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METHOD AND APPARATUS FOR EXTRACTING PURE WATER

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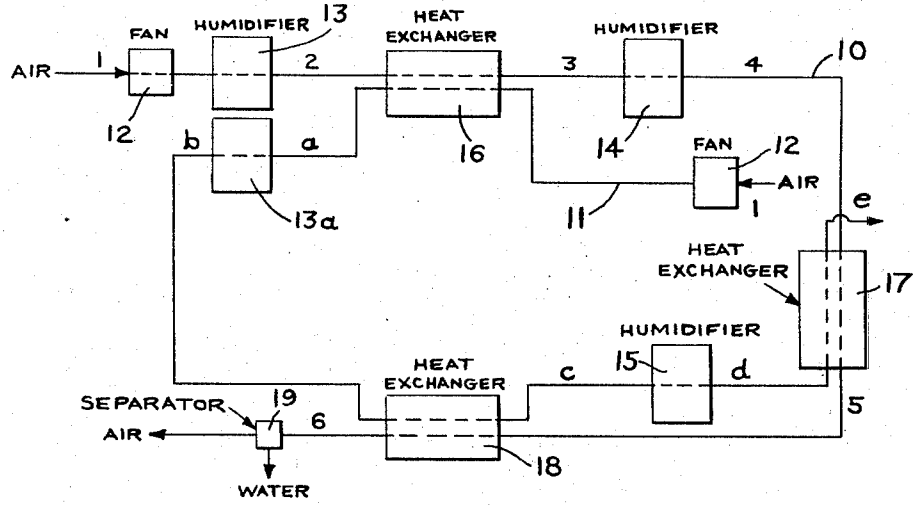


FIG. 1

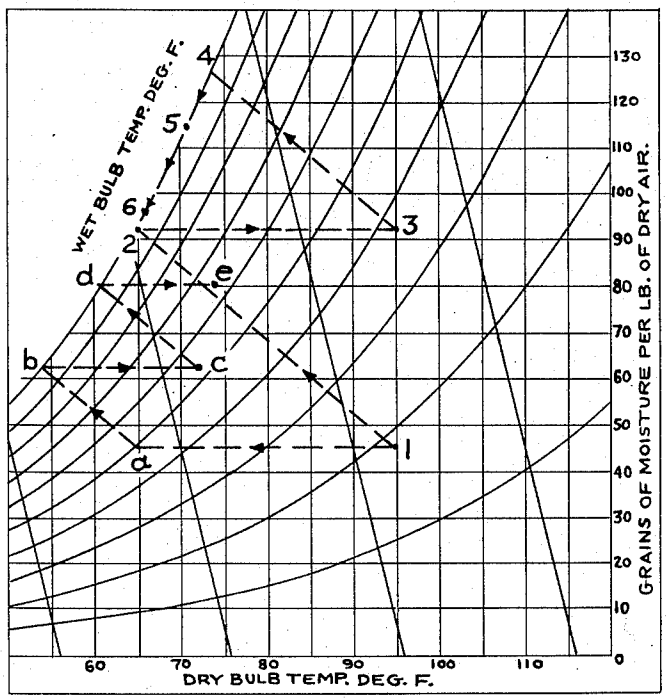


FIG. 2

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METHOD AND APPARATUS FOR EXTRACTING PURE WATER

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This invention relates to a method and apparatus which have for their object the economical extraction of pure water from impure water by utilizing air characterized by a relatively high temperature and low moisture content.

Ideally therefore, the invention is most economically carried out in hot and dry areas where such air is readily available. However, limitation to these areas is not intended since a source of hot and dry air may be economically available in other areas, for example, as a by-product in a power plant.

Prior methods and apparatus for reclaiming water operate on the basic principle of saturating air with water vapor and then condensing this water vapor out of the air. It is known that this condensed water vapor will be pure to the extent that it is usable for drinking purposes, even though evaporated from a source which is biologically, organically, or inorganically impure or contaminated.

The method and apparatus of the present invention likewise operate on this basic principle. However, they are distinguished from the prior art in that they are more economical in practice than the prior art methods and apparatus now used.

More particularly, in the present invention is is an object to utilize the hot and dry ambient air characteristic of various sections of this country, and thus available at no cost, to effect the saturation and condensation of pure water from air.

It has been found that because of the natural propensity of hot and dry air to readily absorb moisture, that after saturation, psychometric temperature changes can be readily induced in this air, and afterwards two circulated streams of the air passed in heat exchange relationship with each other to effect condensation of pure water from one of the air streams.

More particularly, the method of the present invention contemplates the use of hot and dry atmospheric air divided into two interacting streams. One of these is a temperature control stream and follows one path through the apparatus, and the other is a water vapor or moisture carrier stream and follows another path through the apparatus. It is the function of the control stream to supply the thermal head required for all heat transfer processes with the carrier stream and as a result induce the carrier stream to yield pure and drinkable water. Accordingly, all heat transfer operations occur internally between the two streams and no external source of heat is required.

The method of the present invention may be practiced utilizing any one of several well known types of heat exchangers, and for this reason no one particular unit is described in detail herein. On the other hand, the more efficient the heat exchanger, the greater the yield of pure and drinkable water. For this reason, it is preferred to use a heat exchanger through which the air streams pass counterflow rather than parallel flow, since such a heat exchanger is known to provide efficiency of

heat transfer in some instances as high as 96%, and otherwise generally approaching 90%, whereas in parallel flow heat exchangers the best that can be expected is an averaging of the temperatures of the air streams. The details of construction and operation of counterflow heat exchangers which may be used in the present invention are fully disclosed in U.S. Patents 2,464,766 and 2,563,415, issued March 15, 1949, and August 7, 1951, respectively.

Further, in describing the method of the present invention, 100% or maximum theoretical efficiency is assumed for each heat exchanger in order to greatly simplify the calculation of the temperatures of the air streams, it being understod that while these temperatures cannot actually be attained, they are nevertheless realistic in view of the high operating efficiency of known counterflow heat exchangers.

The invention will be better understod when considered in connection with the accompanying specification and drawings forming a part thereof, in which:

Figure 1 is a diagrammatic representation of the apparatus of the invention in which the flow path of the circulated air streams are also illustrated.

Figure 2 is a graph of the temperature and moisture content of the air streams throughout their flow through the apparatus of Figure 1.

The apparatus

In Figure 1, conduits or other suitable flow passage means are diagrammatically represented by the lines **10** and **11**, which lines also serve to indicate the path of flow of the circulated air streams through the apparatus shown. The air is circulated through these said conduits by the fans **12**, likewise shown diagrammatically, situated at the inlet of each of the conduits. Downstream of the fans **12** the conduits **10** and **11** have suitable connections to the elements of apparatus also shown diagrammatically and labeled either "humidifier" or "heat exchanger."

It is proposed that each of the humidifiers **13**, **13***a*, **14** and **15** be a well known type of apparatus which connected to a source of raw or impure water (not shown) is adapted to continuously spray the raw water onto a rotating matrix in contact with the air streams circulating through the conduits **10** and **11** so that the air streams becomes saturated with water vapor. Likewise, each of the heat exchangers **16**, **17** and **18** is to be a well known type of apparatus which is adapted to permit heat transfer between the air streams passing through it in counterflow relationship. Since structurewise these types of apparatus are well known in the prior art, they are not shown in detail in Figure 1. The separator **19** is likewise a well known type of apparatus, such as an electrostatic precipitator, which is adapted to induce the precipitation of water vapor from air, and thus is not shown in detail in Figure 1.

The direction of flow of the carrier and control air stream through each of the conduits **10** and **11** respectively is indicated by the arrows by the fans **12**. Through conduit **10**, the carrier stream proceeds from the point designated **1** to the point designated **6**. Through the conduit **11**, the sequence of flow of the control stream is from the point also designated **1** to the point designated *e*. Thus during flow of the carrier and control air streams through each conduit, the heat exchanger **16** is the first heat exchanger encountered. In this respect, in conduit **10** the humidifiers **13** and **14** are connected on opposite sides of this first encountered heat exchanger **16**, and the conduit then terminates through the heat exchangers **17** and **18**. In conduit **11**, the first encountered humidifier **13***a* is connected after the heat exchanger **16**, and the conduit terminates through the

heat exchanger **18**, the additional sprayer **15**, and then the heat exchanger **17**, in this order. The significance of the placement of the humidifiers and heat exchangers in the conduits **10** and **11** as just described will subsequently be apparent.

The method

To better understand the effect of the humidifiers and the heat exchangers on the circulating carrier and control air streams, attention is directed to the graph of Figure 2. In this graph, the numerals **1** through **6** and the letters *"a"* through *"e"* correspond to the like references shown in Figure 1, and thus the temperature and moisture content of the respective carrier and control air streams may be observed on this graph at each of these selected points.

Thus, at point **1**, or upon entry into each of the conduits **10** and **11**, both the carrier and control air streams are at the same temperature of 95° F. and have 45 grains of moisture per pound of dry air. Since the ambient air characteristic of the southwestern states of this country is commonly at this temperature and humidity, the supply of air for the invention when practiced within this area would entail no expense.

The first change in the condition of the air occurs to the carrier air stream of conduit **10** when it passes through the raw water sprayer **13** and as a result absorbs from 45 to 92 grains of moisture and undergoes a psychometric temperature drop from the dry bulb temperature of 95° F. to the wet bulb temperature of 65° F. (see graph line **1—2**). In this and the other raw water sprayers or humidifiers **13***a*, **14** and **15**, it is preferred to use water which is at the same temperature as the air stream passing through the humidifier thereby permitting adiabatic humidification to take place.

Thus, when the carrier and control air streams next pass through the heat exchanger **16**, the control air stream of conduit **11** still being at 95° F., will lose some of its heat to the carrier air stream of conduit **10** (see the graph lines **2—3** and **1—***a*). As a result of this heat transfer the temperature of the carrier air stream of conduit **10** is raised from **65°** F. to **95°** F. and its capacity to absorb additional moisture is accordingly increased.

The carrier and control air streams are next passed through a humidifier, although for different purposes. In the case of the carrier air stream of conduit **10** it is passed through the humidifier **14** principally to absorb the additional moisture of from 92 to 125 grains, and the drop in temperature to the wet bulb temperature of 74° F. is incidental (see graph line **3—4**). In the case of the control air stream of conduit **11** it is passed through the humidifier **13***a* principally to lower its temperature from the dry bulb temperature of 65° F. to the wet bulb temperature of 54° F., and the absorption of moisture is incidental (see graph line *a—b*).

After passage of the control and carrier air streams through the humidifiers **13***a* and **14** respectively, the control air stream of conduit **11** is at 54° F. while the carrier air stream of conduit **10** is at the higher temperature of 74° F. and is completely saturated with water vapor. It will thus be appreciated that when these air streams are passed in heat exchange relationship with each other, as is proposed in the final step of the method of the present invention, that some of the heat from the carrier air stream of conduit **10** will transfer to the control air stream of conduit **11**, and as a result of the heat loss from the saturated carrier air stream of conduit **10**, pure water will condense out of, or precipitate from this said air stream during passage through the separator **19**.

This final heat transfer step may be accomplished in a single heat exchanger, but in the present invention, it is preferred to use the two heat exchangers **17** and **18**. This particular arrangement is preferred since it permits connecting the humidifier **15** in the conduit **11** between the heat exchangers **18** and **17**, and thereby permits lowering the temperature of the control air stream of this conduit at this point to insure a more efficient heat transfer between the air streams in the heat exchanger **17**. In other words, after the control air stream of conduit **11** has emerged from the heat exchanger **18** at the temperature of 72° F. due to the heat absorbed therein, passage through the humidifier **15** will lower its temperature to 61° F. before it enters the heat exchanger **18** (see graph lines *b—c* and *c—d*).

The effect on the saturated carrier air stream of conduit **10** of passing through the heat exchangers **17** and **18**, as previously stated, is a loss of some of its heat to the lower temperature control air stream of conduit **11**. More particularly, with theoretical maximum heat transfer between the carrier and control air streams in the heat exchangers **17** and **18**, the carrier air stream of conduit **10** will drop in temperature from 74° F. to 66° F. and thus readily precipitate approximately 42 grains of water per pound of dry air during passage through the separator **19** (see graph lines **4—5** and **5—6**).

Thus, in the method and apparatus of the present invention, the utilization of hot and dry circulated streams of air as herein described, results in effective and economical extraction of pure water from a source that is impure without the need of any external source of heat.

It will be understood that the invention is not to be limited to the specific steps of the method herein disclosed, or to the specific apparatus or arrangement of apparatus herein shown, but that wide modifications can be made in each within the invention as defined by the claims.

What is claimed is:

1. In a method of extracting pure water from raw water using two or more circulating streams of relatively hot and dry air comprising the steps of saturating a first air stream with water vapor and effecting a temperature drop therein, passing said first air stream in heat exchange relationship with a second air stream and effecting a rise in temperature and increase in water vapor carrying capacity of said first air stream and a lowering in temperature of said second air stream, saturating the air streams with water vapor to increase the water vapor content of said first air stream and further lowering the temperature of said second air stream, and thereafter passing the air streams in heat exchange relationship with each other whereby heat transfer from the first to the second air stream causes the precipitation of pure water from the first air stream.

2. In the method as claimed in claim 1 wherein the last named heat exchange step is accomplished in two successive passes between the air streams, and between these heat exchange passes the second air stream is saturated with water vapor to lower its temperature to insure an effective heat transfer from the first air stream during the last heat exchange pass of the second air stream.

3. In a method of extracting pure water from raw water in a relatively hot and dry climate by the heat exchange interaction of two or more circulated streams of ambient air comprising the steps of saturating a first air stream with water vapor and effecting a dry to wet bulb temperature drop therein, passing said first air stream in heat exchange relationship with a second air stream and effecting a rise in temperature and increase in water vapor carrying capacity of said first air stream and a lowering in temperature of said second air stream, saturating the air streams with water vapor to increase the water vapor content of said first air stream and to effect a dry to wet bulb temperature drop in said second air stream, and thereafter passing the air streams in heat exchange relationship with each other whereby heat transfer from the first to the second air stream causes the precipitation of pure water from the first air stream.

4. In the method as claimed in claim 3 wherein the

last named heat exchange step is accomplished in two successive passes between the air streams, and between these heat exchange passes the second air stream is saturated with water vapor to lower its temperature to insure an effective heat transfer from the first air stream during the last heat exchange pass of the second air stream.

5. In the method as claimed in claim 4 wherein during the heat exchange steps the air streams are passed in counterflow relationship with each other to insure more efficient heat transfer therebetween.

6. In a method of extracting pure water from raw water in a hot and dry climate in which a first circulated stream of ambient air is saturated with water vapor and subsequently the water vapor is condensed out of said air stream, the improvement in said method of using a second stream of ambient air to cause said condensation of water vapor comprising the steps of passing said second air stream in heat exchange relationship with the saturated first air stream to initially lower the temperature of said second air stream, subsequently saturating the second air stream with water vapor to further lower its temperature with respect to the saturated first air stream, and thereafter passing the air streams in heat exchange relationship with each other whereby the loss of heat from the saturated first air stream to said second air stream causes a precipitation of pure water from the first air stream.

7. In the method as claimed in claim 6 wherein the last named heat exchange step is accomplished in two successive passes between the air streams, and between these heat exchange passes the second air stream is saturated with water vapor to lower its temperature to insure an effective heat transfer from the first air stream during the last heat exchange pass of the second air stream.

8. An apparatus for extracting pure water from raw water including, a pair of spaced heat exchangers, two separate conduits connected between said heat exchangers and adapted to pass fluids in counterflow relationship with respect to each other through said heat exchangers, humidifiers in one of said conduits connected before and after the first encountered heat exchanger, humidifiers in the other conduit connected intermediate the heat exchangers, means for supplying raw water to said humidifiers, and means for forcing streams of relatively hot and dry air through said conduits whereby psychometric changes in the air stream in passing through the humidifiers and heat exchangers will result in the precipitation of pure water from the first named air stream.

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