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(54) INDIRECT EVAPORATIVE COOLING OF A GAS USING COMMON PRODUCT AND WORKING GAS IN A PARTIAL COUNTERFLOW CONFIGURATION

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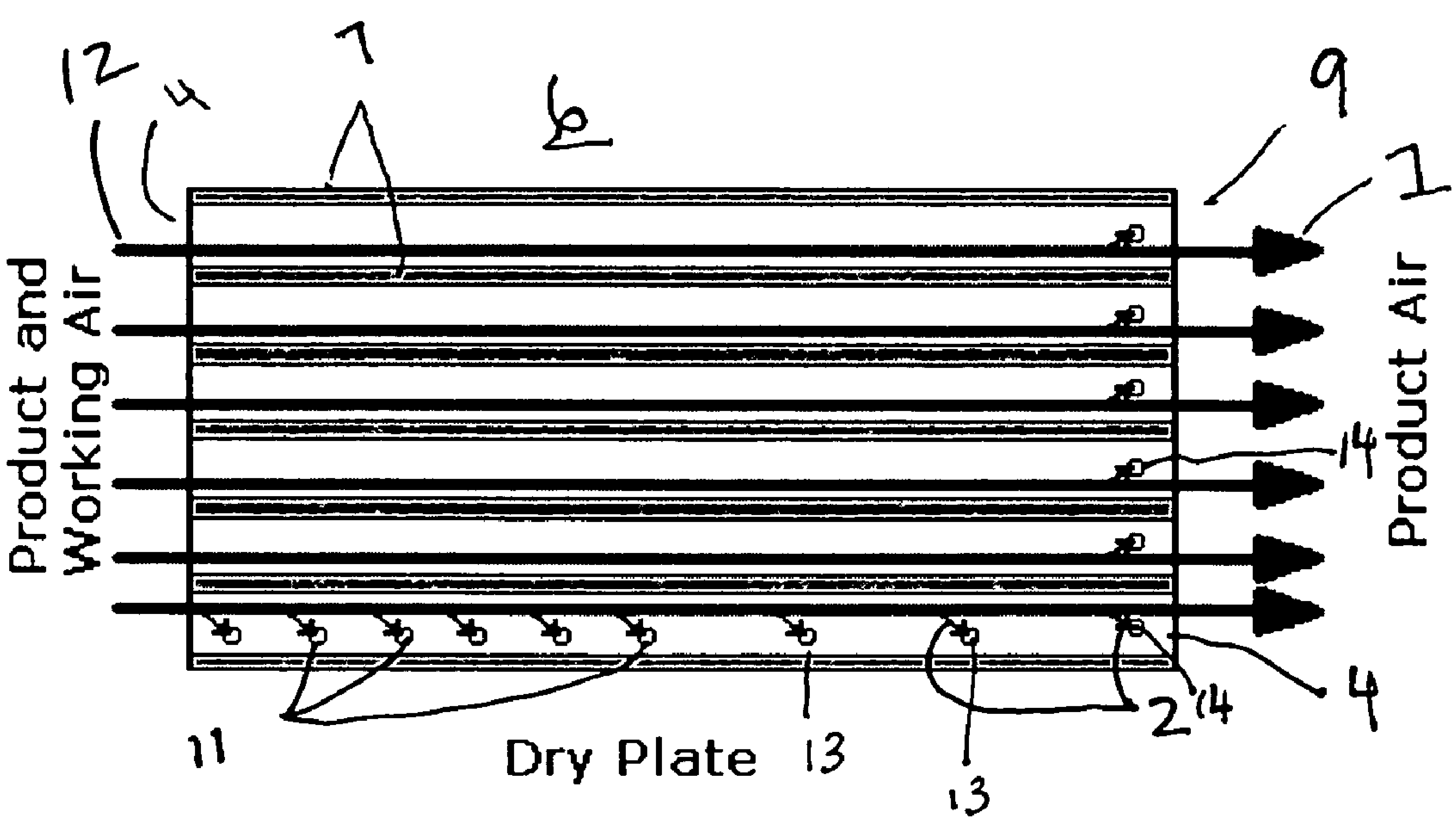
(57) **ABSTRACT**

An indirect evaporative cooler includes a number of heat transfer plates. Each plate has a wet side and a dry side, and the dry sides of adjacent plates face each other. The plate dry sides have low permeability to an evaporative liquid. Input air flows over the dry sides from an input end to an output end. Part of the input air becomes product air and exits at the output end. The rest of the input air passes through perforations in the plates to the other side of the plates to become working air. The other side of each plate is a wet side, which is wet by an evaporative liquid. Working gas flows over the wet side, evaporating the evaporative liquid and cooling the evaporative liquid, the plate, and finally the product gas by heat transfer. The perforations are formed both toward the input end of the plate and toward the output end of the plate. Part of the wet side of the plate, toward the output end of the plate, has a plurality of barriers placed to cause the working gas at that end of the plate to flow in a direction generally counter to the input air.



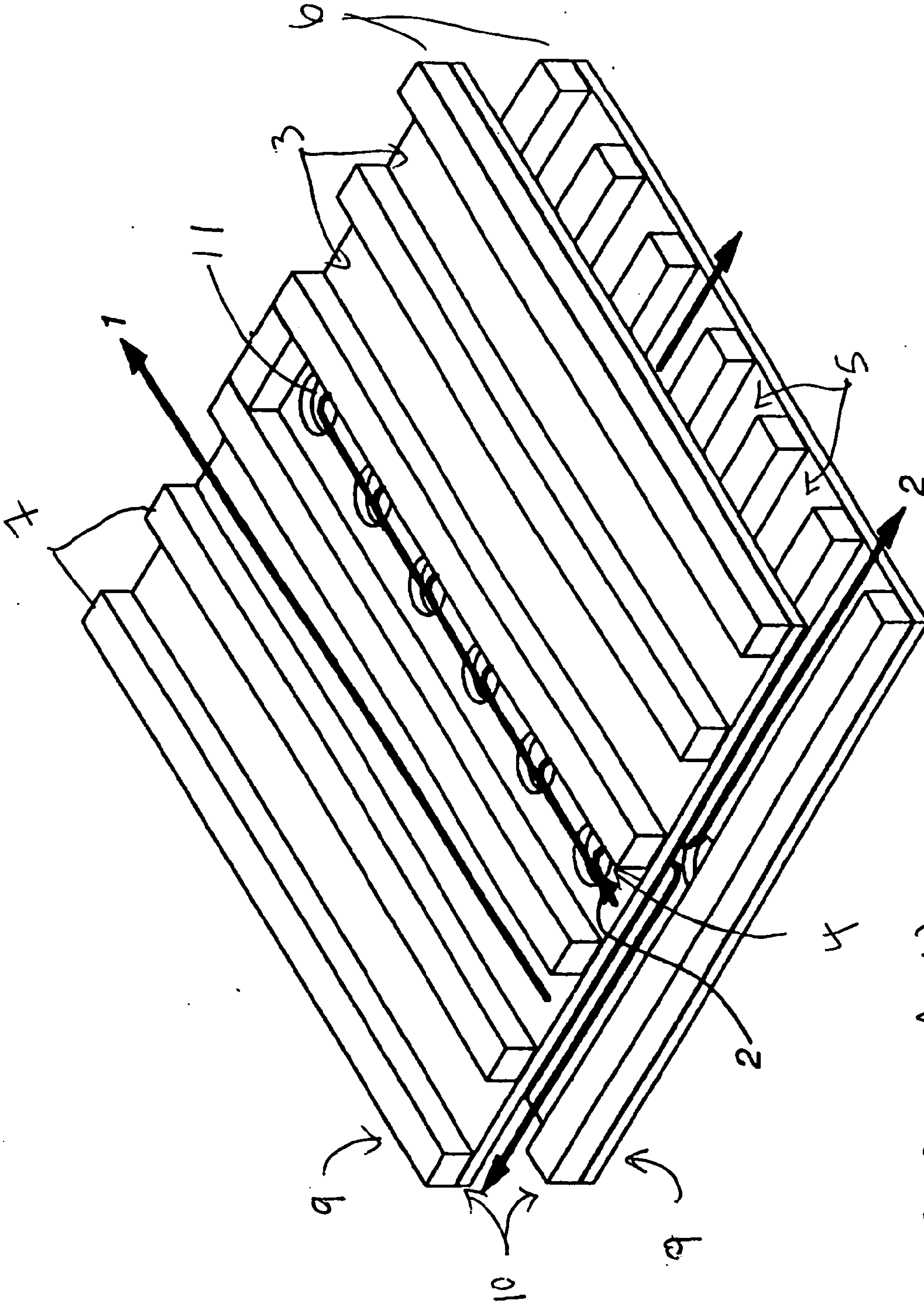
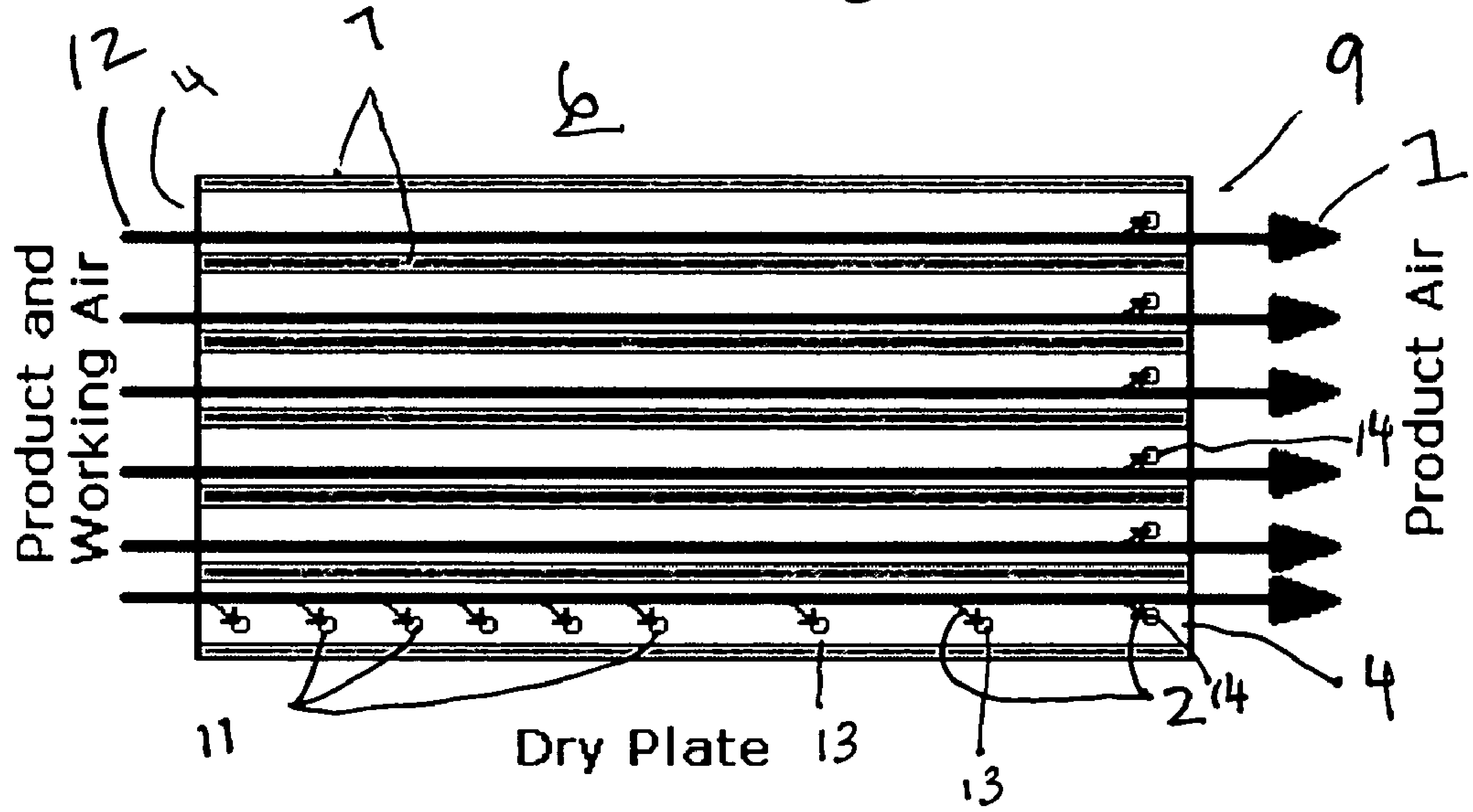


Fig. 1 (Prior Art)

Figure 2



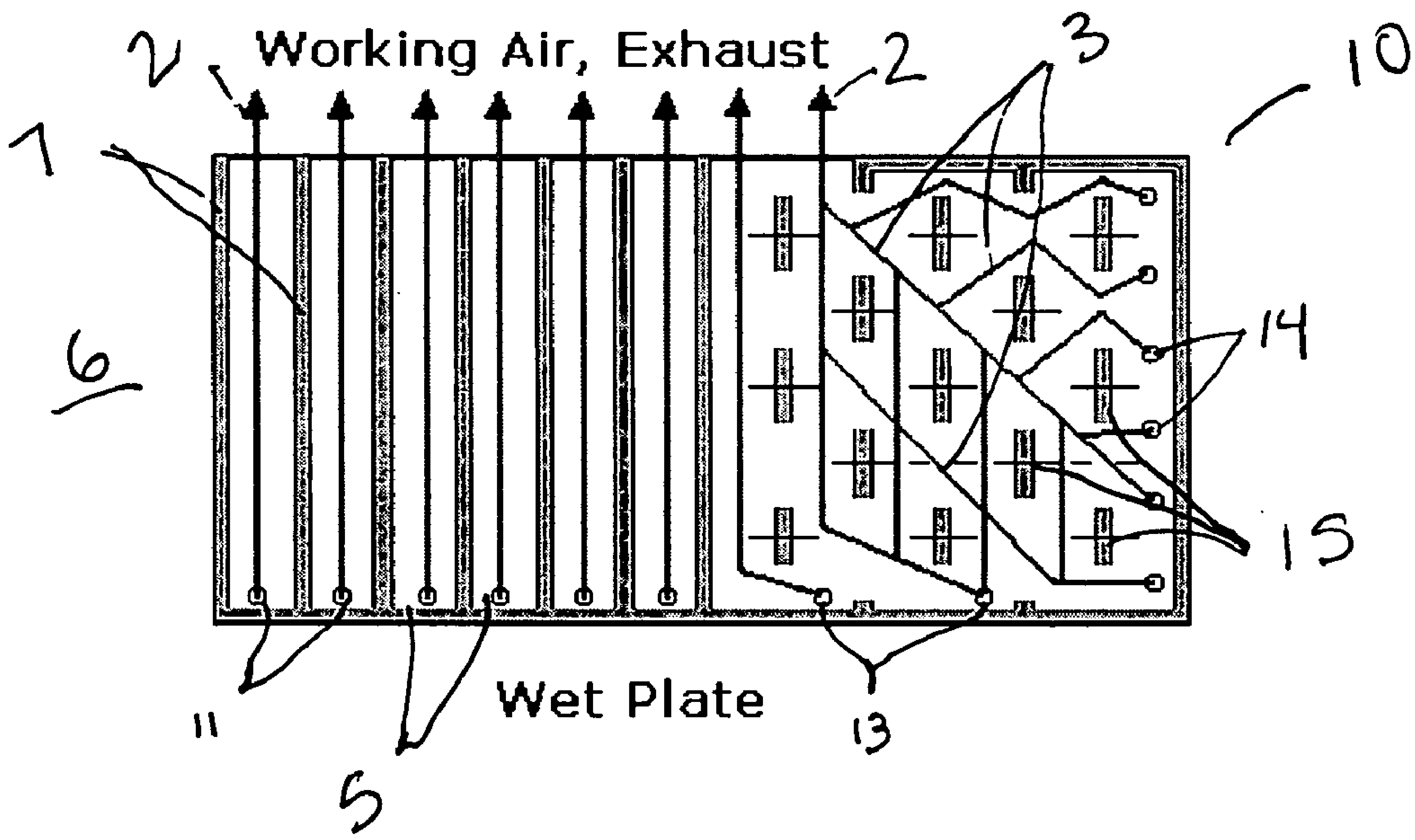


Figure 3

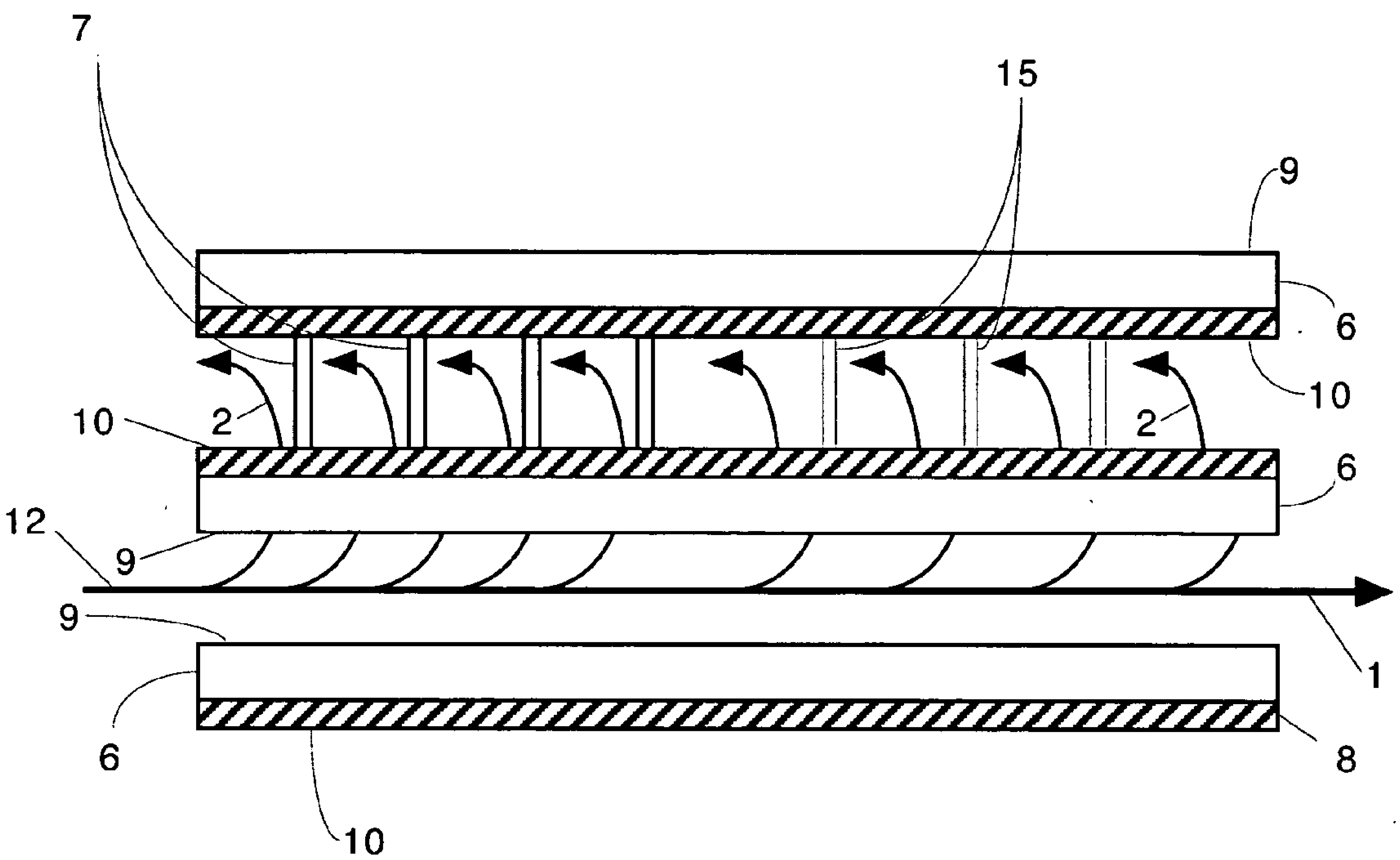


Figure 4

INDIRECT EVAPORATIVE COOLING OF A GAS USING COMMON PRODUCT AND WORKING GAS IN A PARTIAL COUNTERFLOW CONFIGURATION

[0001] U.S. Pat. No. 6,581,402, issued Jun. 24, 2003 is incorporated herein by reference. U.S. Pat. No. 6,705,096, issued Mar. 16, 2004 is incorporated herein by reference. U.S. patent application Ser. No. 11/061,124, filed on Feb. 18, 2005, entitled "Plate Exchanger Edge Extension" is incorporated herein by reference. This application claims the benefit of U.S. Provisional Patent Application No. 60/553,875, filed Mar. 17, 2004

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present invention relates to indirect evaporative coolers. In particular, the present invention relates to such coolers configured to utilize common product and working gas, with part of the working gas flowing in a counter-direction to the product gas.

[0004] 2. Discussion of the Background Art

[0005] Indirect evaporative cooling is a method of cooling a fluid stream; usually air, by evaporating a cooling liquid, usually water, into a second air stream while transferring heat from the first air stream to the second. The method has certain inherent advantages compared to conventional air conditioning: low electricity requirements, relatively high reliability, and the ability to do away with the need for refrigerants such as R-134 and all the disadvantages they entail.

[0006] U.S. Pat. No. 6,581,402 shows a number of embodiments for indirect evaporative cooling using plate apparatus. FIG. 1 (Prior art) shows a perspective and schematic representation of two plates showing the wet side channels formed by the wet sides of a first and a second plate opposing each other, with their passages oriented in the same general area and illustrating the working gas entering on the dry side, passing through the passages and into the wet side channels. The product fluid is separated from the working gas as they pass along the dry side of the first and second plates. Additional plates form a stack, and adjacent plates have their dry sides facing each other. Thus, the stack of plates would have every odd plate oriented with its dry side facing the same direction and opposite of all even plates.

[0007] The invention of U.S. Pat. No. 6,581,402 provides an indirect evaporative cooler having cross flowing wet and dry channels on opposite sides of a plurality of heat exchange plates which allow heat transfer through the plates.

[0008] For purposes of the present application, we wish to define certain terms:

[0009] 1. Heat transfer surface or heat exchange surface has many configurations. All are encompassed within the subject of this disclosed invention with appropriate adjustment to the wetting and flows as are well known in the industry. For illustration we make use of a plate configuration.

[0010] 2. Wet side or wet portion of the heat exchange surface means that portion having evaporative liquid on or in its surface, thus enabling evaporative cooling of the surface and the absorption of latent heat from the surface.

[0011] 3. Dry side or dry portion of the heat exchanger means that portion of the heat exchanger surface where there is little or no evaporation into the adjacent gas or fluid. Thus, there is no transfer of vapor and latent heat into adjacent gases.

[0012] 4. Working stream or working gas stream is the gas flow that flows along the heat exchange surface on the dry side, passes through the passages in the surface to the wet side and picks up vapor and by evaporation, taking latent heat from the heat exchange surface and transporting it out into the exhaust. In some embodiments, the working stream may be disposed of as waste and in others it may be used for special purposes, such as adding humidity or scavenging heat.

[0013] 5. Product stream is the gas flow that passes along the heat exchange surface on the dry side and is cooled by the absorption of heat by the working gas stream on the wet side absorbing latent heat by the evaporation in the wet area.

[0014] The plate also has passageways or perforations or similar transfer means between the dry side of the plate and the wet side in defined areas providing flow from the dry working channels to the working wet channels in which direct evaporative cooling takes place.

[0015] The method of the invention makes use of the separation of a working gas flow (that is used to evaporate liquid in the wet channels and thus to cool the wet surface of the heat exchanger plate) from the product fluid flow, flowing through dry product channels and dry working channels respectively on the same side of the heat exchange plate. Both give up heat to the heat exchange plate that on its obverse surface is being cooled by evaporation in the working wet channels.

[0016] The working gas flow first enters the dry working channel and then through perforations, pores or other suitable means of transfer across the barrier of the plate to the wet side and thence into the wet working channels where evaporation of liquid on the wet channel surface, cools this plate.

[0017] The dry product channels are on the dry side of this plate. The plate is of a thin material to allow easy heat transfer across the plate and thus to readily allow heat to transfer from the dry product channel to the wet working channel. This is one basic unit or element of the invention illustrating the method of the separation of working gas flows to indirectly cool the separate product fluid by evaporative cooling.

[0018] The indirect evaporative cooler of U.S. Pat. No. 6,581,402, in which the product and working air are kept separate works well. However, in some applications, there is an advantage to using a portion of the product gas as working gas to reduce the total amount of working and product gas combined such as in desiccant air-drying applications. When air is dried with a desiccant moisture absorbing system, the desiccant must be regenerated or have the moisture it absorbed removed generally by heating the desiccant and driving the moisture off. Thus, desiccant-dried air is expensive to be using to cool the product air.

[0019] A need remains in the art for a design using common product and working gas, and allowing some of the cooler exhaust air to be placed in counter flow with the product air.

SUMMARY OF THE INVENTION

[0020] It is an object of the present invention to provide apparatus and methods for indirect evaporative cooling devices which use a common product gas and working gas and provide for some of the working gas to flow in a direction counter to the product gas.

[0021] Counter flow increases the temperature of the working gas by passing it in heat exchange first with the coldest product air then with warmer product air. A higher exhaust temperature will allow the air to hold much more evaporate increasing the latent heat load of the working air considerably. The resulting higher enthalpy of the exhaust air means that considerably less working air is needed while maintaining low product air temperatures.

[0022] A heat exchanger plate for use in an indirect evaporative cooling system has a dry side having low permeability to an evaporative liquid and formed to allow an input fluid to flow over its surface from an input end to an output end, and a wet side designed to have its surface wet by an evaporative liquid, and formed to allow a working gas to flow over its surface to evaporate the evaporative liquid. Perforations are formed in the plate to allow a portion of the input fluid to pass from the dry side to the wet side, the perforations placed both toward the input end of the plate and toward the output end of the plate. A portion of the wet side, toward the input end of the plate, forms channels for guiding the working air which passes through the input-end perforations in a direction generally transverse to the product air flow. Another portion of the wet side, toward the output end of the plate, includes a plurality of barriers placed to cause the working air from the output-end perforations to flow in a direction generally counter to the product air.

[0023] The channels are generally perpendicular to the flow of input air. The barriers are elongated, and are oriented generally perpendicular to the input airflow. Generally the barriers cause the working gas at the output end of the plate to flow in a circuitous route.

[0024] Preferably the dry side forms channels to guide the input air from the input end toward the output end.

[0025] In a preferred embodiment, the output-end perforations include output-end side-perforations (along a side parallel to product air flow) and output-end edge-perforations (along the edge where the product air exits).

BRIEF DESCRIPTION OF THE DRAWINGS

[0026] **FIG. 1** (Prior Art) is an isometric illustrating a conventional indirect evaporative cooler configuration.

[0027] **FIG. 2** is a plan view of the dry side of a heat transfer plate used in an evaporative cooler according to the present invention.

[0028] **FIG. 3** is a plan view of the wet side of a heat transfer plate used in an evaporative cooler according to the present invention.

[0029] **FIG. 4** is a side view of three heat transfer plates of **FIGS. 3 and 4**, in parallel configuration.

DETAILED DESCRIPTION OF THE INVENTION

[0030] **FIGS. 2-4** illustrate one embodiment of an indirect evaporative cooler wherein part of the product gas is used as working gas. Note that while the term "air" is frequently used in the following description, others types of gas may be used as well, so long as the same kind of gas is used for the product gas and the working gas. The following table lists reference numbers used in this patent:

1	output product gas
2	output working gas
3	wet side paths
4	dry side channels
5	wet side channels
6	plates
7	channel guides
8	wick material
9	dry sides of plates
10	wet sides of plates
11	input end side perforations
12	Input common product and working air
13	output end side perforations
14	output end edge perforations
15	wet side path barriers

[0031] **FIG. 2** is a plan view of the dry side **9** of a heat transfer plate **6** used in an evaporative cooler according to the present invention. Combined product and working air **12** enters dry side channels **4** from the left of the figure. Channels **4** are generally formed with a series of parallel channel guides **7**. A portion of input gas **12** exits as cooled product gas **1**, at the right of the figure. Generally between ½ and ¾ of input air **12** exits as product air **1**. The rest passes through perforations **11**, **13**, and **14** and operates as working air on the wet side **10** of the plate **6**.

[0032] Perforations **11** are formed on the input side of the plates, along the side of the plate between ¼ to ½ the length of the plate. Perforations **13** are formed on the product output side of the plates in areas that best allow air flow distribution across and in counter flow on the wet side. Perforations **14** are formed on the product output edge of the plate.

[0033] **FIG. 3** is a plan view of the wet side **10** of heat transfer plate, working air **2** from the dry side of plate **6** comes through perforations **11**, **13**, and **14**. An evaporative fluid (not shown) is evaporated into working air **2**, cooling heat transfer plate **6**. This, in turn, cools product air **1**. Often a wicking material **8** (see **FIG. 4**) is used to thoroughly distribute the evaporative fluid on wet side **10**.

[0034] The portion of working air **2** arriving through input-end side-perforations **11** pass across plate **6** via parallel wet side channels **5**, generally perpendicular to input air **12**. Channels **5** are generally formed by channel guides **7**. The portion of working air coming through output-end side-perforations **13** and output-end edge-perforations **15** follow more circuitous paths **3**, but generally move in a direction counter to the product flow. Barriers **15** are short channel guides that provide airflow direction and separation of plates. Barriers **15** are scattered on this portion of the plate to force working air **2** to wind its way among them in a direction generally counter to the product air flow and to provide structure to the heat exchanger. Generally barriers **15** are elongated generally parallel to wet side channel guides **7**, as this provides structural strength (because barriers **15** are then perpendicular to dry side channel guides **7**). However, the configuration and orientation of the barriers may be varied.

[**0035**] **FIG. 4** is a side view of three heat transfer plates **6**, in parallel configuration. **FIG. 4** illustrates a very small evaporative cooler, though generally many more plates will be used. In a more practical embodiment of an indirect evaporative cooling system (described here by way of an example), 80 plates are stacked in a 10 inch high stack. The dimensions of the plates are 20 inches by 18 inches. The plate material is polyethylene coating on cellulose fiber paper (the paper acts as a wicking material). The spacing between the plates is 0.125 inches.

[**0036**] Each plate **6** has a wet side **10** and a dry side **9**. The dry sides of adjacent plates face each other. Often a wicking material **8** is used to distribute the wet side evaporative fluid.

[**0037**] Input combined product and working air **12** enters between two dry sides **9**. The portion of input air **12** that comes out the other end of the plates as product air **1** remains dry. The rest of input air **12** passes through perforations **11**, **13**, **14** as shown in **FIGS. 2 and 4** to become working air **2**. The portion of working air **2** coming through input-end side-perforations **11** is guided by channel guides **7** straight across plates **6**. This portion of working air **2** in is crossflow to the product air **1**. The portion of working air **2** coming though output-end side-perforations **13** and output-end edge-perforations **14** passes among barriers **15**. This portion of working air **2** is in counterflow to product air **1**.

[**0038**] This counterflow increases the temperature of working gas **2**, allowing it to hold more evaporate and therefore have a higher enthalpy, thus using considerably less air while maintaining low product air temperatures. The partial counterflow configuration of the present invention requires a larger exhaust pressure drop than a pure crossflow configuration, but less than a pure counterflow configuration.

[**0039**] Those skilled in the art of indirect evaporative cooling systems will recognize various changes and modifications which can be made to the exemplary embodiments shown and described above, which are still within the spirit and scope of the invention.

What is claimed is:

1. A heat exchanger plate for use in an indirect evaporative cooling system, the plate comprising:

a dry side having low permeability to an evaporative liquid and formed to allow an input fluid to flow over its surface from an input end to an output end;

a wet side designed to have its surface wet by an evaporative liquid, and formed to allow a working gas to flow over its surface to evaporate the evaporative liquid; and

perforations formed in the plate to allow a portion of the input fluid to pass from the dry side to the wet side, the perforations placed both toward the input end of the plate and toward the output end of the plate;

wherein a portion of the wet side toward the input end of the plate forms channels for guiding the working air which passes through the input-end perforations in a direction generally transverse to the product air flow; and

wherein a portion of the wet side toward the output end of the plate further includes a plurality of barriers placed to cause the working air from the output-end perforations to flow in a direction generally counter to the product air.

2. The plate of claim 1 wherein the channels are generally perpendicular to the flow of input air.

3. The plate of claim 1, wherein the barriers are elongated.

4. The plate of claim 3 wherein the barriers are oriented generally perpendicular to the input airflow.

5. The plate of claim 1 wherein the dry side further forms channels to guide the input air from the input end toward the output end.

6. The plate of claim 1 wherein the output-end perforations include output-end side-perforations along a side parallel to product air flow and output-end edge-perforations along an edge where the product air exits.

7. The plate of claim 1 wherein the barriers cause the working gas at the output end of the plate to flow in a circuitous route.

8. An indirect evaporative cooler comprising:

a plurality of generally parallel, spaced apart plates wherein each plate has—

a dry side having low permeability to an evaporative liquid and formed to allow an input gas to flow over its surface from an input end to an output end,

a wet side designed to have its surface wet by an evaporative liquid, and formed to allow a working gas to flow over its surface to evaporate the evaporative liquid, and

perforations formed in the plate to allow a portion of the input gas to pass from the dry side to the wet side, the perforations placed both toward the input end of the plate and toward the output end of the plate,

wherein the dry sides of adjacent plates face each other, and

wherein a portion of the wet side toward the output end of the plate further includes a plurality of barriers placed to cause the working gas from the perforations toward the output end of the plate to follow a counter flow path to the input gas; and

means for providing input gas at the input side of the plates and exiting product gas at the output side of the plates; and

means for exiting working gas.

9. The evaporative cooler of claim 8, wherein the channels are generally perpendicular to the flow of input air.

10. The plate of claim 8, wherein the barriers are elongated.

11. The plate of claim 10 wherein the barriers are oriented generally perpendicular to the input airflow.

12. The plate of claim 8 wherein the dry side further forms channels to guide the input air from the input end toward the output end.

13. The plate of claim 8 wherein the output-end perforations include output-end side-perforations along a side parallel to product air flow and output-end edge-perforations along an edge where the product air exits.

14. The plate of claim 8 wherein the barriers cause the working gas at the output end of the plate to flow in a circuitous route.

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