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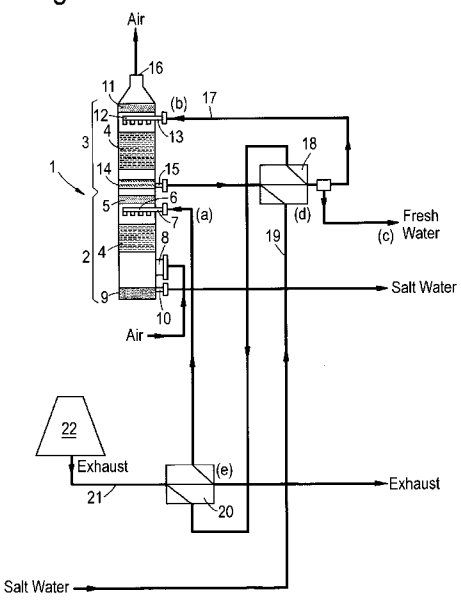
(54) Title: DESALINATION METHOD

Fig.1



(57) Abstract: There is disclosed a method for desalination of salt water in order to produce substantially fresh water. The method involves (a) passing a flow of salt water into an evaporator (2) and therein evaporating at least a portion of the salt water to form water vapour. The method also involves (b) passing the water vapour into heat exchange relationship with a colder fluid (17) so that at least a portion of the water vapour condenses into fresh water. At least a portion of the fresh water that condenses in step (b) is collected in step (c). One embodiment of the invention is characterised by the additional step of (d) passing substantially the entire flow of salt water (19) into heat exchange relationship with the colder fluid (17) to cool the fluid and heat the salt water prior to step (a). In another embodiment of the method, the step (a) of passing the flow of salt water into an evaporator involves feeding substantially the entire said flow of salt water into the evaporator (2) at a single stream. A further method of the present invention involves passing the flow of salt water (19) into heat exchange relationship with exhaust gases (21) from a heat engine (22) so as to cool the exhaust gases and heat the water prior to step (a).

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DESALINATION METHOD

The present invention relates to a desalination method for producing substantially fresh water from salt water. More particularly, the invention relates to desalination methods involving evaporation of salt water to form water vapour and subsequent condensation of the water vapour into fresh water.

The term "salt water" is used herein to refer to water having a substantial salt content, and the term "fresh water" is used herein to refer to water without substantial salt content.

Previously proposed desalination methods for recovering substantially fresh water from salt water generally fall into two main categories; namely thermal processes and non-thermal processes. The most commonly used non-thermal desalination process uses the principal of Reverse Osmosis in which pressure is used to force a solution through a semi permeable membrane which retains the solute on one side and allows the pure solvent (i.e. the fresh water) to pass to the other side. This process requires that a high pressure be exerted on the high concentration side of the membrane (typically in the region of 40 to 70 bar for sea water) which is higher than the osmotic pressure. Reverse Osmosis plants involve high capital investment, and also involve relatively high operating costs making them expensive to operate.

Two examples of thermal desalination processes are Multi Effect Distillation (MED) and Multi Stage Flash (MSF) processes, both of which involve heating the salt water, for example by the use of steam from a steam turbine in order to drive the process. The sea water is evaporated and condensed in a number of successive stages in order to

recover substantially pure water by lowering the operating pressure continuously in each section of the process. Both of these technologies are well proven and, indeed, most commercial desalination plants in operation today use one of these thermal methods, but operate best at very large scale with resultant very high capital investment costs. Nevertheless, it has been proposed previously to operate desalination plants on ships using the MED technology in much smaller scale plants.

Whilst the MED and MSF processes mentioned above use only the salt water as the working fluid, other thermal desalination processes have been proposed which use a carrier gas such as air in conjunction with the salt water to evaporate pure water from the salt water into the carrier gas. US 5,096,543 discloses such a method in which waste heat from a steam turbine engine is used to heat the salt water in a steam condenser, after which the heated salt water is sprayed into a packed bed evaporating column to humidify the carrier gas. The humidified carrier gas is then condensed in a condenser which can either take the form of a packed bed direct-contact type or a surface condenser type.

The various prior art desalination methods proposed above suffer from problems of efficiency and production costs and there is therefore a need for a more efficient thermal desalination process.

It is therefore an object of the present invention to provide an improved desalination method for producing substantially fresh water from salt water.

According to a first aspect of the invention, there is provided a desalination method for producing substantially fresh water from salt water, the method comprising the steps of: (a) passing a flow of salt water into an evaporator and therein evaporating at least a portion of

the salt water to form water vapour; (b) passing the water vapour into heat exchange relationship with a colder fluid so that at least a portion of the water vapour condenses into fresh water; and (c) collecting at least a portion of the fresh water that condenses in step (b), characterised by the additional step of (d) passing substantially the entire said flow of salt water into heat exchange relationship with said colder fluid to cool said fluid and heat the salt water prior to step (a).

According to another aspect of the invention, there is provided a desalination method for producing substantially fresh water from salt water, the method comprising the steps of: (a)passing a flow of salt water into an evaporator and therein evaporating at least a portion of the salt water to form water vapour; (b) passing the water vapour into heat exchange relationship with a colder fluid so that at least a portion of the water vapour condenses into fresh water; and (c) collecting at least a portion of the fresh water that condenses in step (b), characterised by the additional step of (d) passing at least part of said flow of salt water into heat exchange relationship with said colder fluid to cool said fluid and heat the salt water prior to step (a), and wherein said step (a) of passing the flow of salt water into an evaporator involves feeding substantially the entire said flow of salt water into the evaporator as a single stream.

Additionally, the method may comprise the step of (e) passing substantially the entire flow of salt water which is passed into heat exchange relationship with said colder fluid in step (d) into heat exchange relationship with exhaust gases from a heat engine so as to cool the exhaust gases and heat the water prior to step (a).

According to a further aspect of the invention, there is provided a desalination method for producing

substantially fresh water from salt water, the method comprising the steps of: (a) passing a flow of salt water into an evaporator and therein evaporating at least a portion of the salt water to form water vapour; (b) passing the water vapour into heat exchange relationship with a colder fluid so that at least a portion of the water vapour condenses into fresh water; and (c) collecting at least a portion of the fresh water that condenses in step (b), characterised by the additional steps of (d) passing at least part of said flow of salt water into heat exchange relationship with said colder fluid to cool said fluid and heat the salt water, and then (e) passing said part of the flow of salt water into heat exchange relationship with exhaust gases from a heat engine so as to cool the exhaust gases and heat the water prior to step (a).

Preferably, said step (a) of passing the flow of salt water into an evaporator involves feeding substantially the entire said flow of salt water into the evaporator as a single stream.

The method may include the additional step of (f) passing part of the flow of salt water into heat exchange relationship with the heat engine so as to cool the engine and heat the water prior to step (a).

In such a method, said part of the flow of from step (e) and said part of the flow of from step (f) are preferably combined into a single stream prior to step (a). The colder fluid of steps (b) and (d) is preferably substantially fresh water previously obtained by step (b). In preferred embodiments of the method, step (d) involves circulating the fresh water obtained by step (b) through a heat exchanger, and then feeding a portion of the fresh water exiting the heat exchanger back into heat exchange relationship with the water vapour in step (b), and wherein step (c) involves collecting the remaining portion of the

fresh water exiting the heat exchanger.

The method may be such that step (d) involves passing the flow of salt water into direct heat exchange relationship with the colder fluid. However, in an alternative method, step (d) may instead involve passing the flow of salt water into indirect heat exchange relationship with the colder fluid, in which case step (d) preferably involves (g) passing the flow of salt water into direct heat exchange relationship with a coolant fluid, and then (h) passing said coolant fluid into direct heat exchange relationship with said colder fluid.

Said coolant fluid may flow around a substantially closed circuit between heat exchange relationship with the flow of salt water, and heat exchange relationship with said colder fluid.

The method may include the additional step of (i) passing said coolant fluid into heat exchange relationship with an additional coolant fluid (such as air or water), after step (g) but before step (h).

Where the method of the invention is used with a heat engine as mentioned above, the heat engine may be a combustion engine or a fuel cell.

The heat engine may be a combustion engine in the form of a gas turbine engine, and in certain embodiments of the method, it envisaged that the gas turbine could be arranged to operate under an advanced thermodynamic cycle producing exhaust gases containing substantial water vapour, in which case it is envisaged that the method may further comprise the step of (j) passing the exhaust gases from step (e) into heat exchange relationship with a colder fluid so that water vapour in the exhaust gases condenses into fresh water.

Such an advanced-cycle method may further comprise the step of (k) feeding at least a portion of the fresh water

condensed in step (j) back to the gas turbine engine in the form of water vapour in the flow of compressed air passing through the engine, prior to the combustion stage of the engine.

Additionally, the method preferably comprises the further step of (l) passing part of said flow of salt water into heat exchange relationship with said colder fluid of step (j) to cool the colder fluid and heat the salt water. The colder fluid of steps (j) and (l) is preferably substantially fresh water previously obtained by step (j). Step (l) preferably involves circulating the fresh water obtained by step (j) through a heat exchanger, and then feeding a portion of the fresh water exiting the heat exchanger back into heat exchange relationship with the exhaust gases in step (j).

Advantageously, step (k) involves collecting the remaining portion of the fresh water exiting the heat exchanger and feeding it back to the gas turbine engine.

Conveniently, said part of the flow of salt water from step (e) and said part of the flow of salt water from step (l) are combined into a single stream prior to step (a).

Step (j) is preferably performed in a condenser having a droplet separator.

Step (j) may be performed in a direct-contact condenser.

Step (j) can be performed in a counter-current condenser.

In preferred embodiments of the desalination method, the water vapour from step (a) is passed through a droplet separator prior to step (b). Step (b) also preferably involves passing the water vapour through a droplet separator.

Step (a) of the method is preferably is performed in an evaporator having a droplet separator.

Step (a) may be performed in a direct-contact evaporator.

Step (a) can be performed in a counter-current evaporator.

Step (b) of the method is preferably performed in a condenser having a droplet separator.

Step (b) may be performed in a direct-contact condenser.

Step (b) can be performed in a counter-current condenser.

In preferred embodiments of the method, the evaporator used for step (a) and the condenser used in step (b) are combined in a single unit.

So that the invention may be more readily understood, and so that further features thereof may be appreciated, embodiments of the invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a schematic illustration showing a desalination method in accordance with a first embodiment of the present invention;

Figure 2 is a schematic illustration generally corresponding to that of figure 1, illustrating a modified method in accordance with a second embodiment of the present invention; and

Figure 3 is a schematic illustration showing a desalination method in accordance with a third embodiment of the present invention.

Referring now in more detail to Figure 1, there is illustrated, in schematic form, a desalination process in accordance with a first embodiment of the present invention. As will be explained in more detail below, this process is a thermal process which uses ambient air as an intermediate media or so-called carrier gas which is

humidified with warm salt water and then condensed to produce substantially fresh water. As will also be explained in more detail below, the method uses heat generated by a heat engine in the form of, for example, a gas turbine engine or a fuel cell, to heat the salt water prior to evaporation of the salt water in the flow of ambient air.

The method involves the use of an evaporation/condensation column 1 incorporating an evaporator 2 and a condenser 3 which are combined as a single unit. The evaporator 2 and the condenser 3 are preferably both formed of a packed bed construction incorporating a respective region of packing 4 of generally conventional form such as multi-chambered, large surface area plastic bodies or the like configured to provide a large surface area and to allow the passage of both liquid and gas through the packing.

The evaporator 2 is constructed so as to incorporate a droplet separator 5 in its uppermost region which may either take the form of an inertia design or of an agglomerator design in a manner known *per se*. Immediately below the level of the droplet separator 5, there is provided a series of spray nozzles 6 in fluid communication with a fluid inlet 7, and which are configured to spray a liquid fed into the evaporator via the fluid inlet 7 in the form of a thin mist over the packing 4 located below the nozzles. Below the level of the packing 4, the evaporator 2 is provided with an air inlet, and below the level of the air inlet, there is provided a sump region 9 having a fluid outlet 10.

As illustrated in Figure 1, a supply of ambient air is fed into the evaporator 2 via the air inlet 8. The flow of air is preferably driven by a generally conventional fan arrangement and so the air is driven upwardly through the

packing 4 of the evaporator, past the spraying nozzles 6, through the droplet separator 5 and then straight into the lower end of the condenser region 3.

The condenser 3 has a generally similar configuration to that of the evaporator 2, and incorporates a droplet separator 11 at its upper end, immediately below which are provided a series of spray nozzles 12 in fluid communication with a fluid inlet 13. Below the level of the packing 4, the condenser 3 is provided with a water collector 14, for example in the form of a tray, which is provided in fluid communication with an outlet opening 15. The condenser 3 is provided with an air outlet opening 16 at its uppermost end.

During operation of the evaporator 2 in accordance with the method of the first embodiment illustrated in Figure 1, a flow of salt water is fed into the evaporator 2 via the fluid inlet 7 as indicated generally at (a) in Figure 1. The salt water is fed to the spray nozzles 6 which serve to spray the salt water as a fine mist over the packing 4. As will be explained in more detail below, the flow of salt water fed into the evaporator 2 is heated prior to entering the evaporator 2 and the evaporator 2 serves to evaporate most of the salt water into the flow of carrier gas (the ambient air) passing through the evaporator 2 to form water vapour. The resulting water vapour passes through the droplet separator 5 which serves to prevent any water droplets entrained in the carrier gas from exiting the evaporator section 2. Any of the salt water which is not evaporated falls into the sump 91 from where it is withdrawn from the evaporator via the outlet 10 and discarded.

The water vapour flows out of the evaporator 2 and straight into the condenser 3. A flow of colder fluid 17 is fed into the top of the condenser 3, via the fluid inlet

13 and is sprayed as a relatively cold fine mist over the packing 4 through which the water vapour passes. In this manner, the water vapour is passed into heat exchange relationship with the colder fluid (as indicated generally at (b)), which causes the water vapour to condense out of the carrier gas and to fall as substantially fresh water for collection in the water collector 14. From here, the substantially fresh water is drawn out of the condenser 3, for example under the action of a pump for collection, as indicated generally at (c) in Figure 1.

As will be appreciated, the droplet separator 11 provided at the top of the condenser 3 serves to prevent any droplets of water vapour entrained in the flow of carrier gas from exiting the condenser so that the air exiting the condenser through the air outlet opening 16 is substantially free of water vapour.

As illustrated in Figure 1, the colder fluid 17 which is passed into heat exchange relationship with the water vapour within the condenser 3 is actually substantially fresh water obtained by condensation within the condenser 3 and drawn from the condenser 3 via the outlet opening 15. The substantially fresh water drawn from the condenser 3 via the outlet opening 15 is passed though a heat exchanger 18, after which a portion of the fresh water is fed into the condenser 3 via the fluid inlet 13, with the remaining portion of the fresh water being collected as product, indicated generally at (c) in Figure 1.

Within the heat exchanger 18, the fresh water drawn from the condenser 3, representing the colder fluid 17 which is fed into the top of the condenser 3, is passed into heat exchange relationship with a flow of salt water 19, as indicated generally at (d) in Figure 1. As the salt water is typically sea water drawn directly from the sea,

it is relatively cold and so when passed into heat exchange relationship with the fresh water within the heat exchanger 18, the fresh water is cooled prior to flowing into the top of the condenser 3 as the relatively colder fluid 17. The flow of salt water 19 is also heated as a result of this heat exchange relationship with the fresh water within the heat exchanger 18 which helps to ensure effective evaporation of the salt water when it is fed into the evaporator 2.

Substantially the entire flow of salt water exiting the heat exchanger 18 at step (d) is then further heated by being directed through a second heat exchanger 20 which is also fed by a flow of hot exhaust gases 21 from the heat engine 22. Thus, within the second heat exchanger 20, substantially the entire flow of salt water exiting the first heat exchanger 18 is then passed into heat exchange relationship with the hot exhaust gases 21 which serves to further heat the flow of salt water prior to injection into the evaporator 2 for effective evaporation, but also serves to cool the flow of exhaust gases 21 which then exit the second heat exchanger 20 to atmosphere at a lower temperature than that at which they exited the engine 22, thereby reducing thermal pollution from the heat engine 22.

As will therefore be appreciated, in the process described above and illustrated schematically in Figure 1, substantially the entire flow of salt water 19 is pre-heated in two distinct stages prior to being fed into the evaporator 2. The first of these stages occurs in the first heat exchanger 18 at (d) where the salt water 19 is passed into heat exchange relationship with a flow of fresh water obtained from the condenser 3. The second heating stage occurs in the second heat exchanger 20 where the flow of salt water exiting the first heat exchanger 18 is passed into heat exchange relationship with the hot exhaust gases

21 from the engine 22.

It should also be noted that even though the flow of salt water entering the evaporator 2 is pre-heated in two distinct heat exchangers (18, 20) the entire flow of salt water is fed into the evaporator 2 as a single stream via the inlet 7. This is significant because it means that the entire flow of heated salt water entering the evaporator 2 is sprayed over the packing 4 at the same level, thereby maximising the efficiency of the evaporator 2 in creating water vapour to flow into the condenser 3.

It should also be noted that both the evaporator 2 and the condenser 3 are of a direct-contact, counter-current form. In other words, taking the example of the evaporator 2, the salt water which is sprayed through the nozzle 7 is brought into direct contact with the carrier gas of ambient air flowing through the evaporator 2, and is directed in the opposite direction to the flow of ambient air through the evaporator. Similarly, in the case of the condenser 3, the colder liquid 17 is sprayed through the nozzles 12 into direct contact with the water vapour passing through the condenser 3, and in a direction opposite to that in which the water vapour flows through the condenser. It has been found that direct-contact, counter-current evaporators and condensers are particularly suited to the methods of the present invention due to their high efficiency and compact design.

Turning now to consider Figure 2, there is illustrated an alternative desalination process in accordance with a second embodiment of the present invention which, in many respects, is largely identical to that of the first embodiment described above and illustrated schematically in Figure 1. The same reference numerals are therefore used to identify like components, flows and stages in the process, for the sake of simplicity. The process

illustrated in Figure 2 differs from that of Figure 1 by the implementation of a further heat exchange step indicated generally at (f) in Figure 2. In this process, not all of the flow of salt water entering the evaporator 2 is passed through the first heat exchanger 18. Instead, a portion of the salt water is diverted as a separate flow 23 and is passed through a third heat exchanger 24 preferably taking the form of an engine-jacket heat exchanger and which serves to pass the flow of salt water 23 into heat exchange relationship with the engine 22 in order to cool the engine itself and to pre-heat the flow of salt water 23. The heated salt water exiting the third heat exchanger 24 is then combined with the preheated flow of salt water exiting the second heat exchanger 20 prior to being passed into the evaporator 2, again as a single steam at (a). The modified method illustrated in Figure 2 is particularly suitable for use with a combustion engine 22, for example, in the form of a gas or diesel engine which generates internal waste heat in addition to producing waste heat in the exhaust gases 21.

Figure 3 illustrates a more complicated desalination method in accordance with a third embodiment of the present invention, and which is particularly suitable for use with a heat engine 22 in the form of a gas turbine engine operating in accordance with an advanced thermodynamic cycle such that the engine 22 produces a flow of exhaust gases 21 containing a substantial level of water vapour. For example, such an advanced gas turbine cycle can involve the injection of steam and evaporation of water into the flow of compressed air passing through the engine prior to the combustion stage. The process of the embodiment illustrated in Figure 3 thus makes use of the high water vapour content of the exhaust gases 21 in order to recover moisture from the exhaust gases, thereby reducing the level

of moisture ejected into the atmosphere, as well as recovering heat from the exhaust gases in order to pre-heat a portion of the salt water being fed into the evaporator 2.

As will be appreciated, the advanced process illustrated schematically in Figure 3 involves the use of a substantially identical evaporation/condensation column 1 as used in the processes of Figures 1 and 2. However, in this embodiment, the heat exchanger 18 through which the fresh water drawn from the condenser 3 is passed, is not fed directly with a flow of salt water, but instead is connected to a flow of coolant fluid circulating around a closed loop 25. The coolant fluid circulating around the closed loop 25 is thus passed into direct heat exchange relationship with the fresh water representing the flow of colder fluid 17 which is passed into the top of the condenser 3. This heat exchange step is illustrated schematically at (h) in Figure 1. In this context, it should be noted that "direct heat exchange relationship" means that the coolant fluid and the fresh water are passed into a heat exchange relationship without the use of an intermediary fluid - the term does not mean that the two fluids are brought into direct physical contact with one another.

Prior to entering the heat exchanger 18 at step (h), the coolant fluid passing around the closed loop 25 flows through a further heat exchanger 26 which is also fed with a flow of 27. Within the heat exchanger 26, the flow of salt water 27 is thus passed into heat exchange relationship with the coolant fluid flowing around the closed loop 25. Because the salt water is typically drawn directly from the sea it is relatively cold and this heat exchange relationship is thus effective to heat the flow of salt water 27 and cool the coolant fluid flowing around the

loop 25. This heat exchange step is illustrated schematically at (g) in Figure 3, and from here the coolant fluid flows around the closed loop 25 to a further heat exchanger 28 arranged immediately before the heat exchanger 18. In this heat exchanger 28, the coolant fluid flowing around the closed loop 25 is passed into heat exchange relationship with a flow of an additional coolant fluid such as coolant water 27 (or alternatively any other convenient coolant fluid such as air). This heat exchange step is illustrated schematically at (i) and is effective to cool the coolant within the closed loop 25 even further prior to the heat exchange step (h). As will be appreciated, the additional coolant fluid 27 is heated during the heat exchange step (i) and this coolant fluid is then expelled as a waste product.

As will therefore be appreciated, through the combined effect of the heat exchangers 18, 26 and 28, the flow of salt water 27 is again passed into heat exchange relationship with the fresh water drawn from the condenser 3 and circulated back to the condenser as the colder fluid 17. However, in this method, this heat exchange relationship between the salt water and the colder fluid 17 is effectively an indirect one involving direct heat exchange between the salt water 27 and the coolant 25 and subsequent direct heat exchange relationship between the coolant 25 and the colder fluid 17, the coolant 25 thus serving as an intermediary fluid.

The flow of pre-heated salt water exiting the heat exchanger 27 after heat exchange step (g) is then fed into the heat exchanger 20 for heat exchange with the flow of exhaust gases 21 generated by the gas turbine engine 22 at step (e) in substantially the same manner as described above in the context of the methods of Figures 1 and 2. However, in the method illustrated in Figure 3, the exhaust

gases 21 exiting the heat exchanger 20, which still have a high moisture content, are fed into the gas inlet 29 of a flue gas condenser 30.

The flue gas condenser 30 has a configuration which is generally identical to that of the condenser 30 forming part of the combined evaporation/condensation column 1. Accordingly, the flue gas condenser 30 is also of a direct-contact counter-current design incorporating a region of packing 31 above which are provided an array of spray nozzles 32 fluidly connected to a fluid inlet 33. A droplet separator 34 is provided above the spray nozzles 32. At the bottom of the flue gas condenser 30, a fluid collecting sump 35 is provided which has a fluid outlet 36. As will therefore be appreciated, the hot exhaust gases 21, having a high content of water vapour, are passed up through the flue gas condenser 30, whilst a flow of colder fluid 37 is fed into the condenser 30 via the fluid inlet 33 and is sprayed downwardly, opposite the direction of flow of the exhaust gases, by the spray nozzles 32. In this manner, the exhaust gases 21 from heat exchange step (e) are passed into heat exchange relationship (illustrated schematically at (j)) with the colder fluid 37 so that the water vapour within the exhaust gases 21 condenses into fresh water and is collected in the sump 35 and drawn out of the flue gas condenser 30 via the fluid outlet 36 for collection as fresh water as illustrated at (k). Although the fresh water collected at (k) can be added to the fresh water collected at (c) from the condenser 3 as product, it is envisaged that in most cases the fresh water collected from the flue gas condenser 30 will be recycled back to the gas turbine engine 22 for evaporation into the flow of gases passing through the gas turbine engine, prior to the combustion stage of the engine, in accordance with its advanced operating cycle.

As can be seen in Figure 3, the fresh water drawn from the bottom of the flue gas condenser 30 via the outlet 36 is passed though a further heat exchanger 38, after which a portion of the fresh water is cycled back to the top of the flue gas condenser 30 as the colder fluid 37. The water fed into the flue gas condenser 30 and the water drawn out from the flue gas condenser 30 is therefore cycled in a similar manner to that passing through the condenser 3 of the combined evaporation/condensation column 1. Within the heat exchanger 38, the fresh water drawn from the flue gas condenser 30 is passed into heat exchange relationship with a flow of salt water 39 which is thus effective to heat the flow of salt water 39 and cool the fresh water prior to it being passed into the top of the flue gas condenser 30. The heated flow of salt water exiting this heat exchange step (l) within the heat exchanger 38 is then combined (at 40) with the pre-heated flow of salt water exiting the heat exchange step (e) within the heat exchanger 20, whereafter the combined pre-heated flows are passed into the condenser 2 as a single stream at (a).

It should therefore be appreciated that each of the above-described desalination processes has been carefully designed so as to recover as much heat energy as possible from a heat engine in order to pre-heat a flow of cold salt water, such as that obtained directly from the sea, before the salt water is evaporated into a carrier flow of air. The processes have also been optimised to recover as much heat energy as possible from the condensation stages and to use that heat energy also to pre-heat the salt water prior to evaporation.

Although the invention has been described above in connection with particular embodiments, it should be appreciated that certain modifications or alterations could

be made to the various methods without departing from the scope of the present invention. For example, although the three methods proposed above all utilise an open-loop evaporation/condensation column 1 in the sense that the air passing through the column as the carrier gas does so only once, it is envisaged that in modified embodiments, the evaporation/condensation column 1 could be configured so as to operate in a closed loop manner in which the carrier gas is circulated around a closed loop. It is envisaged that such an arrangement would have the advantage of pressuring the air, thereby allowing the size of the evaporator 2 and the condenser 3 to be reduced, although at the expense of a certain degree of efficiency.

When used in this specification and claims, the terms "comprises" and "comprising" and variations thereof mean that the specified features, steps or integers are included. The terms are not to be interpreted to exclude the presence of other features, steps or components.

The features disclosed in the foregoing description, or in the following claims, or in the accompanying drawings, expressed in their specific forms or in terms of a means for performing the disclosed function, or a method or process for obtaining the disclosed results, as appropriate, may, separately, or in any combination of such features, be utilised for realising the invention in diverse forms thereof.

While the invention has been described in conjunction with the exemplary embodiments described above, many equivalent modifications and variations will be apparent to those skilled in the art when given this disclosure. Accordingly, the exemplary embodiments of the invention set forth above are considered to be illustrative and not limiting. Various changes to the described embodiments may be made without departing from the spirit and scope of the

invention.

CLAIMS

1. A desalination method for producing substantially fresh water from salt water, the method comprising the steps of: (a) passing a flow of salt water into an evaporator (2) and therein evaporating at least a portion of the salt water to form water vapour; (b) passing the water vapour into heat exchange relationship with a colder fluid (17) so that at least a portion of the water vapour condenses into fresh water; and (c) collecting at least a portion of the fresh water that condenses in step (b), characterised by the additional step of (d) passing substantially the entire said flow of salt water (19) into heat exchange relationship with said colder fluid (17) to cool said fluid and heat the salt water prior to step (a).

2. A desalination method for producing substantially fresh water from salt water, the method comprising the steps of: (a) passing a flow of salt water into an evaporator (2) and therein evaporating at least a portion of the salt water to form water vapour; (b) passing the water vapour into heat exchange relationship with a colder fluid (17) so that at least a portion of the water vapour condenses into fresh water; and (c) collecting at least a portion of the fresh water that condenses in step (b), characterised by the additional step of (d) passing at least part of said flow of salt water (19) into heat exchange relationship with said colder fluid (17) to cool said fluid and heat the salt water prior to step (a), and wherein said step (a) of passing the flow of salt water into an evaporator involves feeding substantially the entire said flow of salt water into the evaporator (2) as a single stream.

3. A desalination method according to claim 1 or claim 2, including the step of (e) passing substantially the entire flow of salt water (19) which is passed into heat exchange

relationship with said colder fluid (17) in step (d) into heat exchange relationship with exhaust gases (21) from a heat engine (22) so as to cool the exhaust gases and heat the water prior to step (a).

4. A desalination method for producing substantially fresh water from salt water, the method comprising the steps of: (a) passing a flow of salt water into an evaporator (2) and therein evaporating at least a portion of the salt water to form water vapour; (b) passing the water vapour into heat exchange relationship with a colder fluid (17) so that at least a portion of the water vapour condenses into fresh water; and (c) collecting at least a portion of the fresh water that condenses in step (b), characterised by the additional steps of (d) passing at least part of said flow of salt water (19) into heat exchange relationship with said colder fluid to cool said fluid and heat the salt water, and then (e) passing said part of the flow of salt water (19) into heat exchange relationship with exhaust gases (21) from a heat engine (22) so as to cool the exhaust gases and heat the water prior to step (a).

5. A desalination method according to claim 1, or claim 4, wherein said step (a) of passing the flow of salt water into an evaporator (2) involves feeding substantially the entire said flow of salt water into the evaporator (2) as a single stream.

6. A desalination method according to claim 3 as dependant upon claim 2, or claim 4, including the additional step of (f) passing part (23) of the flow of salt water into heat exchange relationship with the heat engine (22) so as to cool the engine and heat the water prior to step (a).

7. A desalination method according to claim 6, wherein said part of the flow of salt water (23) from step (e) and

said part of the flow (19) of salt water from step (f) are combined into a single stream prior to step (a).

8. A desalination method according to any preceding claim, wherein the colder fluid (17) of steps (b) and (d) is substantially fresh water previously obtained by step (b).

9. A desalination method according to claim 8, wherein step (d) involves circulating the fresh water (17) obtained by step (b) through a heat exchanger (18), and then feeding a portion of the fresh water (17) exiting the heat exchanger back into heat exchange relationship with the water vapour in step (b), and wherein step (c) involves collecting the remaining portion of the fresh water exiting the heat exchanger (18).

10. A desalination method according to any preceding claim, wherein step (d) involves passing the flow of salt water (19) into direct heat exchange relationship with the colder fluid (17).

11. A desalination method according to any one of claims 1 to 9, wherein step (d) involves passing the flow of salt water into indirect heat exchange relationship with the colder fluid (17).

12. A desalination method according to claim 11, wherein step (d) involves (g) passing the flow (25) of salt water into direct heat exchange relationship with a coolant fluid (25), and then (h) passing said coolant fluid (25) into direct heat exchange relationship with said colder fluid (17).

13. A desalination method according to claim 12, wherein said coolant fluid flows around a substantially closed circuit (25) between heat exchange relationship with the flow of salt water (23), and heat exchange relationship with said colder fluid (17).

14. A desalination method according to claim 12 or claim

13, including the additional step of (i) passing said coolant fluid (25) into heat exchange relationship with an additional coolant fluid (27), after step (g) but before step (h).

15. A desalination method according to claim 14, wherein said additional coolant fluid (27) is either air or water.

16. A desalination method according to claim 3 or claim 4, or any other claim dependant thereon, wherein the heat engine (22) is a combustion engine or a fuel cell.

17. A desalination method according to claim 3 or claim 4 or any other claim dependant thereon, wherein the heat engine (22) is a gas turbine engine.

18. A desalination method according to claim 3 or claim 4, or any other claim dependant thereon, wherein the heat engine (22) is a gas turbine engine producing exhaust gases (21) containing substantial water vapour, and the method further comprises the step of (j) passing the exhaust gases from step (e) into heat exchange relationship with a colder fluid (37) so that water vapour in the exhaust gases (21) condenses into fresh water.

19. A desalination method according to claim 18, further comprising the step of (k) feeding at least a portion of the fresh water condensed in step (j) back to the gas turbine engine (22) in the form of water vapour in the flow of compressed air passing through the engine, prior to the combustion stage of the engine.

20. A desalination process according to claim 18 or claim 19, comprising the further step of (l) passing part of said flow of salt water (39) into heat exchange relationship with said colder fluid (37) of step (j) to cool the colder fluid and heat the salt water (39).

21. A desalination method according to claim 20, wherein the colder fluid (37) of steps (j) and (l) is substantially fresh water previously obtained by step (j).

22. A desalination method according to claim 21, wherein step (l) involves circulating the fresh water (37) obtained by step (j) through a heat exchanger (38), and then feeding a portion of the fresh water exiting the heat exchanger back into heat exchange relationship with the exhaust gases in step (j).

23. A desalination method according to claim 22 as dependant upon claim 19, wherein step (k) involves collecting the remaining portion of the fresh water exiting the heat exchanger (38) and feeding it back to the gas turbine engine (22).

24. A desalination method according to any one of claims 20 to 23, wherein said part of the flow of salt water from step (e) and said part of the flow of salt water from step (l) are combined into a single stream prior to step (a).

25. A desalination method according to any one of claims 18 to 24, wherein step (j) is performed in a condenser (30) having a droplet separator (34).

26. A desalination method according to any one of claims 18 to 25, wherein step (j) is performed in a direct-contact condenser (30).

27. A desalination method according to any of claims 18 to 26, wherein step (j) is performed in a counter-current condenser (30).

28. A desalination method according to any preceding claim wherein the water vapour from step (a) is passed through a droplet separator (5) prior to step (b).

29. A desalination method according to any preceding claim, wherein step (b) involves passing the water vapour through a droplet separator (11).

30. A desalination method according to any preceding claim, wherein step (a) is performed in an evaporator (2) having a droplet separator (5).

31. A desalination method according to any preceding

claim, wherein step (a) is performed in a direct-contact evaporator (2).

32. A desalination method according to any preceding claim, wherein step (a) is performed in a counter-current evaporator (2).

33. A desalination method according to any preceding claim, wherein step (b) is performed in a condenser (3) having a droplet separator (11).

34. A desalination method according to any preceding claim, wherein step (b) is performed in a direct-contact condenser (3).

35. A desalination method according to any preceding claim, wherein step (b) is performed in a counter-current condenser (3).

36. A desalination method according to any one of claims 30 to 35, wherein the evaporator (2) used for step (a) and the condenser (3) used in step (b) are combined in a single unit (1).

Fig.1

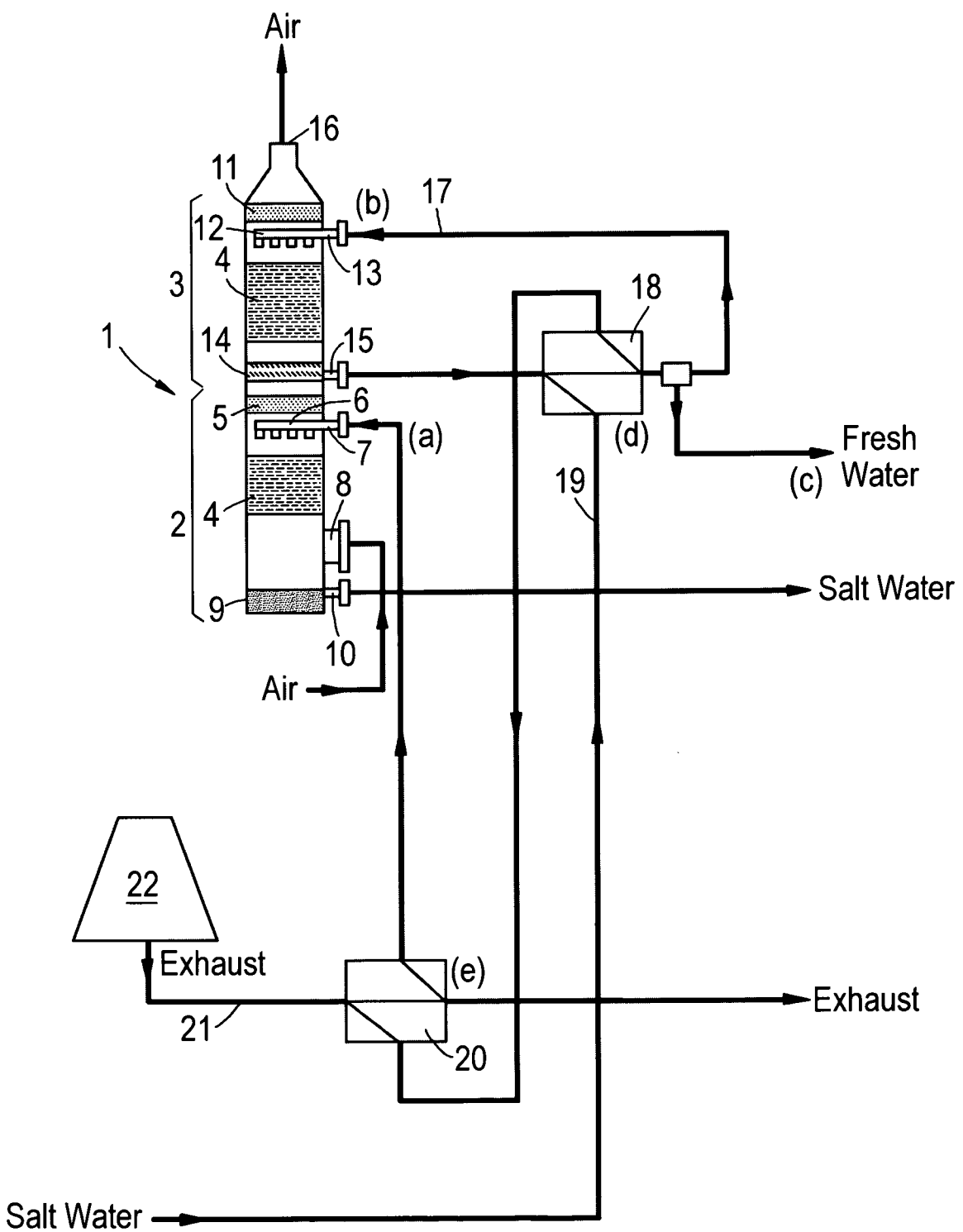
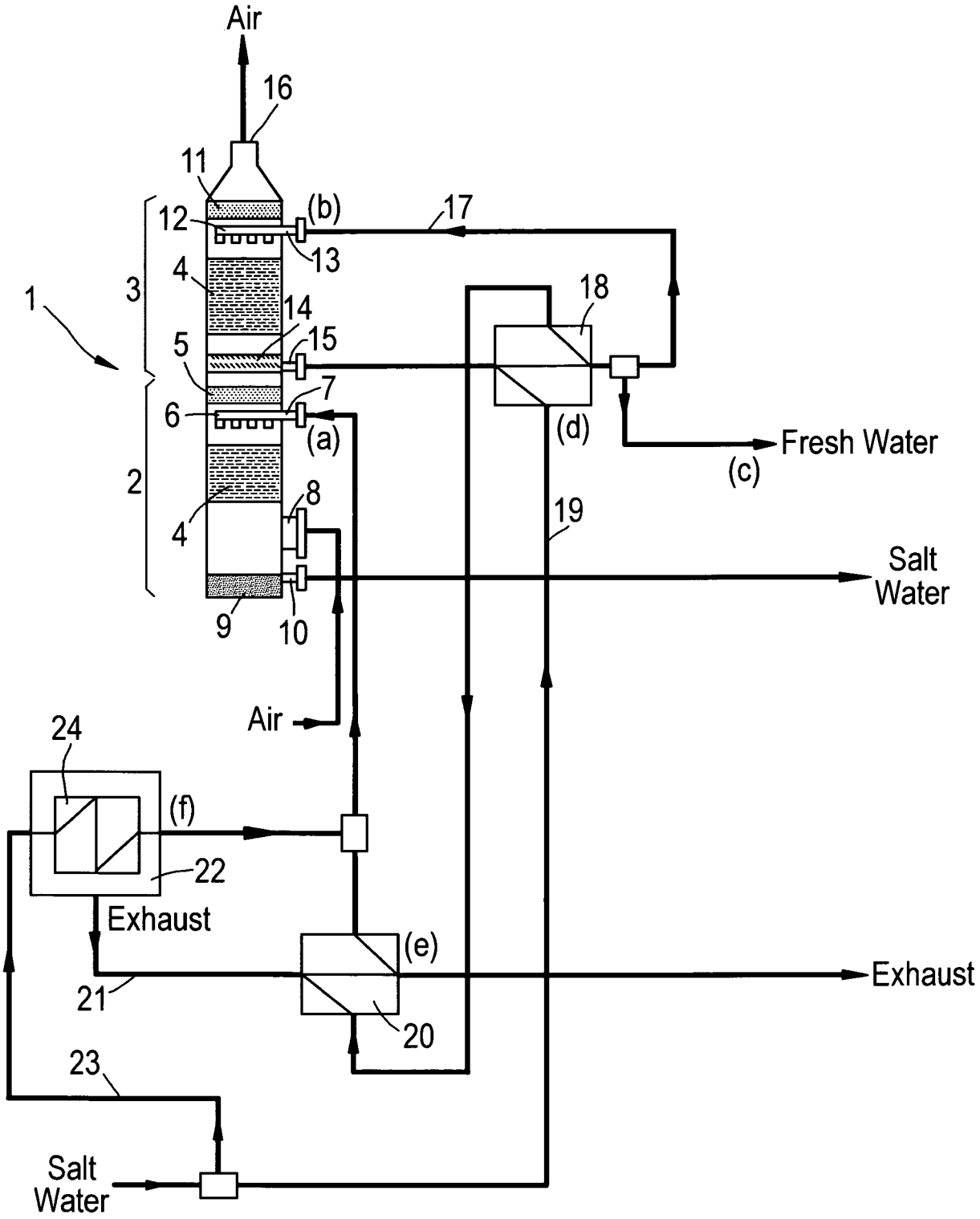

Air
16
11
(b)
17
12
13
4
3
18
1
14
15
6
5
(a)
7
(d)
Fresh
(c) Water
19
8
2
4
Salt Water
9
10
Air
22
Exhaust
(e)
Exhaust
21
20
Salt Water

Fig.2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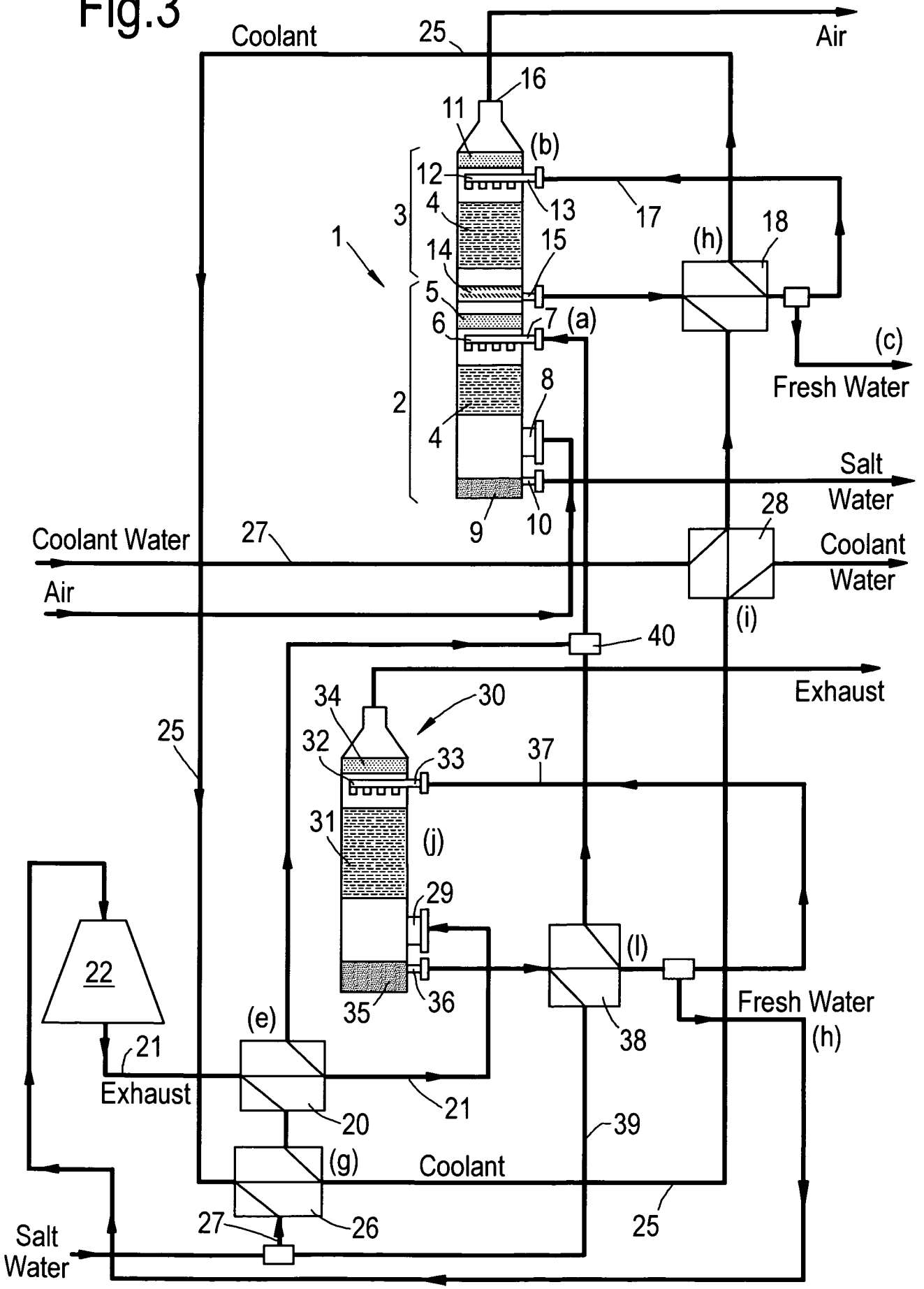
16
11
12
(b)
17
13
4
3
1
14
18
5
15
7
6
(a)
(d)
Fresh Water
(c)
2
8
19
4
Salt
Water
9
10
Air
24
(f)
22
Exhaust
(e)
Exhaust
21
20
23
Salt
Water

Fig.3


Coolant
25
Air
16
11
(b)
12
13
17
3
4
1
14
15
(h)
18
5
6
7
(a)
(c)
Fresh Water
2
8
4
Salt
Water
9
10
28
Coolant Water
27
Coolant
Water
Air
(i)
40
Exhaust
34
30
25
32
33
37
31
(j)
29
22
(l)
35
36
Fresh Water
(h)
(e)
38
21
Exhaust
21
20
39
(g)
Coolant
27
26
25
Salt
Water

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2009/007099

A. CLASSIFICATION OF SUBJECT MATTER
INV. C02F1/12 C02F1/16 B01D1/16
ADD. C02F103/08 C02F1/00

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)
C02F B01D

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.
X Y	US 3 833 479 A (FREDRIKSSON C) 3 September 1974 (1974-09-03) column 1, line 19 - column 2, line 5; figure 1 column 2, line 29 - line 35	1-17, 28-36 18-27
X	US 5 096 543 A (ELMORE CARL L [US]) 17 March 1992 (1992-03-17) column 4, line 1 - line 26; figure 1 column 5, line 12 - line 22	1-17, 28-36
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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
17 December 2009	28/12/2009

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INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2009/007099

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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INTERNATIONAL SEARCH REPORT

Information on patent family members

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