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Single Cycle Apparatus For Condensing Water From Ambient Air

FIELD OF THE INVENTION

The present invention broadly relates to a method and apparatus for condensing water from ambient air and collecting the water for use. The apparatus in at least one form provides a means for generating potable water for consumption or other purposes and finds particular application in areas where potable water supplies are limited. The invention also relates to a method and apparatus for providing heating and/or cooling during a work cycle of the apparatus.

BACKGROUND OF THE INVENTION

10 In many locations around the world access to a fresh potable water supply is limited, forcing many to use water for everyday needs that would not generally be deemed suitable for such use. Indeed, many water supplies are contaminated or polluted and in order to be able to use the water safely, it is necessary for the water to be boiled or treated in some other way.

15 While yachts and ships carry their own water supplies during a voyage, it is often necessary to restrict daily usage of the available water due to access to fresh water supplies other than rainfall being unavailable. Similarly, mining companies, road and rail repair gangs as well as for instance military units operating in remote locations, and island resorts all have a need for fresh water.

20 Water, of course, has thousands of uses in addition to being required to sustain life. Such uses include washing and use in industrial processes amongst others. In areas or locations where the supply of water is limited, it is desirable to have access to regular supplies of fresh water. While supplies can be replenished by rainwater, rainfall can be variable and insufficient. Moreover, the cost of transporting fresh water to remote locations on a regular basis can be expensive.

SUMMARY OF THE INVENTION

In a first aspect of the present invention there is provided a method for condensing water from ambient air, the method comprising:

providing at least one condensation surface for contact with the ambient air;

5 heating a solution of a refrigerant and a fluid, to drive gaseous refrigerant from the solution;

cooling the gaseous refrigerant to condense the gaseous refrigerant into liquid refrigerant, and collecting the liquid refrigerant;

10 evaporating refrigerant from the liquid refrigerant such that heat is exchanged between the refrigerant and the condensation surface which is thereby cooled to, or below, the dew point of the water in the ambient air; and

contacting the cooled condensation surface with the ambient air to effect condensation of water from the ambient air onto the condensation surface.

The step of heating the solution preferably comprises solar energy. The hearing step
15 preferably comprises direct solar energy. However, the step of heating the solution may comprise heat from any suitable source. For example, the heating step may comprise discharge heat from a condenser of a refrigeration or air conditioning unit. The step of heating the refrigerant and fluid solution is preferably controlled in response to temperature of the refrigerant and fluid solution and pressure within a container containing that solution. The
20 step of heating the refrigerant and fluid solution is preferably at least partially reduced if, according to the temperature of the refrigerant and fluid solution and the pressure within the container, the concentration of ammonia in solution is less than or equal to about 39.5% by weight.

Typically, the method further comprises returning the refrigerant evaporated from the liquid
25 refrigerant to the fluid for repeating heating and evaporation steps. A heating and corresponding evaporation step is typically described by persons skilled in the relevant art as a heating and evaporation work cycle. This terminology will therefore be used throughout the

specification. The method preferably further comprises drawing away any heat generated on contact of the returned refrigerant with the fluid to promote return of further refrigerant evaporated from the liquid refrigerant to the fluid. The heat drawn away from the fluid may be dissipated into the atmosphere, or used for heating or other purposes. For example, the heat may be used as an energy input for processes or equipment.

The step of returning evaporated refrigerant to the refrigerant and fluid solution preferably further comprises the step of controlling the flow rate of gaseous refrigerant to the refrigerant and fluid solution. By controlling this flowrate the rate of evaporation of refrigerant is controlled. The rate of return of gaseous refrigerant to the refrigerant and fluid solution is also controlled to thereby control generation of gaseous refrigerant upon heating of the refrigerant and fluid solution.

The step of controlling the flowrate of gaseous refrigerant to the refrigerant and fluid solution preferably comprises the step of comparing the dewpoint of the ambient air with the temperature of ambient air following its contact with the condensation surface. The dewpoint of the ambient air is preferably determined by sensing the temperature at which water condenses from the ambient air onto the condensation surface. The steps of sensing and comparing temperatures preferably comprise the steps of measuring corresponding temperatures.

The step of cooling the gaseous refrigerant to collect liquid refrigerant preferably comprises the step of distilling gas comprising gaseous refrigerant and gas evaporated from the fluid. This step preferably also comprises the step of drawing heat from the gas. The step of drawing heat from the gas preferably comprises the step of directing the ambient air which has contacted the cooled condensation surface to cool the gaseous refrigerant.

The method of the first aspect of the present invention preferably also comprises the step of collecting water condensed onto the condensation surface.

In a second aspect of the present invention there is a method for heating comprising:

heating a solution of a refrigerant and a fluid, to drive gaseous refrigerant from the solution;

cooling the gaseous refrigerant such that the gaseous refrigerant condenses into liquid refrigerant, and collecting the liquid refrigerant;

- evaporating refrigerant from the liquid refrigerant and returning the refrigerant evaporated from the liquid refrigerant to the fluid to produce heat upon contact of the
5 refrigerant with the fluid; and

utilising the heat for heating.

The method of the second aspect of the present invention preferably further comprises the step of drawing heat generated by the contact of the refrigerant with the fluid away from the fluid to promote return of further evaporated refrigerant into the fluid.

- 10 Preferably, the heat generated by the contact of the refrigerant with the fluid will be utilised to drive an apparatus for collecting water from ambient air. The apparatus may, for example, be an apparatus of the present invention.

In a third aspect of the present invention there is provided a method for cooling comprising:

- providing at least one cooling surface for contact with ambient air;
- 15 heating a solution of a refrigerant and a fluid, to drive gaseous refrigerant from the solution;
- cooling the gaseous refrigerant to condense the gaseous refrigerant into liquid refrigerant, and collecting the liquid refrigerant;
- 20 evaporating refrigerant from the liquid refrigerant such that heat is exchanged between the refrigerant and the cooling surface which is thereby cooled;
- contacting the cooling surface with the ambient air to cool the ambient air; and
- using the cooled ambient air for cooling.

The method of the third aspect of the present invention preferably comprises the step of returning the evaporated refrigerant to the fluid.

In a fourth aspect of the present invention there is provided an apparatus for condensing water from ambient air, the apparatus comprising:

heating means for heating a solution of a refrigerant and a fluid, to drive evaporation of the refrigerant from the solution to produce gaseous refrigerant;

5 cooling means for cooling the gaseous refrigerant such that the gaseous refrigerant condenses into liquid refrigerant; and

an evaporator having at least one condensation surface for contact with the ambient air and being arranged for collecting the liquid refrigerant, and subsequent evaporation of gaseous refrigerant from the liquid refrigerant; wherein

10 the condensation surface is arranged for being cooled to, or below, the dew point of the water in the ambient air by heat exchange between the refrigerant and the condensation surface upon evaporation of the refrigerant from the liquid refrigerant, and thereby effecting condensation of water from the ambient air onto the condensation surface.

Preferably, the heating means comprises a heat collector for collecting heat. The heat
15 collector is preferably arranged to collect solar energy. The heat collector is preferably arranged to directly transfer collected solar energy to the refrigerant and fluid solution. However, the heat collector may be arranged for collecting heat from any suitable source including heat discharged from a condensor of a refrigeration or air conditioning unit.

The heating means preferably also comprises a heat exchanger arranged to transfer heat from
20 the heat collector to the refrigerant and fluid solution. The heat exchanger preferably comprises a metal jacket in fluid communication with the heat collector. The communicating fluid is preferably mineral oil. The heating means is preferably arranged to at least partially restrict the communicating fluid between the heat collector and heat exchanger if the communicating fluid rises above a predetermined temperature.

25 The heating means is preferably arranged to control heating of the refrigerant and fluid solution in response to temperature of the refrigerant and fluid solution and pressure within a container containing that solution. The heating means is preferably arranged to at least partially reduce heating of the refrigerant and fluid solution if, according to the temperature of

the refrigerant and fluid solution and the pressure within the container, the condensation of ammonia in solution is less than or equal to about 39.5% by weight.

Preferably, the cooling means comprises a heat sink for dissipating heat from the gaseous refrigerant to effect the condensation of the gaseous refrigerant. The cooling means
5 preferably comprises distillation means for distilling gaseous refrigerant from gas comprising gaseous refrigerant and gas evaporated from the fluids. The distillation means is preferably arranged to condense gas evaporated from the fluid. The distillation means preferably comprises a riser conduit. The distillation means preferably also comprises cooling fins.

The cooling means preferably also comprises heat absorbing means arranged to absorb heat
10 from the gaseous refrigerant. The heat absorbing means is preferably arranged to absorb heat following distillation by the distillation means. The heat absorbing means preferably comprises a water jacket.

The apparatus for condensing water from ambient air is preferably arranged to draw ambient
15 air over the condensation surface. The apparatus for condensing water from ambient air preferably comprise a fan.

The apparatus for condensing water from ambient air preferably comprises refrigerant vapour return means for returning refrigerant vapour evaporated by the evaporator to the refrigerant and fluid solution. The refrigerant vapour return means preferably comprises a port of the evaporator for return of the gaseous refrigerant to the refrigerant and fluid solution. The
20 refrigerant vapour return means preferably comprises refrigerant vapour flow rate control means for controlling the flow rate of refrigerant vapour. The refrigerant vapour flow rate control means is preferably arranged to control the flow rate of refrigerant vapour by comparing the dewpoint of the ambient air with the temperature of the ambient air following its contact with the condensation surface. The refrigerant vapour flow rate control means is
25 preferably arranged to determine the dewpoint by measuring the temperature at which water condenses from the ambient air onto the condensation surface. The refrigerant vapour control means is preferably also arranged to measure the temperature of the ambient air following its contact with the condensation surface to compare it with the dewpoint.

The refrigerant vapour return means preferably also comprises a diffuser for diffusing refrigerant vapour into the refrigerant and fluid solution.

5 The apparatus for condensing water from ambient air preferably also comprises heat absorber means for absorbing heat from the refrigerant and fluid solution following the return of refrigerant vapour to the refrigerant and fluid solution via the refrigerant vapour return means. The heat absorber means is preferably also arranged to store heat to heat the refrigerant and fluid solution. The heat absorber means is preferably arranged to heat the refrigerant and fluid solution using the stored heat at times of reduced availability of solar energy.

10 The heat absorber means preferably comprises means for directing ambient air toward the refrigerant and fluid solution, the heat collector or heat exchanger.

The apparatus of the fourth aspect of the present invention preferably also comprises water collection means arranged to collect water condensed onto the condensation surface.

In a fifth aspect of the present invention there is provided an apparatus for heating comprising:

15 heating means for heating a solution of a refrigerant and a fluid, to drive evaporation of the refrigerant from the fluid to produce gaseous refrigerant;

cooling means for cooling the gaseous refrigerant such that the gaseous refrigerant condenses into liquid refrigerant;

20 an evaporator arranged for collecting the liquid refrigerant, subsequent evaporation of gaseous refrigerant from the liquid refrigerant, and return of the gaseous refrigerant to the fluid, the gaseous refrigerant generating heat on contact with the fluid; and

heat drawing means for drawing heat from the fluid following contact of the gaseous refrigerant with the fluid for heating.

25 In a sixth aspect of the present invention there is provided an apparatus for cooling comprising:

heating means for heating a solution of a refrigerant and a fluid, to drive evaporation of the refrigerant from the fluid to produce gaseous refrigerant;

cooling means for cooling the gaseous refrigerant such that the gaseous refrigerant condenses into liquid refrigerant;

5 an evaporator having at least one cooling surface for contact with ambient air and being arranged for collecting the liquid refrigerant and subsequent evaporation of refrigerant from the liquid refrigerant, the condensation surface arranged for being cooled by heat exchange between the refrigerant and the condensation surface upon evaporation of the refrigerant from the liquid refrigerant.; and

10 directing means for directing the ambient air into contact with the cooled cooling surface for cooling.

Condensing water from ambient air provides a way of supplementing fresh or stored water supplies in remote or extreme locations where fresh water is scarce or otherwise unavailable, and may reduce reliance on, or the need for, water to be transported to such locations.

15 Similarly, where it is necessary to carry water supplies such as on a ship or boat during a voyage, condensing water from ambient air provides an alternative source of water during travel and so allows less reliance to be placed on stored water. Indeed, by being able to condense water from the ambient air, stores of carried water may be reduced. In addition, condensing water from air provides some certainty as to the quality of the water and so
20 provide a source of water in areas where there is doubt as to the quality of the existing water supplies or the available water is known to be polluted or contaminated, or is otherwise not suitable for the intended purpose of the water.

Rather than wasting the heat or cooled air generated during the operation of an apparatus encompassed by the present invention, the heat or cooled air can be utilised as stand alone
25 heating or cooling, or to supplement other heating or cooling systems. Accordingly, embodiments of the present invention may find application in a number of practical situations.

The features and advantages of the present invention will become further apparent from the following description of the preferred embodiments of the present invention together with the accompanying drawings.

BRIEF DESCRIPTION OF THE FIGURES

- 5 **Figure 1** is a front view of an apparatus to be used in conjunction with the present invention for condensing water from ambient air;

Figure 2 is a side view of the apparatus of Fig. 1;

Figure 3 is a schematic view of the apparatus of Fig. 1;

Figure 4 is a view of the evaporator of the apparatus of Fig. 1;

- 10 **Figure 5** is a partial longitudinal cross-sectional view of the condenser of the apparatus of Fig. 1;

Figure 6 is a cross-sectional view taken through B-B of the condenser of Fig. 5;

Figure 7 is a schematic view of a control system of the apparatus of Fig. 1;

- 15 **Figures 8 and 9** are schematic plan and end views of a heat tracking system of the apparatus of Fig. 1;

Figure 10 is a schematic view of an apparatus embodied by the present invention.

Figures 11 and 12 are schematic views of further embodiments of the present invention.

Figure 13 is a schematic view of yet another embodiment of the present invention;

Figure 14 is a schematic view of a water return system of the embodiment of Figure 13; and

- 20 **Figure 15** is a schematic view of yet another embodiment of the present invention.

DETAILED DESCRIPTION OF THE [INVENTION/PREFERRED EMBODIMENT

Heat generated by a water condenser apparatus of an embodiment of the present invention such as those examples disclosed in Figs. 10 – 15 may be utilised to drive apparatus such as that shown in Figs. 1-9.

- 5 The apparatus 2 of Fig. 1 comprises an evaporator 4 containing iso-butane (R600a) refrigerant for cooling the evaporator to, or below, the dew point of water in ambient air flowing through the evaporator in use. Briefly stated, the cooling of the evaporator is achieved by passing a system gas such as ammonia that is substantially inert with respect to the refrigerant into a headspace of the evaporator. This lowers the partial pressure of gaseous refrigerant in the
- 10 headspace and thereby causes further refrigerant to evaporate from the liquid refrigerant. The resulting gaseous mixture in the headspace comprising the system gas and the gaseous refrigerant passes from the evaporator and the gas and the refrigerant are separated. The separated gaseous refrigerant is condensed, and the gas and condensed liquid refrigerant are recirculated back to the evaporator 4 in a continuous cycle.
- 15 As shown more clearly in Fig. 2, the gaseous mixture from the evaporator passes to a condenser 6 due to a pressure differential between the evaporator and the condenser. The separation of the gas from the refrigerant vapour occurs in the condenser and is achieved by contacting the gas within the gaseous mixture with a liquid absorbent fed into the condenser. The gas is absorbed by the liquid absorbent to form a solution which passes from the
- 20 condenser to a separation reservoir for separation of the gas from the solution prior to the return of the gas to the evaporator. The liquid absorbent separated from the solution is recirculated by a pump system generally indicated by the numerals 8 and 10 to the condenser for further separation of gas from the gaseous mixture entering the condenser from the evaporator.
- 25 More particularly, as shown in Fig. 3, the evaporator 4 comprises a housing 12 having a lower chamber 14 which is in fluid communication with a headspace 16 of the evaporator through a plurality of spaced apart tubular pipes 18. The evaporator 4 is filled with liquid iso-butane refrigerant 28 except for the headspace 16 of the evaporator. Several rows of pipes 18 are provided across the evaporator. Spaces 20 between the pipes provide a pathway for ambient
- 30 air to flow through the evaporator over cooling fins 22. The upper side 22a and under

side 22b of each fin 22 provide condensation surfaces for the condensation of water from the ambient air. The evaporator and thereby the fins 22 are arranged at a 45° angle relative to horizontal such that the condensed water runs off the fins and falls onto a sloping surface of a casing 24 housing the evaporator and the condenser, which directs the water to an outflow spigot 26 for collection as illustrated in Fig. 4.

The system gas 30, in this instance ammonia gas, is bubbled through the liquid refrigerant from an inlet in the form of a diffuser 32 arranged within the lower chamber 14 of the evaporator. The ammonia gas passes up through the pipes 18 into the headspace where it mixes with refrigerant vapour that has evaporated from the underlying liquid refrigerant. The entry of the ammonia gas into the headspace causes the partial pressure of the refrigerant vapour to decrease. This causes further refrigerant to evaporate from the liquid refrigerant in the evaporator. As a result, heat is drawn into the liquid refrigerant from the cooling the fins 22 which in turn cools ambient air flowing over the fins.

An outlet 34 is provided in the headspace 16 of the evaporator through which the gaseous mixture flows to the condenser 6 through a feed pipe 36. The feed pipe 36 opens into an upper region 38 of the condenser through an inlet 40. The condenser 6 is partly filled with a bath in a bottom region 43 of the condenser, having a layer of liquid refrigerant 28 which overlies a layer of a solution 42 of water and dissolved ammonia gas. A mixer unit 44 is suspended within the upper region of the condenser by dual axis gimbals 46 secured to the walls of the condenser. The gimbals ensure that the mixer unit remains in a substantially upright position if the ground surface on which the apparatus 2 is located is not horizontal.

A well 48 defined in an upper end of the mixer unit receives the liquid absorbent 50 from a further inlet 52 provided in the upper region 38 of the condenser. The liquid absorbent comprises water containing a substantially lower concentration of dissolved ammonia gas than the solution 42 in the bottom region of the condenser. The liquid absorbent 50 overflows from the rim 54 of the well and down the outer peripheral surface 56 of the mixer unit prior to falling into the layer of liquid refrigerant 28 in the bath.

As the liquid absorbent travels down the outer peripheral surface of the mixer unit under the effect of gravity, it contacts the gaseous mixture entering the condenser from the evaporator and absorbs ammonia from the gaseous mixture. As indicated in Fig. 5, the mixer unit is

provided with a plurality of spaced apart circumferential ridges 58 which form annular rings around the mixer unit. The rings produce turbulence in the flow of the liquid absorbent down the mixer unit as the absorbent passes over each one. This facilitates mixing of the liquid absorbent with the ammonia gas in the gaseous mixture from the evaporator and thereby, absorption of the ammonia gas into the liquid absorbent. A cross-sectional view taken through B-B of the mixer unit is shown in Fig. 6. As can be seen, the liquid absorbent falls into the centre of the well 48 through aperture 60 of the inlet 52.

The liquid absorbent and dissolved ammonia gas has a higher density than the liquid refrigerant, and so settles from the pool of the liquid refrigerant into the solution 42 in the bottom region 43 of the condenser.

The solution 42 flows from the condenser through a feed pipe 62 and enters the separation reservoir 64 through an inlet 66. The storage reservoir 64 is partially filled with a weaker solution of the liquid absorbent and dissolved ammonia gas, and has an internal headspace 68 filled with vapour from the solution and more particularly, ammonia gas and water vapour. In use, the separation reservoir is heated forcing the majority of the ammonia gas in the solution entering from the condenser to evaporate into the internal headspace 68 of the separation reservoir.

An outlet 70 is provided in the storage reservoir through which the weaker solution 41 flows to a heating reservoir 72 of the pump system through a feed pipe 74. The heating reservoir 72 is heated to a sufficient temperature, typically the boiling point of the weaker solution, to force the weaker solution up through tube 76 into collection reservoir 78. As the heated solution passes up the tube 76 water vapour and ammonia gas evaporate from the solution, forming pockets of gas which are driven up through the tube with passage of the solution to the collection reservoir 78. The solution entering the collection reservoir therefore has a lower concentration of dissolved ammonia gas compared to both the solution 42 entering the storage reservoir and the weaker solution passing from the storage reservoir to the heating reservoir.

After entering the collection reservoir, the solution is recirculated from the collection reservoir 78 to the condenser 6 as the liquid absorbent 50 for absorbing further ammonia gas

from the gaseous mixture passing into the condenser 6 from the headspace 16 of the evaporator 4.

In particular, as indicated in Fig. 4, the liquid absorbent exiting the tube 76 pools within the collection reservoir 78 and travels back down recycling tube 80 which passes through the
5 solution 42 in the separation reservoir 64 in a heat exchange relationship with the inlet 66, for heat exchange with the solution entering the storage reservoir from the condenser. From the storage reservoir, the recycling tube 80 directs the liquid absorbent to inlet 52 of the condenser.

A feed pipe 82 feeds the ammonia gas and water vapour entering the collection reservoir from
10 riser tube 76 to a common feed pipe 84 which opens at one end into the headspace 68 of the separation reservoir through outlet 86. An opposite end of the common feed pipe 84 opens into the diffuser 32 arranged in the evaporator 4. The common feed pipe 84 has an inclined section 88 for trapping water which condenses in the common feed pipe from water vapour entering with ammonia gas from the collection reservoir 78 and separation reservoir 64, and
15 directing the condensed water back to the storage reservoir.

As also indicated in Fig. 4, the common feed pipe 84 passes through a heat exchanger 90 comprising a section of the feed pipe transporting the gaseous mixture from the headspace 16 of the evaporator 4 to the condenser 6. A further feed pipe 92 recycling condensed
20 refrigerant 28 from the condenser to the lower chamber 14 of the evaporator 4 also passes through the heat exchanger 90 and continues on in a heat exchange relationship with the common feed pipe 84 from the heat exchanger 90 to the lower chamber 14 of the evaporator 4. As will be appreciated, the heat exchanger 90 facilitates heat exchange between the gaseous mixture in the heat exchanger and the refrigerant in feed pipe 92 and the ammonia
25 gas in the common feed pipe 94. Similarly, the side by side arrangement of the common feed pipe 84 and feed pipe 92 from the heat exchanger 90 to the evaporator 4 allows for heat exchange between the refrigerant in feed pipe 92 and the ammonia gas in the common feed pipe.

As described above, the evaporator 4 and condenser 6 are housed within a casing 24. As best illustrated in Fig. 7, the casing 24 has a main air intake 96 at one end and a fan 98 arranged at
30 an outlet end 100 for drawing ambient air into the casing from the atmosphere through the

main air intake. The ambient air flows through the evaporator into contact with the fins 22 causing water to condense from the air on to the fins 22 of the evaporator, and then on through the casing past the condenser 6. As the cooled air passes over the housing 94 of the condenser heat is drawn off from the housing. The gaseous refrigerant in the upper region of the condenser and the underlying liquid refrigerant are thereby also cooled.

For efficient operation of the apparatus of the invention, the flow rate of the ambient air through the casing 24 is adjusted to optimise condensation of water per unit volume of the ambient air flowing through the evaporator, while maintaining sufficient air flow over the condenser for heat transfer from the condenser to the ambient air for condensation of the gaseous refrigerant within the condenser.

In particular, the fan 98 is initially operated at maximum speed to achieve maximum air flow through the casing 24 and the speed of the fan progressively reduced. The dew point of the ambient air entering the evaporator is determined by a sensor 102. The sensor is arranged so as to be progressively cooled by the ambient air as the ambient air entering the evaporator is cooled by the cooling fins 22. When condensation forms on the sensor 102 from the ambient air, the sensor is short circuited indicating the dew point of the ambient air. This temperature is compared in control module 106 to the dry bulb temperature of the air leaving the evaporator measured by a temperature sensor 104. If the temperature measured by temperature sensor 104 is above the dew point of the water in the ambient air determined by sensor 102, the speed of the fan is further progressively reduced on command from the control module 106 lowering the flow rate of the ambient air through the evaporator.

Once the optimum flow rate of the ambient air over the evaporator 4 has been achieved, the temperature of the condensed refrigerant 28 in the condenser 6 is measured by a further temperature sensor 112 and compared in the control module 106 with the total pressure in the upper region 38 of the condenser measured by pressure sensor 114. As the pressure in the upper region of the condenser varies according to ambient conditions, there are temperature and pressure conditions within the condenser for optimum condensation of the refrigerant vapour within the upper region of the condenser.

The temperature and pressure measured by the temperature sensor 112 and pressure sensor 114 are compared in control module 106 and the control module determines whether

the optimum conditions for condensation of the gaseous refrigerant have been achieved. If the control module determines that the temperature in the condenser is too high for the condensation of the refrigerant, the speed of the fan 98 is progressively increased on command from the control module. This increases the flow rate of the cooled ambient air
5 passing from the evaporator to the condenser, causing further heat to be removed from the housing of the condenser by the ambient air and the temperature in the condenser to thereby be progressively lowered. The speed of the fan continues to be increased until a temperature in the condenser at which condensation of the gaseous refrigerant occurs has been reached.

After a short time delay of typically 1 to 2 minutes, the dew point of the ambient air entering
10 the evaporator and the dry bulb temperature of the ambient air leaving the evaporator are again measured by temperature sensors 102 and 104, and those temperatures are compared in the control module. If a temperature measured by the temperature sensor 104 has risen above the dew point of the water, an air-intake comprising a hinged by-pass damper 108 arranged in a lower region of the casing 24 is opened to at least a limited extent by an actuator 110
15 operated by the control module.

The opening of the by-pass damper 108 allows uncooled ambient air to flow into the casing through the further air-intake and past the condenser. This reduces the flow rate of the ambient air through the evaporator to that required for cooling of the ambient air to the dew point of the water in the ambient air while maintaining or otherwise increasing the flow rate
20 of the ambient air past the condenser.

The control module 106 continues to monitor the temperatures of the air flow of the ambient air through the casing measured by temperature sensors 102 and 104, as well as the temperature of the liquid refrigerant in the condenser and the total pressure in the upper region of the condenser measured by pressure sensor 114 and temperature sensor 112, and to adjust
25 the position of the damper 108 and the speed of the fan 98 in response to changing ambient conditions as required for continued condensation of water from the ambient air onto the cooling fins 22 and condensing of the refrigerant vapour within the condenser 6.

The monitoring cycle is repeated at regular intervals to ensure optimum efficiency of the apparatus and thereby, maximum production of water from the ambient air. The timing

circuit for initiating operation of the monitoring cycle is also located within the control module. Such control circuitry is well within the scope of the skilled addressee.

For the purpose of heating the heating reservoir 72 and separation reservoir 64, the apparatus 2 is provided with an elongate parabolic reflector (not shown) having a rectangular shape. The reflector is arranged to receive heat impinging on the apparatus 2 from the sun, and reflecting the heat onto the heating reservoir 72 and the storage reservoir 64. For maximum efficiency, the separation reservoir and heating reservoir are located at the focus of the parabolic reflector. The reflector is further arranged for tracking the movement of the sun during the day and in particular, for being driven by a tracking mechanism 116 from a substantially eastern facing alignment to a western facing alignment with movement of the sun relative to the apparatus in use.

As indicated in Fig. 8 and Fig. 9, the tracking mechanism comprises a balance 116 on which the reflector (not shown) is mounted. The balance incorporates a frame pivotally mounted on a stand 118. The frame consists of hollow side tanks 120 containing freon, and opposite end members 122. The interiors of the tanks are connected together through the passageway of a hollow tube 124. A shade panel 126 lies along each side tank for shading the corresponding tank from behind. A reflective surface 128 on the front side of each shade panel reflects incident solar heat onto the corresponding tank when facing the sun.

The side tanks 120 are arranged such that in use, a first of the tanks is exposed to the sun to a greater degree than the second of the tanks. As the first tank is heated by the sun, the pressure in the tank increases creating a pressure differential between the tanks, and freon progressively flows from the first tank to the other through tube 124. As the freon flows into the second tank, the weight of the second tank becomes heavier than the first, causing the frame of the balance to pivot about the stand and the reflector to be moved in a westerly direction substantially synchronously with the movement of the sun.

At the end of the daylight period, when the heat of the sun decreases, the pressure differential between the side tanks 120 reduces and the direction of the flow of the freon through the hollow tube 124 connecting the tanks reverses. The return of the freon to the first tank causes the weight of that tank to increase and the frame of the balance to progressively pivot about the stand in an opposite direction and the reflector to thereby be progressively returned to its

initial sunrise position. A shock absorber 130 connected at one end to the frame and at an opposite end to the stand, is provided for inhibiting buffeting of the reflector by wind.

It will be understood that a gas and a liquid refrigerant other than ammonia gas and iso-butane may be utilised. For example, other combinations of gases and liquid refrigerants that may be used include ammonia gas and propane, hydrogen chloride gas and propylene, ammonia gas and pentane, hydrogen chloride gas and iso-butane, and methylamine gas and iso-butane. Embodiments may also be provided without a fan for drawing the ambient air through the evaporator and/or past the condenser. In this instance, the flow of the ambient air may be achieved by thermal convection currents flowing through the casing as a result of temperature differences between the evaporator and external ambient air temperatures.

An apparatus 132 embodied by the present invention is illustrated in Fig. 10. The apparatus comprises heating means in the form of a heating tank 134 partly filled with a solution 136 of water and dissolved ammonia. The solution is heated by a heat exchanger 138 disposed within the heating tank. The heat exchanger comprises a metal jacket in fluid communication with a heat collector 140 through feed conduit 142 and return conduit 144. The heat collector 140 is located externally of the heating tank 134 in a lower position for being heated by incident solar heat impinging on the heat collector from the sun. The heat exchanger 138 and heat collector 140 are filled with mineral oil which circulates between the heat exchanger and heat collector via feed and return conduits 142 and 144 under a thermo-siphon effect upon the heating of the heat collector. Rather than mineral oil, a vegetable oil or for instance water may be used to transfer the heat from the heat collector 140 to the heat exchanger 138.

A three-way thermostatic valve 146 is arranged in feed conduit 142 for directing the circulating oil to return conduit 144 via bypass conduit 148 and thereby effectively bypassing the heat collector, in the event the temperature of the oil in the heat exchanger rises to a predetermined level. An expansion tank 150 defining a pressure chamber which opens into the bypass conduit 148 is provided to allow for expansion of the oil into the pressure chamber as the temperature of the oil increases. A safety pressure valve 152 is also provided in bypass conduit 148 for releasing pressure in the event that an upper pressure limit within the heat transfer system defined by the heat exchanger 138 and heat collector 140 is exceeded. The

heat collector 140 comprises a metal tank with a large surface area for maximising heat transfer from incident solar heat to the oil.

As the heat exchanger 138 is heated by the circulating oil from the heat collector 140 during the daylight period, heat is transferred to the water and solution 136 in the heating tank 134.

- 5 As the temperature of the solution rises, ammonia evaporates from the solution, and the resulting gaseous ammonia flows into the inlet of P-trap 153 and rises up riser conduit 154 accompanied by water vapour from the solution in the heating tank. A plurality of metal cooling fins 156 are provided on an upper end region of the riser conduit and dissipate heat from the gaseous ammonia and water vapour, causing the water vapour to condense into water
- 10 which flows back down the riser conduit into the heating tank 134. The cooling effect is not sufficient to condense the gaseous ammonia which continues to rise up the riser conduit 154 to downwardly sloping conduit trap 158.

- Cooling means in the form of a heat sink 160 comprising a water jacket 162 provided with spaced apart cooling fins 164, is disposed about an upper end of the conduit trap 158. As the
- 15 gaseous ammonia flows down the conduit trap, heat is transferred from the ammonia to the heat sink and dissipated into the atmosphere causing the gaseous ammonia to condense to liquid which flows down the conduit trap into evaporator 166 where it is collected and stored. A manual regulator valve 168 is arranged in the conduit trap 158 and remains in a fully open position to facilitate passage of the liquid ammonia into the evaporator 166. A water purge
- 20 conduit 167 is also provided for return of water condensed with the gaseous ammonia from the evaporator to the heating tank.

- Spaced apart cooling fins 170 in heat transfer contact with the housing of the evaporator are disposed around the evaporator 166 and provide condensation surfaces 172 for contact with the ambient air. A fan 174 is arranged for drawing the ambient air over the condensation
- 25 surfaces of the cooling fins through a baffle (not shown) to maximise the condensation of the water from the air onto the fins.

- During the first stage of the work cycle of apparatus 132, most of the dissolved ammonia is evaporated from the water in the heating tank and collected in the evaporator as ammonia liquid. At the commencement of the second stage of the work cycle at the end of the daylight
- 30 period or during times of low heat input from the sun, ammonia evaporates from the ammonia

liquid in the evaporator and flows back to the heating tank 134 via conduit trap 158. As the ammonia evaporates from the ammonia liquid, heat is drawn from the cooling fins into the evaporator 166 such that the cooling fins are thereby cooled. Accordingly, the ammonia acts as a refrigerant which effects the cooling of the cooling fins.

- 5 The fan 174 remains switched off while the liquid refrigerant collects in the evaporator. At the commencement of the second stage of the work cycle of the apparatus, the regulator valve 168 is closed and the fan is operated directing ambient air into contact with the cooling fins. The regulator valve is then progressively opened to a predetermined upper limit to ensure a controlled return flow of the gaseous ammonia evaporated from the liquid refrigerant back
10 into the heating tank through the conduit trap. Opening of the regulator valve also increases the rate of evaporation of the liquid refrigerant until the temperature of the cooling fins is reduced to, or below, the dew point of the water in the ambient air but above its freezing point. At the dew point temperature, water vapour in the ambient air condenses onto the condensation surfaces 172 of the cooling fins upon contact of the ambient air with the fins.
- 15 The cooling fins 170 are arranged at a sloping angle such that the condensed water runs off them into water collector 180 where it is funnelled to a storage tank (not shown) for storage and subsequent use.

- As will be understood, the regulator valve may be further opened or closed as necessary to control the rate of evaporation of the liquid ammonia and thereby the temperature of the
20 cooling fins to, or below, the dew point. Rather than manually operating the regulator valve to effect condensation of the water from the ambient air on to the cooling fins, the valve may be substituted with an automatically controlled solenoid valve and the condensation of the water monitored as in the apparatus shown in Figs. 1 to 4. More particularly, the dew point of the ambient air entering the evaporator may be determined by a sensor arranged to be
25 progressively cooled by the ambient air as the ambient air is cooled by the cooling fins 170. When condensation forms on the sensor, the sensor is short circuited indicating the dew point of the ambient air. This temperature is compared to the dry bulb temperature of the air leaving the evaporator measured by a temperature sensor. If the temperature measured by the temperature sensor is above the determined dew point, the speed of the fan is progressively
30 reduced lowering the flow rate of the air through the evaporator until the temperature of the ambient air leaving the evaporator is at the dew point.

If the temperature sensor senses that the temperature of the ambient air leaving the evaporator has fallen below the determined dew point temperature, the regulator valve is operated in response to a command signal such that the flow of gaseous ammonia through the valve is lowered and the rate of evaporation of the liquid refrigerant thereby reduced.

- 5 The dew point temperature of the ambient air entering the evaporator and the temperature of the ambient air leaving the evaporator continue to be monitored at regular intervals, and the speed of the fan adjusted, and/or the regulator valve operated to alter the rate of evaporation of the ammonia from the liquid refrigerant as necessary, to maintain the temperature of the ambient air leaving the evaporator at, or below, the dew point of the air to optimise the
10 condensation of the water onto the cooling fins.

The gaseous ammonia flows past the P-trap 153 in the riser conduit and enters the heating tank 134 through a diffuser 178 lying adjacent the floor of the heating tank. The diffuser is provided with a plurality of apertures across its surface for providing relatively even
15 distribution of the ammonia as it bubbles from the diffuser into the ammonia depleted water in the heating tank. As the ammonia entering the heating tank 134 contacts the water, an exothermic process generating heat occurs as the ammonia dissolves. The agitation produced as the ammonia enters the heating tank from the diffuser 178 assists in dispersing the resulting heat throughout the water in the tank.

As shown in Fig. 10, the apparatus 132 is further provided with a heat absorber 182 disposed
20 in the heating tank 134, for withdrawing heat from the heating tank generated as the gaseous ammonia vapour from the evaporator 166 re-enters the heating tank 134. The heat absorber 182 is part of a heat transfer system of the apparatus which further comprises heat bank 184 arranged externally of the heating tank 134. The heat absorber 182 and heat bank 184 consist of tanks filled with mineral oil in fluid communication with each other through
25 feed and return conduits 186 and 188, respectively. As the heat absorber 182 is heated, the heat is transferred by the oil it contains to the heat bank 184 and used to heat the heating reservoir 72 and storage reservoir 64 of water condensing apparatus 2 shown in Figs. 1 to 4 during the night or periods of low solar heat availability.

The transfer of the heat from the heat bank 184 to the storage reservoir 64 and heating
30 reservoir 72 is effected by a heat transfer conduit (not shown) which wraps around the storage

reservoir 64 and heating reservoir 72 for effecting transfer of heat to those components, prior to returning the cooled oil to the heat bank 184 for recirculation back to the heat absorber 182 through return conduit 188. By utilising the heat generated by the return of the gaseous ammonia from the evaporator 166 to the heating tank 134 to heat the storage reservoir 64 and heating reservoir 72, the apparatus embodied by the present invention can be utilised to drive further water making by the apparatus of Figs. 1 to 4 after sunset.

Alternatively, or in addition, heat from the heat bank 184 can also be used for other useful work or heating purposes. For instance, the heat bank 184 may be situated in ducting for heating air as the air is either drawn or forced past the heat bank by a fan, prior to the resulting warmed air being expelled from the ducting into a room or other space. Similarly, the cooled air leaving the cooling fins 170 of the evaporator 166 may be used for cooling purposes. For instance, the cooled air may be directed by separate ducting to a vent which opens into a room of a dwelling. The vent may be the same one used to channel heat into the room from the heat bank after sunset during the second stage of the water making cycle. As will be appreciated, the apparatus itself will be located externally at the dwelling.

A further embodiment 190 of the present invention is illustrated in Fig. 11. This embodiment differs from that shown in Fig. 10 in that the fan 174 blows ambient air across the cooling fins 170 of the evaporator 166 during the first stage of the work cycle which is then directed to rectifier cooling fins 191. The ambient air draws off heat from the rectifier fins causing the gaseous ammonia in the conduit trap 158 to condense. The ambient air also draws off heat from gaseous ammonia flowing into the evaporator which has not condensed in the conduit trap 158, causing the remaining gaseous ammonia to condense and collect in the evaporator. The evaporator 166 in this embodiment therefore serves as both a condenser for condensation of the gaseous ammonia and to facilitate evaporation of gaseous ammonia from the liquid ammonia for return to the heating tank during the second stage of the work cycle.

During the second stage of the work cycle, the fan continues to operate such that ambient air flows into contact with the condensation surfaces 172 of the cooling fins 170 for condensation of water from the air onto the fins. In this embodiment, however, the cooled air flowing from the cooling fins is selectively redirected to heat exchanger 140 and cooling tank 192. The cooling tank is in fluid communication with the heating tank 134 through inlet pipe 194 and

manifold 196. The cooling fins 198 disposed around the cooling tank facilitate the dissipation of heat from the fluid that enters the cooling tank via the inlet pipe 194. The cooler fluid then recirculates from the cooling tank back to the heating tank through the manifold 196 under a thermo-siphon effect achieved by the temperature difference between the fluid in the heating tank and the fluid in the cooling tank.

Using the cooled air from the evaporator 166 to cool the heat exchanger 140 draws further heat from the heat absorber 138 of the heat transfer system of this embodiment, such that the fluid in the heating tank is further cooled. Drawing heat from the fluid in the cooling tank enhances the rate of absorption of the gaseous ammonia entering the heating tank from the diffuser 178 by the fluid. The resulting increase in efficiency in the return of the gaseous ammonia into the fluid lowers the time taken to complete the work cycle.

In this embodiment, water purge conduit 167 also directs water in the evaporator that has condensed with the gaseous ammonia in the conduit trap 158 to the heating tank 134.

A yet further embodiment 200 of the present invention is shown in Fig. 12. In this apparatus, a solenoid operated control valve 202 is provided which is opened during the first stage of the work cycle of the apparatus to allow the flow of ammonia to the evaporator 166. The control valve 202 is closed for the second stage of the work cycle, and the flow rate of gaseous ammonia returning to the heating tank 134 is controlled by throttle valve 204 arranged in the conduit trap 158. The throttle valve incorporates a fluid expansion thermostat 206 for sensing the temperature of the cooling fins 170 of the evaporator 166 and effecting opening or closing of the throttle valve in response to variation in the temperature, to regulate evaporation of the liquid ammonia and thereby condensation of water from the ambient air.

For any given prevailing atmospheric conditions, there is a specific humidity value measured in grams of water vapour per kilogram of air. For example, a specific humidity of between 4.5 and 6 grams of moisture per kilogram of air correlates to a dry bulb temperature of between 1°C and 6.5°C. In use, the apparatus is operated such that the specific humidity of the ambient air flowing from the cooling fins is reduced to a specific humidity correlating with a specific selected dry bulb temperature or temperature range monitored by the thermostat. Typically, the thermostat will be selected or set to maintain the temperature of the

air leaving the cooling fins in a range of from about 3.5°C to about 5.5°C and usually, at a temperature of about 5°C.

That is, if the temperature of the air leaving the cooling fins of the evaporator 166 decreases from a predetermined optimum level for condensation of the water from the ambient air the thermostat effects closing of the throttle valve slowing the rate of gaseous ammonia through the throttle valve. This in turn reduces the rate of evaporation of the gaseous ammonia and as a consequence, raises the temperature of the cooling fins. If the temperature of the air leaving the cooling fins increases from the optimum level, the thermostat 206 effects opening of the throttle valve, increasing the flow rate of gaseous ammonia to the heating tank which in turn, increases the rate of evaporation of the liquid ammonia in the evaporator 166. The temperature of the cooling fins thereby decreases. Accordingly, the thermostat effects automatic regulation of the condensation of the water.

A yet further embodiment of the present invention is illustrated in Fig. 13. In this embodiment, cooling fins 208 are provided around the lower end of the conduit trap 158 which is housed in ducting 210 for directing air drawn across the cooling fins to the cooling tank 192 or to a vent indicated by "A" as described further below.

At the commencement of the first stage of the work cycle, the heating tank 134 contains an aqueous solution 136 comprising 49.5% by weight ammonia (10.68 kg ammonia in 10.92 kg of distilled water). Ammonia vapour and a small quantity of water vapour are present in the remainder of the system. The overall system pressure at this concentration of ammonia is determined by the sum of the water and ammonia vapour pressures which varies according to temperature as indicated in Table 1. The temperature of the solution in the heating tank is measured by a temperature sensor (not shown), while pressure in the heating tank is reassured by a pressure sensor 218.

Table 1: System Pressure

Temp		Pressure	
deg C	psia	psig	KPag
20	39	25	172
24	45	31	214

24

28	50	36	248
32	58	44	303
36	66	52	359
40	74	60	414

As with the embodiment illustrated in Figs. 10 to 12, heat is applied to the heating tank driving gaseous ammonia from the ammonia solution 136 in the heating tank. The heat may for instance be provided by an electrical heating element, solar heat reflected from an appropriately orientated solar reflector as in the related embodiment shown in Fig. 8 and Fig. 9, or by waste heat from a waste source such as hot water from a boiler channelled to the heating tank via conduit arranged in heat transfer contact with the heating tank for effecting transfer of the waste heat to the ammonia solution. The heat transfer from the heat source to the heating tank through the conduit may be achieved by a "thermo-siphon" effect as described above.

The damper 212 is closed thereby directing the ambient air drawn into the ducting 210 to vent A. The first stage of the work cycle continues until the starting concentration of ammonia (49.5% by weight) in the heating tank falls to a concentration of 39.5%. The system pressure – temperature relationship during this stage is indicated in Tables 2 and 3.

Table 2: System Pressure (Ammonia conc. = 49.5% by weight)

Heated Temp		Pressure	
deg C	psia	Psig	KPag
70	170	156	1076
75	195	181	1249
80	220	206	1421
85	245	231	1594
90	270	256	1766

95	300	286	1973
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Table 3: System Pressure (Ammonia conc. 39.5% by weight)

Heated Temp		Pressure	
deg C	Psia	Psig	Kpag
70	118	104	718
75	130	116	800
80	140	126	869
85	160	146	1007
90	180	166	1145
95	200	186	1283
100	225	211	1456
105	255	241	1663
110	280	266	1835

The gaseous ammonia travels up the riser conduit 154 accompanied by water vapour from the solution in the heating tank. A plurality of metal cooling fins 156 are provided on an upper end region of the riser conduit and dissipate heat from the gaseous ammonia and water vapour, causing most of the water vapour to condense into water which flows back down the riser conduit into the heating tank 134. Cooling is not sufficient to condense the gaseous ammonia which continues to rise up the riser conduit 154 to downwardly sloping conduit trap 158 through the non-return control valve 207 (see figure 13) as a result of the pressure differential generated. The ambient air drawn across the cooling fins 208 on the lower end of the conduit trap draws off heat from the gaseous ammonia causing the ammonia vapour to condense and drain by gravity into the evaporator. The pressure at which the gaseous ammonia condenses is dependent on the prevailing temperature of the ambient air. As described above, not all the water vapour which evaporates from the solution 136 in the heating tank condenses in the riser conduit 154, and some carries over and condenses with the gaseous ammonia.

During the first stage of the work cycle the solenoid valve is closed, preventing gaseous ammonia flowing back to the heating tank. When the concentration of the ammonia in solution in the heating tank has fallen to 39.5% by weight as determined by the measured temperature of the solution and pressure in the heating tank, heating of the heating tank is
5 halted and the damper 212 is operated such that the ambient air drawn into the ducting by the fan 174 is directed to the cooling fins 191 of the cooling tank 192. When a solar reflector or waste heat source is utilised for heating the heating tank, the heating of the heating tank may be halted by redirecting the solar reflector away from the heating tank or by a solenoid valve the operation of which redirects the heated water from the waste source away from the heating
10 tank. Similarly, to recommence heating of the heating tank at the start of a new work cycle following the return of the ammonia from the evaporator 166, the solar reflector can be re-orientated onto the heating tank or the solenoid valve operated such that the heated water is directed to the heating tank.

The cooling of the heating tank effected by the ambient air flowing across the fins 191 of the
15 cooling tank facilitates recirculation of the fluid in the heating tank between the heating tank 134 and the cooling tank 192 via the manifold 196 in the direction of the arrows. When the temperature of the recirculating fluid has substantially reached ambient temperature, the solenoid valve opens. The ammonia partial pressure difference between the evaporator and the heating tank results in the rapid evaporation of approximately 12% by weight of the liquid
20 ammonia collected in the evaporator 166. As a result of the generation of this "flash gas", the evaporator and the cooling fins 208 around the lower end of the conduit trap are rapidly cooled to near 0°C.

A temperature controlled evaporator pressure regulator (EPR) valve 216 senses the temperature of the gaseous ammonia passing from the evaporator and opens and closes as
25 necessary to regulate the pressure difference between the evaporator and heating tank to ensure the temperature of the cooling fins 208 on which water from the ambient condenses does not fall below 0°C.

The non-return control valve 207 ensures the gaseous ammonia does not by-pass the EPR valve 216. At the commencement of the second stage of the work cycle the pressure

difference across the EPR valve 216 is 27 psig (186 kPag) which falls to 4 psig (27 kPag) at the completion of this stage of the cycle.

When the concentration of the ammonia in the fluid in the heating tank has returned to substantially the initial starting concentration as indicated by the measured temperature of the fluid and pressure in the heating tank, the solenoid valve 214 is closed, and the work cycle immediately recommences.

The condensed water falls from the cooling fins 208 and is collected in water collector 209.

Gaseous ammonia flowing into the top of the heating tank from the riser conduit 154 during the second stage of the work cycle is absorbed by the upper region of the fluid in the heating tank. The continued absorption of the gaseous ammonia is facilitated by the heat being drawn away from the upper region of the fluid by the recirculation of the fluid between the heating tank and the cooling tank.

Due to the loss of water and ammonia from the heating tank to the evaporator during the first stage of the work cycle, the mass of the fluid in the heating tank is less at the completion of this stage of the work cycle compared to at the beginning of the work cycle. However, as a result of the increase in temperature of the fluid in the heating tank, the volume of the fluid in the heating tank increases, and the level rises by amount "h".

As further shown in Fig. 14, the evaporator 166 incorporates a water return system 220 for returning water which accumulates in the evaporator back to the heating tank via the water return line 222. The water return system comprises a float valve incorporating a ball float 224 arranged in a storage cylinder 226 which opens into the interior of the evaporator. The ball float 224 normally rests on the open end 228 of the water return line 222, thereby sealing the water return line.

A pressure equalising line 230 connects the upper region of the storage cylinder above the ball float 224 to a lower region of the storage cylinder below the ball float. The density of water is greater than that of liquid ammonia of the same temperature and so settles to the bottom of the storage cylinder. The ball float has a density such that it will not float in the liquid ammonia but will float in the water.

When sufficient water accumulates in the storage cylinder 226, the ball float 224 is lifted from the end of the water return line, allowing water to flow into the return line until the level of the water in the storage cylinder decreases such that the ball float returns to its normal position sealing the end of the water return line preventing the escape of liquid ammonia from the evaporator. The pressure difference between the evaporator and the heating tank drives the water through the return line to the riser conduit 154 during the second stage of the work cycle from where it drains back into the heating tank. A non-return valve 232 arranged in the water return line 222 prevents water from flowing back into the water storage cylinder 226 during the first stage of the work cycle.

A yet further embodiment of the present invention is illustrated in Fig. 15. In this embodiment, cooling fins 208 are provided around the lower end of the conduit trap 158 which is housed in ducting 210 for directing air drawn across the cooling fins to a vent indicated by "A" as described further below.

At the commencement of the first stage of the work cycle, the heating tank 134 contains an aqueous solution 136 comprising 49.5% by weight ammonia (10.68 kg ammonia in 10.92 kg of distilled water). Ammonia vapour and a small quantity of water vapour are present in the remainder of the system. The overall system pressure at this concentration of ammonia is determined by the sum of the water and ammonia vapour pressures which varies according to temperature as indicated in Table 1. The temperature of the solution in the heating tank is measured by a temperature sensor (not shown), while pressure in the heating tank is measured by a pressure sensor 218.

Table 1: System Pressure

Temp		Pressure	
deg C	psia	psig	KPag
20	39	25	172
24	45	31	214
28	50	36	248
32	58	44	303

36	66	52	359
40	74	60	414

- As with the embodiment illustrated in Figs. 10 to 12, heat is applied to the heating tank driving gaseous ammonia from the ammonia solution 136 in the heating tank. The heat may for instance be provided by an electrical heating element, solar heat reflected from an
- 5 appropriately orientated solar reflector as in the related embodiment shown in Fig. 8 and Fig. 9, or by waste heat from a waste source such as hot water from a boiler channelled to the heating tank via conduit arranged in heat transfer contact with the heating tank for effecting transfer of the waste heat to the ammonia solution. Alternately heat may also be provided by
- 10 a metal jacket 250 which surrounds cooling tank 192 and which is in fluid communication with a heat collector 140 through feed conduit 142 and return conduit 144. The heat collector 140 is located externally of the heating tank 134 in a lower position for being heated by incident solar heat impinging on the heat collector from the sun. The metal jacket 250 and heat collector 140 are filled with mineral oil which circulates between the metal jacket and
- 15 heating of the heat collector. Rather than mineral oil, a vegetable oil or for instance water may be used to transfer the heat from the heat collector 140 to the metal jacket 250. The heat transfer from the heat source to the metal jacket through the conduits and the heat transfer from the cooling tank to the heating tank may be achieved by a "thermo-siphon" effect as described above.
- 20 A solenoid valve 251 is arranged in feed conduit 142 to stop the "thermo-siphon" heat transfer between the heat collector and the metal jacket when heat transfer is no longer required or when solar heat is unavailable.

The first stage of the work cycle continues until the starting concentration of ammonia (49.5% by weight) in the heating tank falls to a concentration of 39.5%. The system pressure –

25 temperature relationship during this stage is indicated in Tables 2 and 3.

Table 2: System Pressure (Ammonia conc. = 49.5% by weight)

Heated Temp		Pressure	
deg C	psia	Psig	KPag
70	170	156	1076
75	195	181	1249
80	220	206	1421
85	245	231	1594
90	270	256	1766
95	300	286	1973

Table 3: System Pressure (Ammonia conc. 39.5% by weight)

Heated Temp		Pressure	
deg C	Psia	Psig	Kpag
70	118	104	718
75	130	116	800
80	140	126	869
85	160	146	1007
90	180	166	1145
95	200	186	1283
100	225	211	1456
105	255	241	1663
110	280	266	1835

The gaseous ammonia travels up the riser conduit 154 accompanied by water vapour from the solution in the heating tank. A plurality of metal cooling fins 156 are provided on an upper end region of the riser conduit and dissipate heat from the gaseous ammonia and water vapour, causing most of the water vapour to condense into water which flows back down the riser conduit into the heating tank 134. The cooling effect is not sufficient to condense the gaseous ammonia which continues to rise up the riser conduit 154 to downwardly sloping

conduit trap 158 through the non-return control valve 207 as a result of the pressure differential generated. The ambient air drawn across the cooling fins 208 on the lower end of the conduit trap draws off heat from the gaseous ammonia causing the water vapour to condense and drain by gravity into the evaporator. The pressure at which the gaseous ammonia condenses is dependent on the prevailing temperature of the ambient air. As described above, not all the water vapour which evaporates from the solution 136 in the heating tank condenses in the riser conduit 154, and some carries over and condenses with the gaseous ammonia.

During the first stage of the work cycle solenoid valve 216 is closed, preventing gaseous ammonia flowing back to the heating tank. When the concentration of the ammonia in solution in the heating tank has fallen to 39.5% by weight as determined by the measured temperature of the solution and pressure in the heating tank, heating of the heating tank is halted. When a solar reflector or waste heat source is utilised for heating the heating tank, the heating of the heating tank may be halted by redirecting the solar reflector away from the heating tank or by a solenoid valve which redirects the heated water from the waste source away from the heating tank. To recommence heating of the heating tank at the start of a new work cycle following the return of the ammonia from the evaporator 166, the solar reflector can be re-orientated onto the heating tank or the solenoid valve operated such that the heated water is directed to the heating tank.

The metal jacket 250 is in fluid communication with the exterior of heating reservoir 72 and storage reservoir 64 of water condensing apparatus 2 shown in Figs. 1 to 4 through feed conduit 254 and return conduit 253. Condensing apparatus 2 is located externally of metal jacket 250 in a higher position. A solenoid valve 252 is arranged in feed conduit 254. When the first stage of the work cycle is halted solenoid valve 252 opens and allows heated oil in the metal jacket 250 to rise by "thermo-siphon" effect through feed conduit 254 and to heat reservoir 72 and storage reservoir 64 of condensing apparatus 2. As heat is absorbed from the heated oil by heat reservoir 72 and storage reservoir 64 cooled oil returns through return conduit 253 to the metal jacket 250. The cooled oil in the metal jacket effects cooling of the cooling tank 192 which facilitates recirculation of the fluid in the heating tank 134 and the cooling tank via the manifold 196.

When the temperature of the recirculating fluid has substantially reached ambient temperature, the solenoid valve 216 opens and solenoid valve 252 closes. The ammonia partial pressure difference between the evaporator and the heating tank results in the rapid evaporation of approximately 12% by weight of the liquid ammonia collected in the evaporator 166. As a result of the generation of this "flash gas", the evaporator and the cooling fins 208 around the lower end of the conduit trap are rapidly cooled to near 0°C.

A temperature controlled evaporator pressure regulator (EPR) valve 216 senses the temperature of the gaseous ammonia passing from the evaporator and opens and closes as necessary to regulate the pressure difference between the evaporator and heating tank to ensure the temperature of the cooling fins 208 on which water from the ambient condenses does not fall below 0°C.

The non-return control valve 207 ensures the gaseous ammonia does not by-pass the EPR valve 216. At the commencement of the second stage of the work cycle the pressure difference across the EPR valve 216 is 27 psig (186 kPag) which falls to 4 psig (27 kPag) at the completion of this stage of the cycle.

When the concentration of the ammonia in the fluid in the heating tank has returned to substantially the initial starting concentration as indicated by the measured temperature of the fluid and pressure in the heating tank, the solenoid valve 214 is closed, and the work cycle immediately recommences.

The condensed water falls from the cooling fins 208 and is collected in water collector 209.

Gaseous ammonia flowing into the top of the heating tank from the riser conduit 154 during the second stage of the work cycle is absorbed by the upper region of the fluid in the heating tank. The continued absorption of the gaseous ammonia is facilitated by the heat being drawn away from the upper region of the fluid by the recirculation of the fluid between the heating tank and the cooling tank.

Due to the loss of water and ammonia from the heating tank to the evaporator during the first stage of the work cycle, the mass of the fluid in the heating tank is less at the completion of this stage of the work cycle compared to at the beginning of the work cycle. However, as a

result of the increase in temperature of the fluid in the heating tank, the volume of the fluid in the heating tank increases, and the level rises by amount "h".

As further shown in Fig. 15, the evaporator 166 incorporates a water return system 220 for returning water which accumulates in the evaporator back to the heating tank via the water return line 222. The water return system comprises a float valve incorporating a ball float 224 arranged in a storage cylinder 226 which opens into the interior of the evaporator. The ball float 224 normally rests on the open end 228 of the water return line 222, thereby sealing the water return line.

A pressure equalising line 230 connects the upper region of the storage cylinder above the ball float 224 to a lower region of the storage cylinder below the ball float. The density of water is greater than that of liquid ammonia of the same temperature and so settles to the bottom of the storage cylinder. The ball float has a density such that it will not float in the liquid ammonia but will float in the water.

When sufficient water accumulates in the storage cylinder 226, the ball float 224 is lifted from the end of the water return line. In the lifted position the ball float 224 allows water to flow into the return line until the level of the water in the storage cylinder decreases such that the ball float returns to its normal position and seals the end of the water return line to prevent the escape of liquid ammonia from the evaporator. The pressure difference between the evaporator and the heating tank drives the water through the return line to the riser conduit 154 during the second stage of the work cycle from where it drains back into the heating tank. A non-return valve 232 arranged in the water return line 222 prevents water from flowing back into the water storage cylinder 226 during the first stage of the work cycle.

As with the embodiment shown in Figs. 10 to 12, the apparatus shown in Figs. 13, 14 and 15 may also be utilised for cooling or heating purposes. Similarly, the embodiment shown in Figs. 10 to 12 may be provided with a water system as in the embodiment of Figs. 13, 14 and 15.

Heating of the heat collector of the apparatus of the invention shown in Figs. 10 and 11 during the first stage of the work cycle may also be achieved utilising a parabolic reflector and heat tracking mechanism arrangement as illustrated in Figs. 8 and 9, or by using heat from an

external heat source such as a boiler, engine hot water or discharge heat from the condenser of a refrigeration or air conditioning unit generated during operation of such devices. As described above, heated water or for instance, air may also be channelled to the heat collector from the external heat source by conventional copper tubing which wraps around the heat collector in heat transfer contact to effect the transfer of heat to the heat collector, the regions of the tubing not in contact with the heat collector being lagged to limit heat loss.

5 Alternatively, the heating of the heat collector and/or the heating tank 134 may be effected by electrical heating elements powered by mains electricity or other external power source. In such embodiments, the heat collector may not be provided in which case the heat exchanger 138 and heat collector 140 will typically also not be provided.

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The power for driving the operation of electrical components of the apparatus shown in Fig. 1, and those of embodiments of the invention, such as the fans (98, 174), solenoid control valves 214, 251 and 252 and control circuits, may also be provided by an external power source. Preferably, however, solar panel(s) arranged for receiving solar energy and comprising arrays of photovoltaic cells will be provided for generating sufficient energy to meet the overall energy requirements of the apparatus. In this instance, one or more rechargeable batteries and associated recharging circuitry for recharging the battery or batteries using electrical energy generated by the solar panel(s) will also be provided. Such recharging systems are also well known in the art.

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Moreover, rather than utilising a fan to blow or draw the ambient air across the cooling fins 170 the external air temperature.

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It is also and 208 of the evaporator 166 and conduit trap 158 respectively, embodiments of the invention may be provided in which the flow of the ambient air may be achieved by thermal convection currents flowing through a casing housing the apparatus as a result of temperature differences between the evaporator 166 and conduit trap 158 and it not necessary that ammonia be used as the refrigerant in the apparatus embodied by the present invention, and any other suitable gas which generates heat on contact with the fluid in the heating tank and which is capable of being condensed into a liquid under the conditions of the work cycle of the apparatus can be utilised. Similarly, while it is preferred that water be used as the fluid in

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the heating tank for absorption of the gaseous ammonia, any other suitable fluid which is compatible with the refrigerant selected may be utilised.

Besides collecting water from ambient air for drinking or other purposes, an apparatus of the invention may be used as a dehumidifier for dehumidifying silos or other interior spaces

- 5 . where it is desirable to minimise the water content of the air. Similarly, the apparatus may be used for removing water from locations such as from the interior of pipes used for channelling hydrophobic fluids such as oil or petroleum. In such applications, air may be drawn from the silo or pipe(s) prior to being returned to the silo or pipe(s) following the extraction of the water by the apparatus. When a silo (eg. wheat silo) is to be dehumidified, the air may first be
10 filtered to remove dust from the air prior to the air contacting the cooling fins of the apparatus.

- Accordingly, although the present invention has been described hereinbefore with reference to a number of preferred embodiments, the skilled addressee will appreciate that numerous changes and modifications are possible without departing from the spirit or scope of the
15 invention. The present embodiments described are, therefore, to be considered in all respects as illustrative and not restrictive.

36.

CLAIMS

1. A method for condensing water from ambient air, the method comprising:
providing at least one condensation surface for contact with the ambient air;
heating a solution of a refrigerant and a fluid, to drive gaseous refrigerant from the solution;
cooling the gaseous refrigerant to condense the gaseous refrigerant into liquid refrigerant, and collecting the liquid refrigerant;
evaporating refrigerant from the liquid refrigerant such that heat is exchanged between the refrigerant and the condensation surface which is thereby cooled to, or below, the dew point of the water in the ambient air; and
contacting the cooled condensation surface with the ambient air to effect condensation of water from the ambient air onto the condensation surface.
2. A method as claimed in claim 1 wherein the step of heating the solution comprises solar energy.
3. A method as claimed in claim 1 or claim 2 wherein the step of heating the refrigerant and fluid solution is controlled in response to temperature of the refrigerant and fluid solution and pressure within a container containing that solution.
4. A method as claimed in claim 3 wherein the step of heating the refrigerant and fluid solution is at least partially reduced if, according to the temperature of the refrigerant and fluid solution and the pressure within the container, the concentration of ammonia in solution is less than or equal to about 39.5% by weight.
5. A method as claimed in any one of the preceding claims further comprising the steps of returning the refrigerant evaporated from the liquid refrigerant to the fluid for repeating heating and evaporation steps.
6. A method as claimed in claim 5 further comprising the step of drawing away any heat generated on contact of the returned refrigerant with the fluid to promote return of further refrigerant evaporated from the liquid refrigerant to the fluid.

7. A method as claimed in claim 5 or claim 6 further comprising the step of controlling the flow rate of gaseous refrigerant to the refrigerant and fluid solution.
8. A method as claimed in claim 7 wherein the step of controlling the flowrate of gaseous refrigerant to the refrigerant and fluid solution comprises the step of comparing the dewpoint of the ambient air with the temperature of ambient air following its contact with the condensation surface.
9. A method as claimed in claim 8 wherein the dewpoint of the ambient air is determined by sensing the temperature at which water condenses from the ambient air onto the condensation surface.
10. A method as claimed in claim 9 wherein the steps of sensing and comparing temperatures comprise the steps of measuring corresponding temperatures.
11. A method as claimed in any one of the preceding claims further comprising the step of collecting water condensed onto the condensation surface.
12. A method for heating comprising:
 - heating a solution of a refrigerant and a fluid, to drive gaseous refrigerant from the solution;
 - cooling the gaseous refrigerant such that the gaseous refrigerant condenses into liquid refrigerant, and collecting the liquid refrigerant;
 - evaporating refrigerant from the liquid refrigerant and returning the refrigerant evaporated from the liquid refrigerant to the fluid to produce heat upon contact of the refrigerant with the fluid; and
 - utilising the heat for heating.
13. A method as claimed in claim 12 further comprising the step of drawing heat generated by the contact of the refrigerant with the fluid away from the fluid to promote return of further evaporated refrigerant into the fluid.
14. A method for cooling comprising:
 - providing at least one cooling surface for contact with ambient air;

heating a solution of a refrigerant and a fluid, to drive gaseous refrigerant from the solution;

cooling the gaseous refrigerant to condense the gaseous refrigerant into liquid refrigerant, and collecting the liquid refrigerant;

evaporating refrigerant from the liquid refrigerant such that heat is exchanged between the refrigerant and the cooling surface which is thereby cooled;

contacting the cooling surface with the ambient air to cool the ambient air; and

using the cooled ambient air for cooling.

15. A method as claimed in claim 14 further comprising the step of returning the evaporated refrigerant to the fluid.

16. An apparatus for condensing water from ambient air, the apparatus comprising:
heating means for heating a solution of a refrigerant and a fluid, to drive evaporation of the refrigerant from the solution to produce gaseous refrigerant;

cooling means for cooling the gaseous refrigerant such that the gaseous refrigerant condenses into liquid refrigerant; and

an evaporator having at least one condensation surface for contact with the ambient air and being arranged for collecting the liquid refrigerant, and subsequent evaporation of gaseous refrigerant from the liquid refrigerant; wherein

the condensation surface is arranged for being cooled to, or below, the dew point of the water in the ambient air by heat exchange between the refrigerant and the condensation surface upon evaporation of the refrigerant from the liquid refrigerant, and thereby effecting condensation of water from the ambient air onto the condensation surface.

17. An apparatus as claimed in claim 16 wherein the heating means comprises a heat collector for collecting heat.

18. An apparatus as claimed in claim 17 wherein the heat collector is arranged to collect solar energy.

19. An apparatus as claimed in claim 17 or claim 18 wherein the heating means comprises a heat exchanger arranged to transfer heat from the heat collector to the refrigerant and fluid solution.

20. An apparatus as claimed in claim 19 wherein the heat exchanger comprises a metal jacket in fluid communication with the heat collector.
21. An apparatus as claimed in claim 20 wherein the communicating fluid is preferably mineral oil.
22. An apparatus as claimed in claim 20 and claim 21 wherein the heating means is arranged to at least partially restrict flow of the communicating fluid between the heat collector and heat exchanger if the communicating fluid rises above a predetermined temperature.
23. An apparatus as claimed in any one of claims 16 to 22 wherein the heating means is arranged to control heating of the refrigerant and fluid solution in response to temperature of the refrigerant and fluid solution and pressure within a container containing that solution.
24. An apparatus as claimed in claim 23 wherein the heating means is arranged to at least partially reduce heating of the refrigerant and fluid solution if, according to the temperature of the refrigerant and fluid solution and the pressure within the container, the condensation of ammonia in solution is less than or equal to about 39.5% by weight.
25. An apparatus as claimed in any one of claims 16 to 24 wherein the cooling means comprises a heat sink for dissipating heat from the gaseous refrigerant to effect the condensation of the gaseous refrigerant.
26. An apparatus as claimed in claim 25 wherein the cooling means comprises distillation means for distilling gaseous refrigerant from gas comprising gaseous refrigerant and gas evaporated from the fluids.
27. An apparatus as claimed in claim 26 wherein the distillation means is arranged to condense gas evaporated from the fluid.
28. An apparatus as claimed in claim 27 wherein the distillation means comprises a riser conduit.
29. An apparatus as claimed in claim 28 wherein the distillation means also comprises cooling fins.

30. An apparatus as claimed in any one of claims 16 to 29 further comprising refrigerant vapour return means for returning refrigerant vapour evaporated by the evaporator to the refrigerant and fluid solution.
31. An apparatus as claimed in claim 30 wherein the refrigerant vapour return means comprises a port of the evaporator for return of the gaseous refrigerant to the refrigerant and fluid solution.
32. An apparatus as claimed in claim 30 or claim 31 wherein the refrigerant vapour return means comprises refrigerant vapour flow rate control means for controlling the flow rate of refrigerant vapour.
33. An apparatus as claimed in claim 32 wherein the refrigerant vapour flow rate control means is arranged to control the flow rate of refrigerant vapour by comparing the dewpoint of the ambient air with the temperature of the ambient air following its contact with the condensation surface.
34. An apparatus as claimed in claim 33 wherein the refrigerant vapour flow rate control means is arranged to determine the dewpoint by measuring the temperature at which water condenses from the ambient air onto the condensation surface.
35. An apparatus as claimed in claims 33 or 34 wherein the refrigerant vapour control means is arranged to measure the temperature of the ambient air following its contact with the condensation surface to compare it with the dewpoint.
36. An apparatus as claimed in any one of claims 16 to 35 further comprising a diffuser for diffusing refrigerant vapour into the refrigerant and fluid solution.
37. An apparatus as claimed in any one of claims 16 to 36 further comprising heat absorber means for absorbing heat from the refrigerant and fluid solution following the return of refrigerant vapour to the refrigerant and fluid solution via the refrigerant vapour return means.
38. An apparatus as claimed in claim 37 wherein the heat absorber means is arranged to store heat to heat the refrigerant and fluid solution.

39. An apparatus as claimed in claim 38 wherein the heat absorber means is preferably arranged to heat the refrigerant and fluid solution using the stored heat at times of reduced availability of solar energy.
40. An apparatus as claimed in any one of claims 16 to 39 further comprising water collection means arranged to collect water condensed onto the condensation surface.
41. An apparatus for heating comprising:
heating means for heating a solution of a refrigerant and a fluid, to drive evaporation of the refrigerant from the fluid to produce gaseous refrigerant;
cooling means for cooling the gaseous refrigerant such that the gaseous refrigerant condenses into liquid refrigerant;
an evaporator arranged for collecting the liquid refrigerant, subsequent evaporation of gaseous refrigerant from the liquid refrigerant, return of the gaseous refrigerant to the fluid, the gaseous refrigerant generating heat on contact with the fluid; and
heat drawing means for drawing heat from the fluid following contact of the gaseous refrigerant with the fluid for heating.
42. An apparatus for cooling comprising:
heating means for heating a solution of a refrigerant and a fluid, to drive evaporation of the refrigerant from the fluid to produce gaseous refrigerant;
cooling means for cooling the gaseous refrigerant such that the gaseous refrigerant condenses into liquid refrigerant;
an evaporator having at least one cooling surface for contact with ambient air and being arranged for collecting the liquid refrigerant and subsequent evaporation of refrigerant from the liquid refrigerant, the condensation surface arranged for being cooled by heat exchange between the refrigerant and the condensation surface upon evaporation of the refrigerant from the liquid refrigerant.; and
directing means for directing the ambient air into contact with the cooled cooling surface for cooling.