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(54) **MODULATED WATER FLOW FOR ONCE-THROUGH ADIABATIC COOLING**

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(57) **ABSTRACT**

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A once-through dry adiabatic cooler having a water distribution system, a waste water sensor, and a controller, where the amount of waste water, if any, is detected, and the amount of water distributed to an air flow path adjacent to the coils of said cooler is adjusted so that the amount of water detected is as close to zero as possible, or, in the case of the use of adiabatic pads that require flushing, only the amount of water necessary to flush salt and other minerals from said pads.

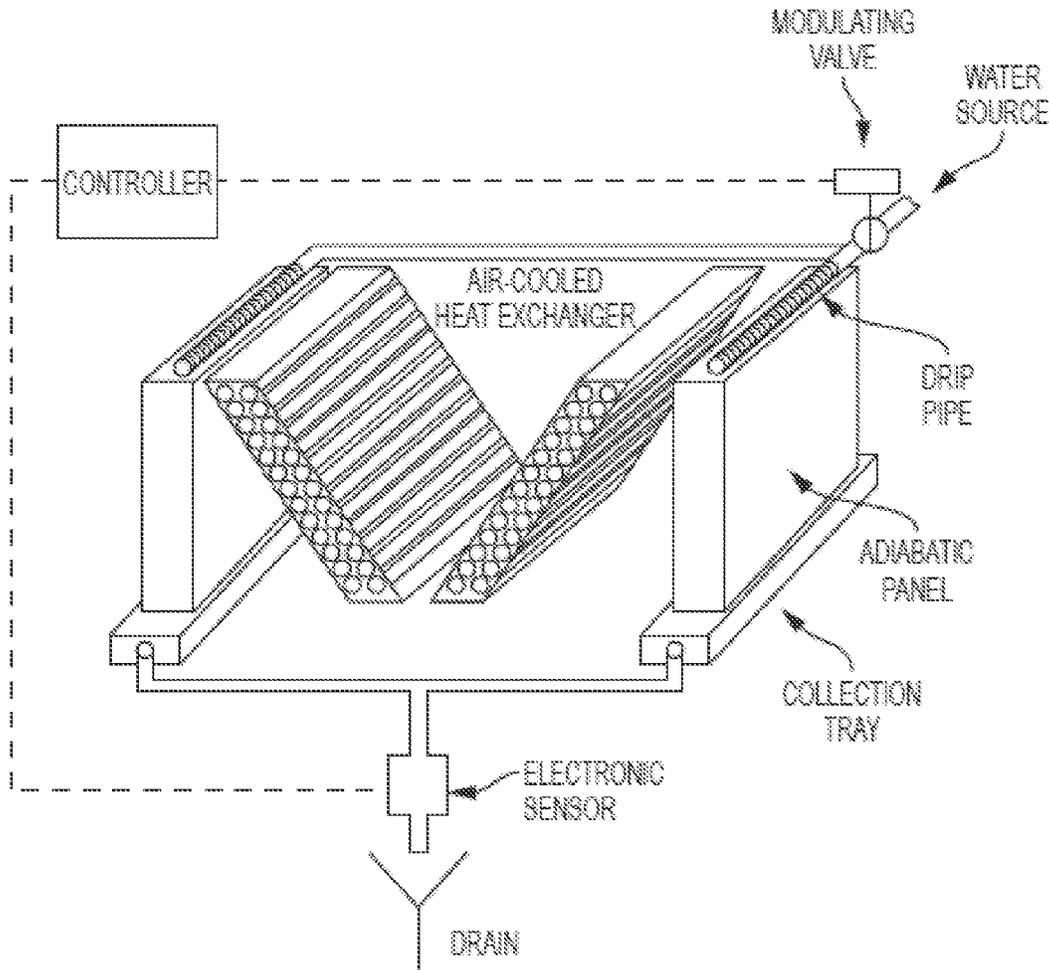




FIG. 1



FIG. 2

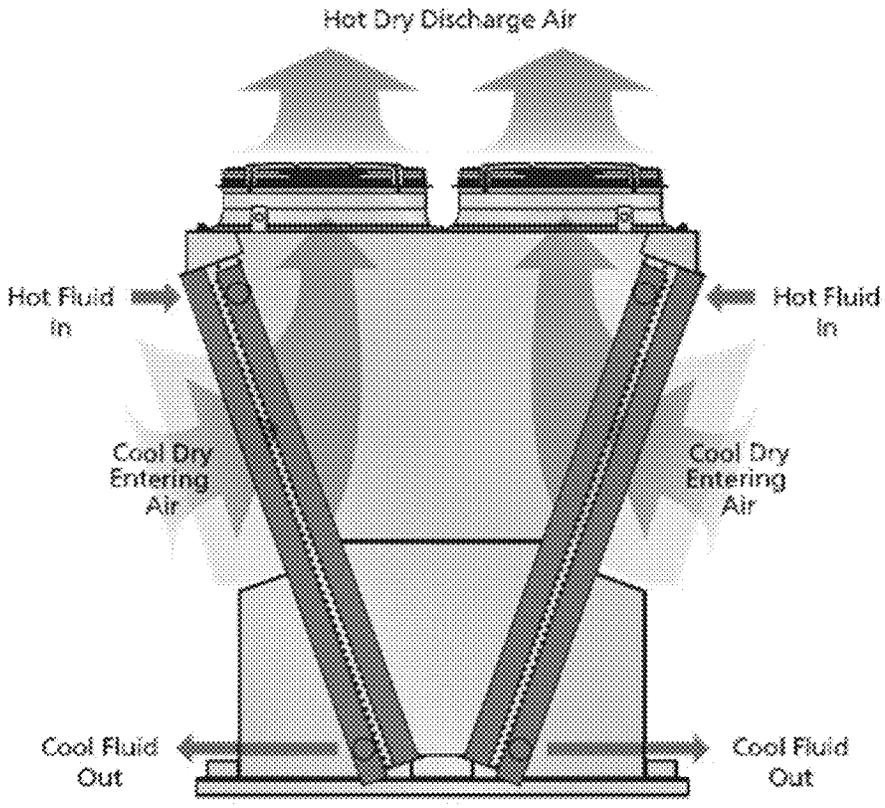


FIG. 3

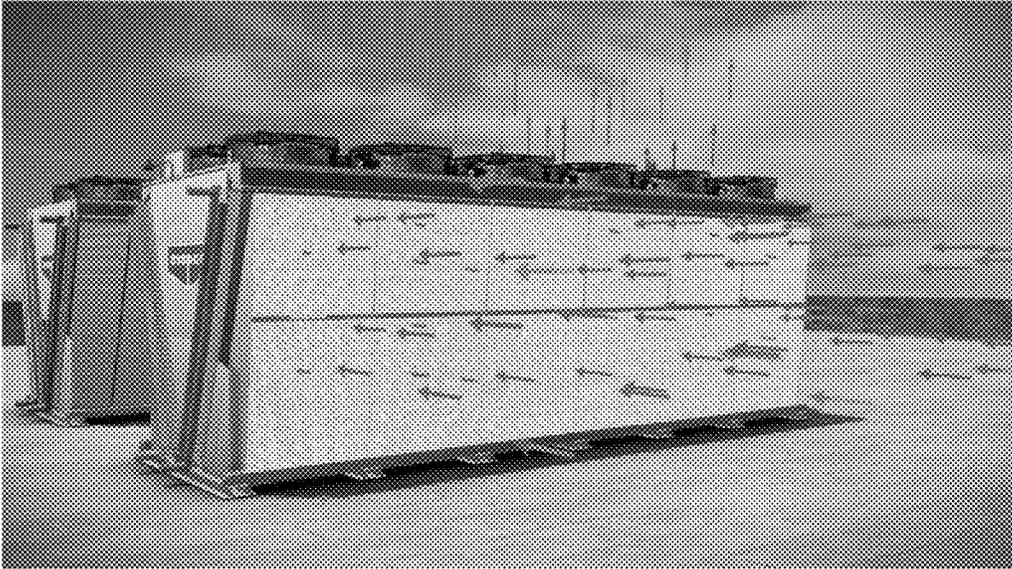


FIG. 4

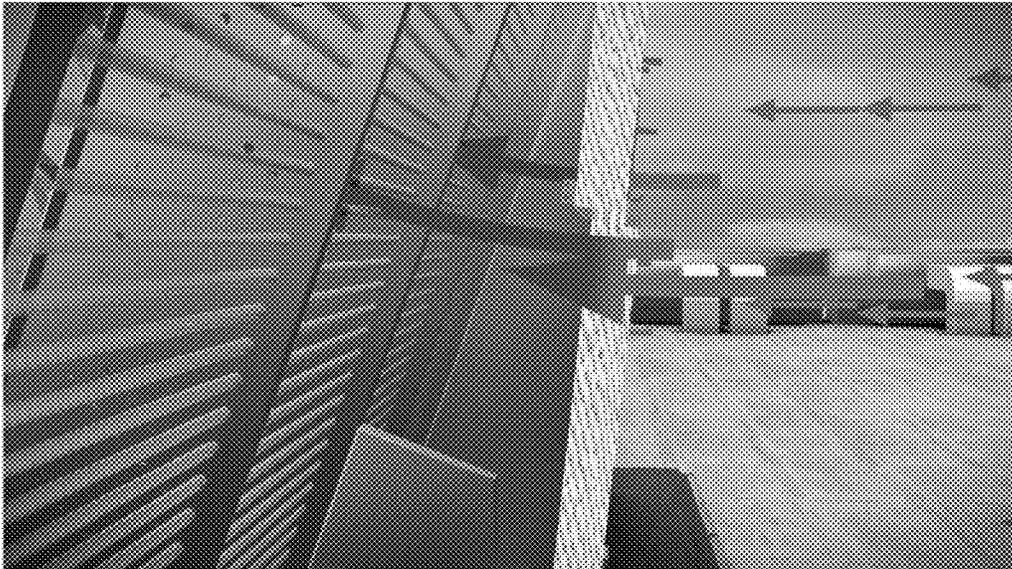


FIG. 5

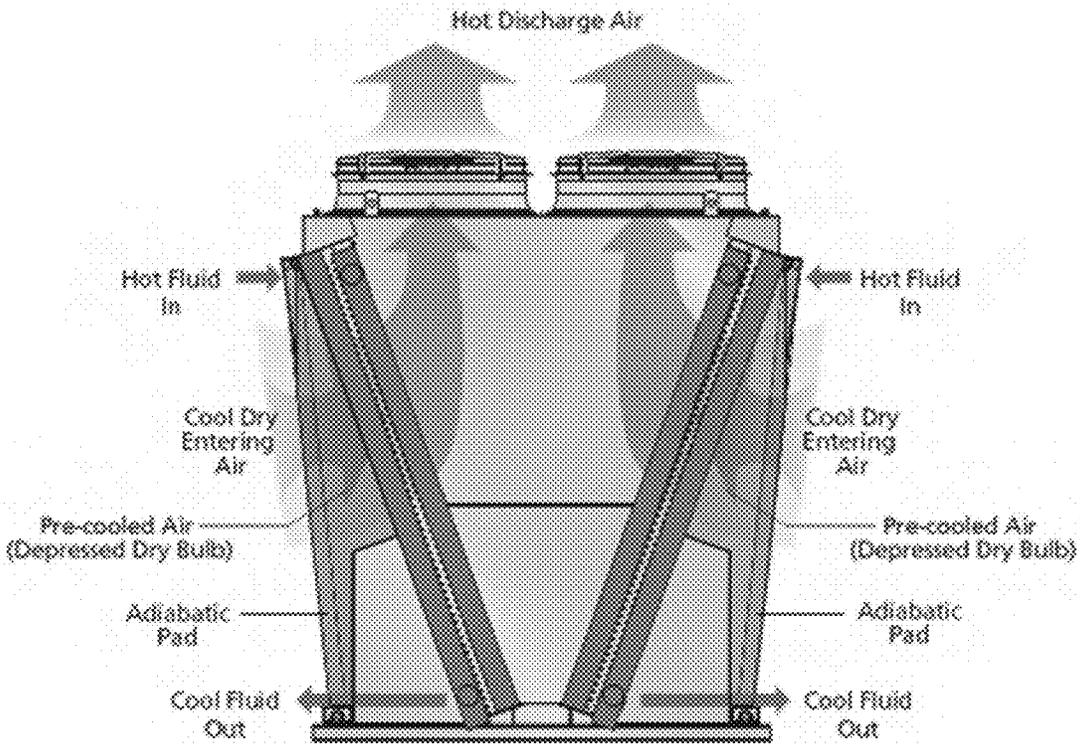


FIG. 6

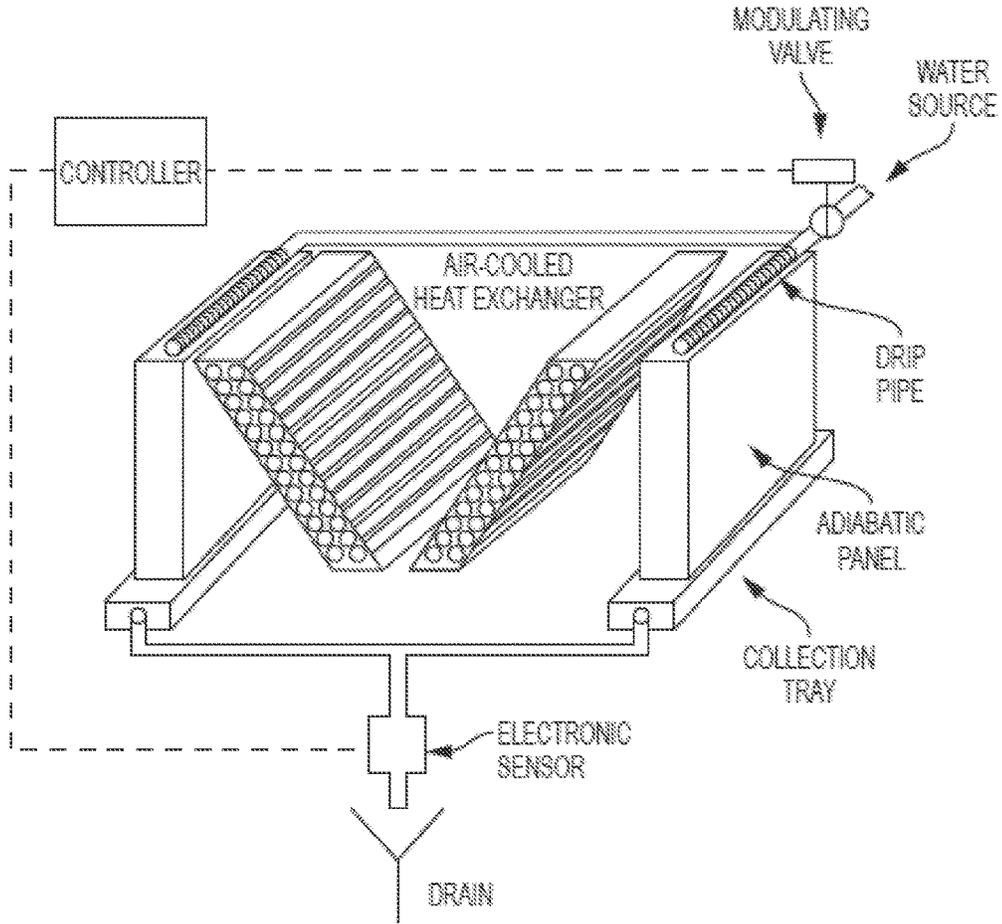


FIG. 7

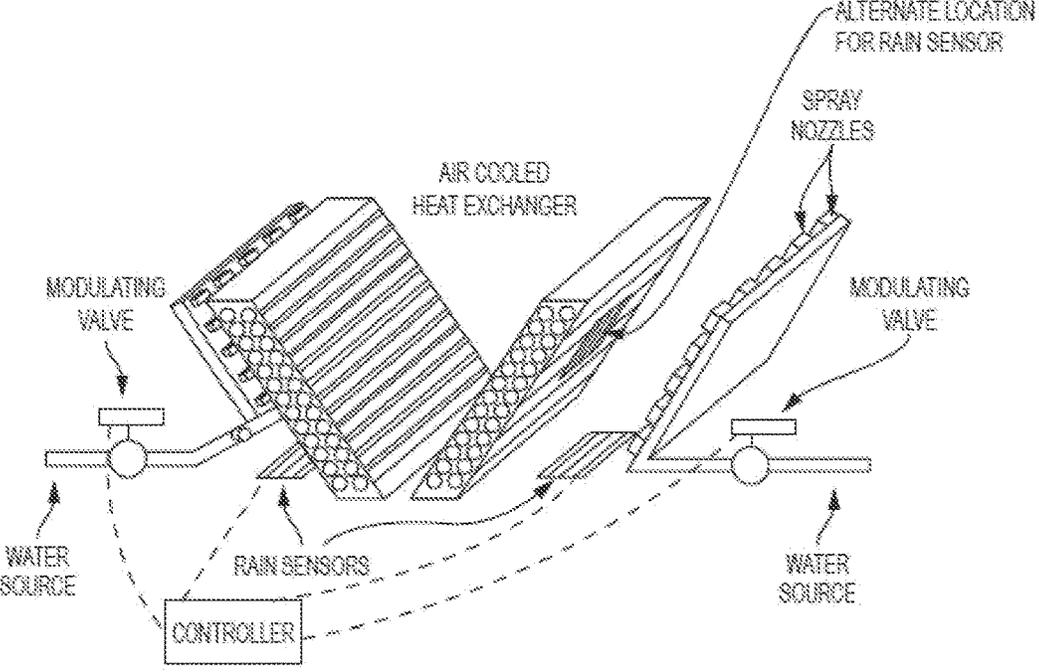


FIG. 8

## MODULATED WATER FLOW FOR ONCE-THROUGH ADIABATIC COOLING

### BACKGROUND OF THE INVENTION

#### Field of the Invention

[0001] The present invention relates to air cooled heat exchanges with adiabatic pads.

#### Description of the Background

[0002] Air-cooled heat exchangers remove heat from a working fluid by transferring that heat to the air. Air-cooled heat exchangers typically consist of tubes connected to fins. The working fluid is sent through the inside of the tubes and the heat is conducted to the outside of the tubes and the fins. Air passing over the fins and tubes removes this heat; one or more fans are generally used to move the air. The working fluid can be a liquid, a gas, a condensing refrigerant, or any other fluid that needs to have heat removed. The tubes are typically constructed of copper, aluminum, or stainless steel but other metals and non-metals have been used. Fins are typically made from copper or aluminum but other thermally conductive materials have been used.

[0003] For heat to be removed from the working fluid, the temperature of the working fluid must be greater than the temperature of the air. The greater the temperature difference between the air and the working fluid the less is needed to remove the heat; hence the less fan horsepower is needed to move the air.

[0004] A known way to lower the ambient air temperature is by adiabatic cooling. With adiabatic cooling an amount of water is either sprayed in the air or over some open-mesh panels. The water evaporates and cools the air with the air dry-bulb temperature approaching the wet-bulb temperature. The adiabatically-cooled air will have a higher humidity level and a lower dry-bulb temperature than the untreated air. A lower dry-bulb temperature will allow cooling at a lower airflow or cooling the working fluid to a lower temperature both of which are desirable effects.

[0005] There are two general approaches for adiabatic cooling of air-cooled heat-exchangers. In one method the incoming ambient air passes through an open-mesh panel that has been saturated with water. The panel can be saturated by a drip-feed, spray, or other method to saturate the panel. The water evaporates as the air passes through the panel cooling the incoming air. There are many variations on the type and location of these panels but all have the incoming air passing through a water saturated panel. The second method uses a nozzle to spray droplets into the incoming air. The fine mist of droplets evaporates and cools the incoming air.

[0006] The water used for adiabatic cooling can either be once-through or recirculated. When the water used is once-through, an amount of water is sprayed into the air or on the panels. The excess water that is not evaporated is sent to drain. In the case of a recirculating water system, the excess water is mixed with fresh water and reused for evaporation. The recirculating water must be periodically dumped and is prone to biological contamination and scale formation. The recirculation equipment is costly and requires regular maintenance.

[0007] The amount of water sprayed is usually calculated to cool the air for "1% design-day" conditions. Design-day

conditions are the maximum temperature and humidity of the incoming air that the equipment will be able to meet performance specification (i.e., usually framed in terms of heat exchange capacity per size of heat exchanger). One percent refers to the fact that this condition will exist for only 1% of the time; 99% of the time it will be cooler than these conditions. These "1% design day" conditions represent the maximum amount of water that will be evaporated. When using a panel system additional water will sometimes be used to flush out the salt that builds up on the panels as water evaporates from them.

[0008] When using a once-through adiabatic at any time other than design-day, water will be wasted as water in excess of what is need for evaporation and salt-flushing is being sent to drain. When adiabatic cooling is required for a milder than design-day condition, less water should be sprayed.

[0009] A solution for this issue has been suggested by US 2016/0252313. This application proposes using a feed-forward evaluation to determine the quantity of water to spray. By having sensors for the fan speed, the ambient dry-bulb, the ambient wet-bulb, cost information for power and water, and details about altitude, a complex algorithm can determine the proper quantity of water to be sprayed to minimize operational cost on a real-time basis. While this is a theoretically elegant solution, it suffers from needing multiple sensors (some prone to failure) and inputs, a complex algorithm, and cannot cover all potential variables such as local wind conditions.

### SUMMARY OF THE INVENTION

[0010] The present invention is a method and system for conserving water in a dry (non-evaporative) adiabatic air cooled cooler-type heat exchanger. As used herein, the terms "dry" and "non-evaporative" refer to a system in which the heat exchange coil is not intentionally wetted using a water distribution system aimed or otherwise directed at the coil and in which the only water used in the system is to pre-cool the air that is drawn over the coil.

[0011] Instead of a complex feed-forward algorithm systems of the prior art, this invention uses a simple feed-back system. To prevent a panel system from prematurely scaling with some waters, excess water needs to pass over the panels to flush away salts formed due to water evaporation. The amount of water required for proper functioning of the panels is equal to the amount that will be evaporated plus a sufficient quantity to flush the pads. If insufficient water is being fed, the flush water exit flow rate from the panels will be too low; if excess water is being fed to the panels, the flush water exit flow rate from the panels will be too high. The amount of flush water exiting from the panels can be measured by placing a simple flow sensor on the discharge from the panels. By adjusting the water input to the panels such that the proper amount of water is measured in the discharge flow meter from the panels, the ideal water input will be maintained for all conditions.

[0012] As an example, a low-flow, low pressure differential flow-meter may be located in the discharge from collection trays located underneath the water-saturated panels. The quantity of flow may be fed to a controller (either a separate controller or one located in the modulating valve or flow meter). The controller would operate a logic such as an on/off control or, preferable, a PID (Proportional Integral Derivative) controller. A PID controller would allow small

changes in the discharge flow rate to result in small changes in the valve open position. Other logical systems could also be used.

**[0013]** The principle of the invention may also be used with a direct nozzle system (water is sprayed into the air as it approaches the tubes and the water evaporates from the air directly, instead of from pads, thus cooling the approaching air). In the case of a direct nozzle system, no excess water is needed to flush pads, and any water not evaporated from the air is wasted. Accordingly, a sensor similar to rain-sensors used in automotive windshield wipers may be used, either with or without a collection tray placed below the nozzle sprays. If due to ambient condition all of the droplets from the spray are not evaporated, the excess moisture will be detected by the sensor and the valve supplying water to the nozzle can be partially closed to reduce the amount of spray water. A panel system designed to operate with no excess water would also use this type of sensor.

#### BRIEF DESCRIPTION OF THE DRAWINGS

**[0014]** FIG. 1 is a perspective view of two padless V-type air cooled heat exchangers of the type that might be used in connection with the present invention.

**[0015]** FIG. 2 is a close up perspective view of the opposite ends of the two padless V-type air cooled heat exchangers shown in FIG. 1.

**[0016]** FIG. 3 is a representation of the operation of a padless V-type air cooled heat exchanger of the type shown in FIGS. 1 and 2.

**[0017]** FIG. 4 shows a perspective view of two V-type air cooled heat exchangers on which adiabatic pads have been mounted for pre-cooling the incoming air.

**[0018]** FIG. 5 shows a close-up side cutaway view of one of the V-type air cooled heat exchangers shown in FIG. 3.

**[0019]** FIG. 6 is a representation of the operation of the V-type air cooled heat exchanger with adiabatic pre-cooling shown in FIGS. 4 and 5.

**[0020]** FIG. 7 is a perspective view sketch of an embodiment of the invention.

**[0021]** FIG. 8 is a perspective view sketch of another embodiment of the invention.

#### DETAILED DESCRIPTION OF THE INVENTION

**[0022]** An example of a V-shaped cooler is shown in FIGS. 1 and 2. A frame supports two coil bundles each comprising a plurality of horizontally arranged finned tubes in a V-shaped configuration. At one end of each tube bundle, the tubes are connected at an inlet end to an inlet header and to an outlet header. At an opposite end of each bundle, each horizontal tube is connected to an adjacent horizontal tube via a return bend. A hot process fluid enters the inlet header via an inlet header connection and is then distributed to the tubes from the inlet header. Cooled fluid exits the tubes via an outlet header and returned to the process/system that headed the fluid. The frame supports a plurality of fans at the top of the cooler and draws ambient air into the unit past the tubes and the fins and out the top of the unit.

**[0023]** The principles of operation of a V-shaped air-cooled heat exchanger of the type shown in FIGS. 1 and 2 is shown in FIG. 3. Hot process fluid, shown in red, enters the inlet header via the inlet header connection. From the inlet header, the hot process fluid travels transversely across

the heat exchanger, generally parallel to the horizontal. Heat from the process fluid dissipates through the coil tubes surface and out to the fins (not shown). Ambient air is drawn over the coil surface by the fans located at the top of the unit. Heat from the process fluid transfers to the air and discharged to the atmosphere. Cool process fluid, shown in blue, exits the unit through the outlet headers.

**[0024]** An example of a V-shaped cooler with adiabatic pre-cooling pads is shown in FIGS. 4 and 5. A frame supports two coil bundles each comprising a plurality of horizontally arranged finned tubes in a V-shaped configuration. At one end of each tube bundle, the tubes are connected at an inlet end to an inlet header and to an outlet header. At an opposite end of each bundle, each horizontal tube is connected to an adjacent horizontal tube via a return bend. A hot process fluid enters the inlet header via an inlet header connection and is then distributed to the tubes from the inlet header. Cooled fluid exits the tubes via an outlet header and returned to the process/system that headed the fluid. Adiabatic pads are mounted along and spanning both sides of the unit left-to-right and top-to-bottom. A water distribution system drips water onto the top of the pads to saturate them. Water that is not evaporated from the pads is collected at the bottom of the unit and either send to drain or recirculated back to the top of the unit and returned to the pads. The frame supports a plurality of fans at the top of the cooler and draws ambient air into the unit through the saturated pads, past the tubes and the fins and out the top of the unit.

**[0025]** The principles of operation of a V-shaped air-cooled heat exchanger with adiabatic pads for pre-cooling the incoming air is shown in FIG. 6. Hot process fluid, shown in red, enters the inlet header via the inlet header connection. From the inlet header, the hot process fluid travels transversely across the heat exchanger, generally parallel to the horizontal. Heat from the process fluid dissipates through the coil tubes surface and out to the fins (not shown). The adiabatic system involves fully wetting a fibrous pad located in front of the coil. Ambient air is drawn through the adiabatic pre-cooling pad by the fans located on top of the unit. The air is humidified as it passes through the adiabatic pad, decreasing the dry bulb temperature within a few degrees of the wet bulb temperature. This new air temperature is referred to as the depressed dry bulb. This pre-cooled air is then drawn through the tube and fin surface, offering a substantial increase in heat rejection capability. Heat from the process fluid transfers to the air and discharged to the atmosphere. Cool process fluid, shown in blue, exits the unit through the outlet headers. In a recirculating water system, the water used to wet the adiabatic pads and which is not evaporated is collected at the bottom of the unit and recirculated to a water distribution system at the top of the pad. In a once-through water system, the water used to wet the adiabatic pads and which is not evaporated is collected and sent to a drain.

**[0026]** FIGS. 7a and 7b illustrate an embodiment of the invention in which the water usage of an air-cooled heat-exchanger with adiabatic panels may be controlled with a modulating valve and a flow sensor. Fans and other structural components are omitted for clarity, but the present invention shown in FIGS. 7a and 7b is intended to be used in connection with any type of air-cooled heat exchanger with adiabatic pads, and particularly the type shown in FIGS. 4-5. According to the embodiment of FIGS. 7a and

7b, the panels are wetted by a drip pipe; water flow is controlled by a modulated valve. When adiabatic cooling is required, the modulated valve opens to a pre-set position and holds that flow for sufficient time for the pads to be fully saturated. After that period the valve will be modulated based on the flow of discharge water as measured by the flow sensor. While a single sensor for both adiabatic panels is shown in the figures, an alternate embodiment may have each set of the panels operating off separate modulating valves and sensors.

[0027] FIGS. 8a and 8b illustrate an embodiment of the invention in which the water usage of a padless air-cooled heat-exchanger using a misting system (no adiabatic pads present) may be controlled with modulating valves and rain sensors. Fans and other structural components are omitted for clarity, but the present invention shown in FIGS. 8a and 8b is intended to be used in connection with any type of air-cooled heat exchanger with adiabatic pads, and particularly the type shown in FIGS. 1-3. According to this embodiment, spray nozzles spray a fine mist of water into the airstream. When adiabatic cooling is required, one or both of the modulating valves open to a pre-set position and water is sprayed into the airstream. If excess water is being used, a fine rain will fall before the inlet air reaches the air-cooled heat exchanger. A rain sensor is located in this area. An alternative location for the sensor would be directly in the air stream such as on the fins or in the air discharge. The sensor is connected to a controller which uses a logic sequence to adjust the spray so little to no excess water is used. According to this embodiment, separate sensors and nozzles may be used to control each side of the spray system. According to alternative embodiments, various different connections of the spray system may be employed which are well within the ability of the ordinary practitioner to design and implement.

1. A once-through dry adiabatic cooler, comprising:

- A frame;
- two tube bundles arranged in said frame in a vertically oriented V-shape;
- each of said tube bundles having an inlet header and an outlet header, said inlet header configured and located to receive hot process fluid and to distribute it to a corresponding tube bundle and said outlet header configured and located to receive cooled process fluid from said tube bundle;
- said two tube bundles each comprising a plurality of horizontally arranged finned tubes connected to adjacent tubes with tube bends;
- a plurality of fans supported by said frame above said tube bundles configured to draw air through said tube bundles and out through a top of said fan;
- a water distribution system configured and located to wet and cool said air prior to being drawn through said tube bundles using fresh uncirculated water;
- a valve system configured and located to control an amount of water that is delivered to said air via said water distribution system;
- a water sensor configured and located to measure an amount of water that is exposed to said air by said water distribution system but which is not evaporated from said air;
- a controller operatively connected to said valve system and said water sensor and configured to receive data from said water sensor and to control said valve system

so that only a predetermined amount of water is delivered by said water distribution system.

2. A dry adiabatic cooler according to claim 1, further comprising adiabatic pads mounted in said frame adjacent to an air intake side of said tube bundles, said water distribution system located above said adiabatic pads and configured to deliver water to said adiabatic pads; said cooler further comprising a water collection tray located below said adiabatic pads and connected to a drain, said water sensor located in a drain water flow path between said collection tray and said drain.

3. A dry adiabatic cooler according to claim 2, wherein said controller is configured to control an amount of water distributed to said adiabatic pads is substantially equal to an amount of water evaporated from said pads plus an amount of water sufficient to flush salt and other minerals from said pads.

4. A dry adiabatic cooler according to claim 2, wherein said adiabatic pads are flushless pads and wherein said controller is configured to control an amount of water distributed to said adiabatic pads is substantially equal to an amount of water evaporated from said pads.

5. A dry adiabatic cooler according to claim 1, which is a padless system and wherein said water distribution system comprises an array of spray nozzles configured and located to spray water into an air flow path adjacent to said tube bundles without substantial contact of said water with said tube bundles, said water sensor comprising a rain sensor configured and located to detect an amount of water sprayed into said air flow path but not evaporated from said air.

6. A method for reducing amount of water wasted in a once-through dry adiabatic cooler, said method comprising: forcing ambient air through a pair of tube bundles arranged in a vertically oriented V-shape;

delivering fresh uncirculated water to an air flow path of said ambient air before it contacts said tube bundles;

allowing said fresh uncirculated water to evaporate upon contact with said ambient air thereby cooling said ambient air before said ambient air contacts said tube bundles, measuring an amount of said fresh uncirculated water that is not evaporated;

controlling an amount of said fresh uncirculated water that is delivered to said ambient air based on said measured amount of fresh uncirculated water that is not evaporated so that substantially all of a second amount of fresh uncirculated water is evaporated upon contact with said ambient air.

7. A method according to claim 6, wherein said fresh uncirculated water is delivered to said air flow path via adiabatic pads.

8. A method according to claim 7, wherein said fresh uncirculated water is allowed to saturate said adiabatic pads.

9. A method according to claim 8, any water not evaporated from said adiabatic pads is collected and delivered to a drain, and wherein said water sensor is located in a drain water flow path between a bottom of said adiabatic pads and said drain.

10. A method according to claim 6, wherein no adiabatic pads are used, and said water sensor is a rain sensor.