser 312 in the condenser unit 311 the vapor can condensate into distilled liquid 310. As schematically indicated in figure 5, the condensation part
309 and/or said condenser unit 311 are connected to a distillate flow passage 313 in order to direct the distilled water to a distillated water tank 98, which is connected to an distillated water output connector 99, as for example shown in figure 4.

In the example shown in figure 5, feed water is preferably used in the condenser 312. In the condenser 312 this feed water takes up heat from the water vapor 307 and is thus pre-heated by the water vapor 307. At least part of this pre-heated feed water is then supplied to the feed water flow passage 304.

The remaining, non-evaporated feed water, also denoted as 'brine', from said water flow passage 304 is provided to a brine flow passage 314 in order to direct the brine to a brine water tank 96, which is connected to a brine water output connector 97, as for example shown in figure 4.

Figure 6 shows a schematic diagram of an absorption cooling system 4 for use in the assembly of the invention. The absorption cooling system 4 comprises two modules 45, 46 each comprising
a reactor part filled with silica-gel and a first heat exchange member 47, 48,
a condenser/evaporator part comprising a second heat exchange member 49, 50, and
a heat discharge unit 43 to remove the excess thermal energy from the adsorption cooling system 4. Preferably, the heat discharge unit 43 comprises a radiator and fan which is arranged to remove the excess thermal energy via the expelled air 44.

When operational, one of said modules, in particular the first module 45 is Recharged' and the other one of said modules, in particular the second module 46 is Emptied', as schematically shown in figure 6.

In this situation, the reactor part of the first module 45 is heated by the heat from the primary heating
circuit 5 by connecting the first heat exchange member 47 to the third heating circuit 41. The silica-gel in the reactor part of the first module 45 is dried by this heating. The second heat exchange member 49 is connected to and cooled by the heat discharge unit 43. The water vapor from the silica-gel will condensate in second heat exchange member 49 due to the lower temperature as provided by the heat discharge unit 43.

The heat discharge unit 43 is also connected to the first heat exchange member 48 of the reactor part of the second module 46, and the silica-gel in the reactor part of the second module 46 is cooled by the heat discharge unit 43 starts to absorb water which results in a reduction of the pressure inside said second module 46. This reduction of the pressure inside said second module 46 brings the water in the condenser/evaporator part of the second module 46 to the boil. This boiling extracts heat from the second heat exchange member 50 of the second module 46, which is coupled to the second cooling circuit 42, and the heat exchange unit 34. Thus the adsorption cooling system 4 is used for cooling the condenser unit of the membrane distillation system 3.

After a certain amount of time, the working of the first and second modules 45, 46 are reversed. In particular, the first heat exchange member 47 of the first module 45 is connected to the heat discharge unit 43 and the second heat exchange member 49 of the first module 45 is connected to the second cooling circuit 42. In addition, the first heat exchange member 48 of the second module 46 is connected to the third heating circuit 41 and the second heat exchange member 50 of the second module 46 is connected to the heat discharge unit 43. In this situation, the first module 45 is 'Emptied' and the second module 46 is 'Recharged'. By repeatedly reversing the working of the first and second modules 45, 46, the adsorption cooling system 4 can convert the heat from the primary heating circuit 5 into cooling for the membrane distillation system 3.
Figure 7 shows schematically an assembly according to the invention arranged inside a mobile container 100. The interior of the container 9 is divided into two compartments by three large tanks: a feed water tank 95, a brine water tank 96, and a distilled water tank 97. On one side of the three large tanks, the electrical power generator/diesel engine 2 is arranged on top of a diesel tank 94. On the other side of the three large tanks, the membrane distillation system 3, several absorption cooling systems 4, 4', 4", one or more boilers 61, 62, a feed water filter unit 93, and a control unit 7 are arranged. The various components are suitable connected by tubing and electrical wiring in accordance with one or more of the examples as described above with reference to one or more of the figures 1 to 6.

It is to be understood that the above description is included to illustrate the operation of the preferred embodiments and is not meant to limit the scope of the invention. From the above discussion, many variations will be apparent to one skilled in the art that would yet be encompassed by the spirit and scope of the present invention.

In summary, the invention relates to an electrical power and distilled water generator comprising: a combustion device for driving an electrical power generator; a membrane distillation system comprising a heat transfer module for providing heat to a distillation module which comprises an evaporation part provided in a feed water flow passage, a condensation part provided adjacent to said evaporation part, and a hydrophobic porous membrane interposed between these parts, and a condenser unit fluidly connected to said condensation part, which condenser unit is coupled to a first cooling circuit, wherein said condensation part and/or said condenser unit are connected.
to a distillate flow passage; and

a cooling system comprising an accumulator, and a
condenser/evaporator which is coupled to a second cooling circuit,

wherein said first and second cooling circuit are thermally coupled, and

wherein the assembly is provided with a primary heating circuit, which is coupled to the combustion device, the heat transfer module, and the accumulator.
1. Assembly for combined electrical power and distilled water generation comprising:
an electrical power generator and a combustion device for driving the electrical power generator;
a membrane distillation system comprising a heat transfer module for providing heat to a distillation module, wherein the distillation module comprises an evaporation part provided in a feed water flow passage, a condensation part provided adjacent to said evaporation part, and a substantially fluid-impermeable, vapor permeable membrane interposed between said evaporation part and said condensation part, and a condenser unit which is arranged in fluid connection with said condensation part, wherein said condenser unit is coupled to a first cooling circuit, wherein said condensation part and/or said condenser unit are connected to a distillate flow passage; and
an adsorption cooling system comprising an accumulator comprising solid adsorption material, a condenser and an evaporator, wherein the evaporator and/or the condenser are coupled to a second cooling circuit, wherein said second cooling circuit is coupled to said first cooling circuit, and wherein the assembly is provided with a primary heating circuit, which primary heating circuit is coupled to the combustion device, the heat transfer module of the membrane distillation system, and the accumulator of the absorption cooling system.

2. Assembly according to claim 1, wherein the second cooling circuit and the first cooling circuit are thermally coupled via a first heat exchange unit.

3. Assembly according to claim 1 or 2, wherein the combustion device comprises a third cooling circuit for removing thermal energy from the combustion device, wherein
the third cooling circuit and the primary heating circuit are thermally coupled via a second heat exchange unit.

4. Assembly according to claim 1, 2 or 3, wherein the heat transfer module of the membrane distillation system comprises a second heating circuit for providing thermal energy to the heat transfer module, wherein the second heating circuit and the primary heating circuit are thermally coupled via a second heat exchange unit.

5. Assembly according to any one of the claims 1 - 4, wherein the accumulator of the absorption cooling system comprises a third heating circuit for providing thermal energy to the accumulator, wherein the third heating circuit and the primary heating circuit are thermally coupled via a fourth heat exchange unit.

6. Assembly according to any one the claims 1 - 5, wherein the assembly comprises one or more boilers, wherein the one or more boilers are arranged in fluid connection with the primary heating circuit for providing thermal energy to the primary heating circuit.

7. Assembly according to claim 6, wherein the electrical power generator is electrically connected to the one or more boilers for providing electrical power to the one or more boilers.

8. Assembly according to any one of the claims 1 - 7, wherein the membrane distillation system comprises a vacuum pump which is arranged for reducing an air pressure in at least the distillation module.

9. Assembly according to any one of the claims 1 - 8, wherein the electrical power generator is electrically connected to the membrane distillation system and the adsorption cooling system for providing electrical power to the membrane distillation system and the adsorption cooling system.

10. Assembly according to any one of the claims 1 - 9, wherein the assembly comprises a feed water input and a filter unit which is arranged between the feed water input and the membrane distillation system.
11. Assembly according to claim 10, wherein the filter unit comprises a disk filter.

12. Assembly according to any one of the claims 1 - 11, wherein the assembly comprises a feed water tank.

13. Assembly according to claim 12, wherein the first cooling circuit is arranged in fluid connection with said feed water tank.

14. Assembly according to any one of the claims 1 - 13, wherein the assembly comprises a sun boiler, wherein the sun boiler are arranged in fluid connection with the primary heating circuit for providing thermal energy to the primary heating circuit.

15. Assembly according to any one of the claims 1 - 14, wherein the primary heating circuit comprises a heat transfer fluid and a pump for circulating said heat transfer fluid through the primary heating circuit, wherein the heat transfer fluid preferably comprises glycol, preferably the heat transfer fluid comprises a water/glycol mixture.

16. Use of an assembly according to any one of the previous claims for the generation of electrical power and/or distilled water.

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BP/HZ
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

INV. F01K17/04 C02F1/16

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)

F01K C02F B01D F02G F25B

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 practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Date of the actual completion of the international search

18 January 2016

Date of mailing of the international search report

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