

PRE-COOLER FOR AIR-COOLED HEAT EXCHANGERS

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the priority benefit of United States patent application
5 number 62/017,705 filed June 26, 2014 entitled PRE-COOLER FOR AIR-COOLED HEAT
EXCHANGERS, the entirety of which is incorporated by reference herein.

BACKGROUND

[0002] Air-cooled heat exchangers (ACHEs) are large, semi-enclosed structures used to
cool fluids in industrial processes requiring dissipation of large quantities of heat. ACHEs
10 generally include a tube bundle, which may have spiral-wound fins upon the tubes, and a fan,
which moves air across the tubes. In locations where seasonal variations in ambient
temperatures are relatively small, air-cooled exchangers may be used for the greater part of
process cooling. In some refining plants or chemical complexes, substantially all cooling
may be done with air. In part, this increased use of ACHEs may be explained by the lack of
15 available water for water cooling, significant increases in water costs, concern for water
pollution, the heat to be removed is too low for water cooling to be economical, etc.

[0003] Process ACHEs, sometimes called fin-fan heat exchangers, function by passing
cooler air (forced or induced) across a bank (or bundle) of tubes via one or more motorized
fans to cool the process fluid passing through the tubes. The process fluid in the tubes may
20 be liquid, vapor, a mixture of both, or contain solids. The tubes may be plain, externally
finned, internally finned, continuously finned, and/or possess numerous heat transfer
enhancements familiar to those experienced in the practice.

[0004] The magnitude of process fluid cooling is dependent on the temperature of the air
entering the heat exchanger. The greater the temperature difference between the inlet air and
25 the desired outlet tubeside process fluid, the greater the heat transfer driving force, the
smaller the required heat transfer area, and the smaller the footprint. Conventionally, the
ambient air temperature drives the overall design and size (physical footprint) of ACHEs.
Ambient temperature is substantially the temperature of the outside air at the location of the
facility, which, depending on the location of the facility, may range from about -40 °C to
30 about +40 °C, depending on the location of the facility and the given time period of concern
(e.g., hour, day, month, season, etc.).

[0005] A design ambient air temperature may be employed in the design of ACHEs. The design ambient air temperature may be based on the maximum-recorded air temperature at the plant or some percentage thereof, e.g., as derived from an accepted exceedance probability percentage. The design ambient air temperature may be used to ensure that the unit will operate satisfactorily (i.e., the tubeside process fluid will reach an acceptable outlet temperature) under most or all expected operating conditions. In conditions exceeding the design ambient air temperature, some or all of the capabilities of the process may have to be taken offline or otherwise operate at less than optimal efficiency and/or performance.

[0006] A design challenge may arise when the applied design ambient air temperature only affects the process for a limited window of time, e.g., seasons, months, weeks, days, or less. In these cases, a maximum ambient air temperature that decreases the temperature difference between the inlet air to the unit and the desired outlet of the tubeside process fluid may control the design of the ACHE. This design practice decreases the heat transfer driving force, increases the required heat transfer area, and increases the unit's footprint. Customary solutions for reaching the desired tubeside outlet temperature in such situations include requiring an additional kit before reaching the next unit operation. These and other solutions are based on an expected maximum air ambient temperature that may occur only for relatively brief periods throughout the operating year. Similar challenges may arise when climates, climate patterns, and/or operating environments change and cause a mismatch between the design ambient air temperature and actual ambient air temperatures, or when system efficiencies decrease over time and the former design criteria are no longer applicable to the in-use system.

[0007] Various air cooler techniques are known in the art. For example, U.S. Patent Publication No. US 2009/0314483, titled "Heat Exchanger with a Flow Connector," describes a heat exchanger (a charge air cooler) that primarily cools charge air that flows within flat tubes against another flow of cooler air. Furthermore, this assembly may contain a pre-cooler assembly integral with the unit to cool the coolant air against some cooling medium. An additional example is U.S. Patent Publication No. US 2013/0206364, titled "Heat Exchanger Arrangement," describing an arrangement for a charge air cooler comprised of two separate heat exchangers. There, a first coolant flows through the first exchanger and a second coolant flow through the second heat exchanger in such a manner that the first heat exchanger cools the first fluid to a first temperature and the second heat exchanger cools the first fluid from the first temperature to a second temperature that is lower than the first temperature.

Another example is U.S. Patent No. US 6092377, titled "Air Cooled Two Stage Condenser for Air Conditioning and Refrigeration System," describing a self-contained two-stage condenser construction for air conditioning a refrigeration system. Still another example is U.S. Patent No. US 6755158, titled "Vehicle Charge Air Cooler with a Pre-Cooler,"
5 describing an air-cooled charge air cooler for vehicles with a coolant-filled pre-cooler integral with the charge air cooler. The pre-cooler has flow paths carrying coolant between manifolds of the pre-cooler and the flow paths define channels there through to direct charge air through the pre-cooler and into a cooling grate of the charge cooler. A final example is U.S. Patent No. US 8225852, titled "Heat Exchanger Using Air and Liquid as Coolants," describing a
10 heat exchanger suitable for a vehicle which includes a plurality of tubular first members arranged in a row forming elongate gaps. A first fluid passes through the formed passageways with cooling air flowing through the gaps. As associated cooling device circulates liquid coolant and comprises flat tube-like second members each extending into a respective gap in a secondary area, which is part of the primary area but smaller.

15 [0008] Existing solutions to the problems described above have proven expensive to implement, highly complex (having many parts), increase the footprint of the ACHEs, and/or otherwise unacceptable. Consequently, a need exists for a simple and cost-efficient way to address the chronologically limited applicability of the design ambient air temperature that does not significantly increase the footprint of the ACHE.

20 SUMMARY

[0009] One embodiment includes an apparatus for conditioning an inlet air for an air-cooled heat exchanger, comprising a pre-cooler tube bundle configured to circulate a cooling medium, wherein the pre-cooler tube bundle is configured to remove heat from air circulated across the pre-cooler tube bundle, wherein the pre-cooler tube bundle is configured to be
25 positioned on an air inlet side of the air-cooled heat exchanger in a plenum.

[0010] Another embodiment includes a method of removing heat from a process fluid, comprising circulating a pre-cooler medium through a pre-cooler disposed on the air inlet side of an air-cooled heat exchanger tube bundle, circulating the process fluid through the air-cooled heat exchanger tube bundle, passing air to the pre-cooler at a first temperature,
30 changing the temperature of the air to create a conditioned air, passing the conditioned air through the air inlet side of the air-cooled heat exchanger tube bundle, and removing heat from the process fluid by heat exchange with the conditioned air.

[0011] Still another embodiment includes an air-cooled heat exchanger system, comprising a tube bundle having an air inlet side and an air outlet side, a fan, wherein the fan is disposed on the air outlet side of the tube bundle for an induced-draft heat exchanger system, and wherein the fan is disposed on the air inlet side of the tube bundle for a forced-draft heat exchanger system, and a pre-cooler disposed on the air inlet side of the tube bundle, wherein the pre-cooler is configured to lower an ambient air temperature to an inlet temperature when a cooling medium is circulated through the pre-cooler, and wherein the air inlet temperature is within a preselected temperature tolerance.

BRIEF DESCRIPTION OF THE DRAWINGS

10 [0012] The advantages of the present techniques are better understood by referring to the following detailed description and the attached drawings, in which:

[0013] **FIG. 1** is a schematic diagram of an ACHE system.

[0014] **FIG. 2** is a schematic diagram of an ACHE system having a pre-cooler.

15 [0015] **FIG. 3** is a flowchart showing a process for removing heat from a process fluid using an ACHE having a pre-cooler.

DETAILED DESCRIPTION

[0016] In the following detailed description section, specific embodiments of the present techniques are described. However, to the extent that the following description is specific to a particular embodiment or a particular use of the present techniques, this is intended to be for exemplary purposes only and simply provides a description of the exemplary embodiments. Accordingly, the techniques are not limited to the specific embodiments described herein, but rather, include all alternatives, modifications, and equivalents falling within the true spirit and scope of the appended claims.

25 [0017] The disclosure includes a bundle of tubes installed below the process tube bundle (located between the fan and the tube bundle in forced flow arrangement) that carries a heat transfer medium that is colder than the ambient air to cool it before passing over the process tube bundle. The air exiting this pre-cooler tube bundle, possessing a lower temperature than the ambient air temperature, may increase the temperature difference between the inlet air and the desired outlet tubeside process fluid, increase the heat transfer driving force, decrease the required heat transfer area, and/or decrease the unit's footprint. This cooling bundle (or bundles) may be used during times of high ambient air temperature alone or during the entire

operating year to enhance the overall operating heat transfer of the unit. The pre-cooler tubes may be plain, externally finned, internally finned, and/or possess numerous heat transfer enhancements familiar to those experienced in the practice. The fluid in the tubes may be liquid, vapor, or a mixture of both. The fluid in the tubes may even carry solid material in solution with liquid and/or vapor. The ACHE system does not feed a gas combustion turbine or a vehicle.

[0018] Some embodiments of the pre-cooler tube bundle may be integral to the design of a new air-cooled heat exchanger (ACHE) system. Other embodiments may be designed to retrofit existing ACHE systems. In other words, some embodiments of the disclosed pre-cooler tube bundle may be designed as after-market components suitable to be incorporated into existing ACHE systems, e.g., due to increased inefficiency of the ACHE system, due to climate or other changes in the operating environment of the ACHE system, etc.

[0019] At the outset, for ease of reference, certain terms used in this application and their meanings as used in this context are set forth. To the extent a term used herein is not defined herein, it should be given the broadest definition persons in the pertinent art have given that term as reflected in at least one printed publication or issued patent. Further, the present techniques are not limited by the usage of the terms shown herein, as all equivalents, synonyms, new developments, and terms or techniques that serve the same or a similar purpose are considered to be within the scope of the present claims.

[0020] The terms “a” and “an,” as used herein, mean one or more when applied to any feature in embodiments of the present inventions described in the specification and claims. The use of “a” and “an” does not limit the meaning to a single feature unless such a limit is specifically stated.

[0021] The terms “substantial” or “substantially,” as used herein, mean a relative amount of a material or characteristic that is sufficient to provide the intended effect. The exact degree of deviation allowable in some cases may depend on the specific context.

[0022] The definite article “the” preceding singular or plural nouns or noun phrases denotes a particular specified feature or particular specified features and may have a singular or plural connotation depending upon the context in which it is used.

[0023] The terms “plate pack” or “plate pack assembly,” as used herein, means a plurality of substantially parallel sheets or planar surfaces formed so as to create flow channels such that a cooling medium and air pass through alternating passes within the plate pack assembly.

Those of skill in the art will recognize that a plurality of coil-in-plate sheets may be suitably employed as one or more of the constituent sheets or plates comprised within the plate pack assembly.

[0024] The term “process fluid,” as used herein, means any industrial fluid for which cooling is desired. The process fluid may be a liquid, a vapor, a mixture of both, and may contain solids in solution with a liquid and/or vapor.

[0025] FIG. 1 is a schematic diagram of an ACHE system **100**. Flow arrows are provided to illustrate the direction of airflow through the ACHE system **100**. The ACHE system **100** includes a tube bundle **102** having an inlet **104** and an outlet **106**. Those of skill in the art will recognize that a wide variety of options are available for tube bundle design, e.g., the tube bundle may have spiral-wound fins upon the tubes, such as embedded, integral, overlapped footed, footed, bonded or other finned-tube constructions. Indeed, the heat exchanger tube bundle can take the form of any suitable heat exchange device, including shell-and-tube heat exchangers, plate-and-frame heat exchangers, falling-film heat exchangers, etc. The tube bundle **102** may comprise a plurality of tube bundles, e.g., extending laterally in parallel and disposed such that the air outlet side of a first tube bundle feeds an air inlet side of a second tube bundle. Alternate embodiments may increase the number of tube bundles or alter the arrangement as known in the art. In some embodiments, the tube bundle **102**, the inlet **104**, the outlet **106**, or a combination thereof may be incorporated into a housing, header, or other structure for enclosing the components, e.g., a floating header (not depicted). The tube bundle **102**, the inlet **104**, the outlet **106**, or a combination thereof may comprise temperature monitoring equipment to monitor the performance of the ACHE system **100**. A process fluid may be circulated, e.g., using a pump, natural circulation, etc., through the tube bundle **102** by passing or circulating the process fluid into the inlet **104** and out of the outlet **106**.

[0026] The ACHE system **100** includes fans **108** and **110** disposed on the air inlet side of the tube bundle **102**. The fans **108** and **110** may be disposed on the air outlet side of the tube bundle for an induced-draft heat exchanger system design or, as illustrated in FIG. 1, on the air inlet side of the tube bundle for a forced-draft heat exchanger system design. Still other embodiments may place one or more fans on either side of the tube bundle **102**. Additionally, while two fans are illustrated, alternate embodiments may have only one or an as-desired plurality of fans. The fans **108** and **110** may be driven by any suitable means known in the art, e.g., electric motors, steam turbines, compressors, etc. Further, the fans **108**

and **110** may be operatively coupled to an air-flow controller (not depicted) for varying the speed of one or more of the fans **108** and **110**. A plenum **112** is disposed between the fans **108** and **110** and the tube bundle **102**. In induced-draft heat exchanger system designs or other ACHE system **100** embodiments having one or more fans disposed on the air outlet side of the tube bundle **102**, the plenum **112** may be a first plenum and a second plenum may be disposed between the tube bundle **102** and the one or more fans disposed on the air outlet side of the tube bundle **102**.

[0027] While the ACHE system **100** includes a bay comprising supporting columns **114**, in some embodiments the ACHE system **100** may be mounted on, enclosed in, or semi-enclosed in a hood, shroud, or other structure (not shown) to protect the structure or components from the environment or debris, for aesthetic purposes, for sound shielding, for filtering or controlling the particulate quality of inlet air, or for other reasons. Embodiments utilizing one or more external structures may optionally comprise screens, louvers, fan guards, fan rings, or other such enclosure variations within the scope of this disclosure. Some embodiments of the ACHE system **100** further comprise monitoring equipment, e.g., temperature monitoring equipment for monitoring an ambient air temperature, an air inlet temperature (e.g., the temperature in plenum **112**), an air outlet temperature, or any combination thereof.

[0028] FIG. 2 is a schematic diagram of an ACHE system **200** having a pre-cooler **202**. The components of the ACHE system **200** may be the same as the corresponding components of the ACHE system **100** except as otherwise noted. While depicted as disposed in the plenum **112**, in alternate embodiments the pre-cooler **202** may be disposed on the inlet side of the fans **108** and **110** or in an alternate location on the air inlet side of the tube bundle **102**. The pre-cooler **202** may comprise a cooling coil, e.g., a plain, externally finned, internally finned, continuously finned, or a combination thereof. Alternately, the pre-cooler **202** may comprise a plate pack assembly or other suitable heat exchange structure known in the art. The pre-cooler **202** has an inlet and an outlet (not depicted) for admitting a pre-cooler medium. A pre-cooler medium may be circulated, e.g., using a pump, natural circulation, etc., through the pre-cooler **202** by passing or circulating the cooling medium into the inlet and out of the outlet for the pre-cooler **202**. The pre-cooler **202**, the inlet, the outlet, or a combination thereof may comprise temperature monitoring equipment to monitor the performance of the pre-cooler. The pre-cooler medium may be any suitable coolant or other cooling medium for heat transfer, for example, ammonia, sulfur dioxide, non-halogenated

hydrocarbons such as propane, any of a variety of halocarbon compounds such as organofluorine compounds, organochlorine compounds, organobromine compounds, and organiodine compounds. A controller **204** is operatively coupled to the ACHE system **200** such that the controller **204** is configured to circulate the cooling medium through the pre-cooler when the ambient air temperature is above a first preselected temperature and stop circulation of the cooling medium through the pre-cooler when the ambient air temperature is below a second preselected temperature. The first and second preselected temperature set-points may be preselected or dynamically adjusted based on predicted temperatures or as-measured temperatures in order to obtain the desired cooling of the air inlet to the ACHE system **200**.

[0029] In some embodiments, the pre-cooler **202** is further configured to circulate a warming medium through the pre-cooler **202**. In some embodiments, the warming medium and the cooling medium are the same. Other embodiments may substitute or replace the cooling medium of one type, e.g., liquid, with a warming medium of another type, e.g., steam. In such embodiments, the controller **204** may be configured to circulate the warming medium through the pre-cooler when the ambient air temperature is below a third preselected temperature and stop circulation of the warming medium through the pre-cooler when the ambient air temperature is above a fourth preselected temperature. Similar to the control operation for the cooling regime, the third and fourth preselected temperature set-points may be preselected or dynamically adjusted based on predicted temperatures or as-measured temperatures in order to obtain the desired warming of the air inlet to the ACHE system **200**.

[0030] The pre-cooler **202** may be compatibly designed to retrofit existing ACHE systems or may be designed to be integrally incorporated into new ACHE systems. In either scenario, it should be apparent to those of skill in the art that the pre-cooler **202** may be incorporated without significantly changing the footprint of current ACHE systems. Further, in systems where ACHE system efficiency has degraded, e.g., due to fouling, etc., a temporary pre-cooler **202** may be installed to increase efficiency and/or maintain operations until defouling operations or maintenance can be conducted.

[0031] FIG. 3 is a flowchart showing a process **300** for removing heat from a process fluid using an ACHE system having a pre-cooler, e.g., the ACHE system **200** with the pre-cooler **202** of FIG. 2. At **302**, the process **300** includes circulating a pre-cooler medium through a pre-cooler disposed on the air inlet side of an air-cooled heat exchanger tube bundle and circulating the process fluid through the air-cooled heat exchanger tube bundle.

At **304**, the process **300** includes passing air to the pre-cooler, e.g., using one or more fans in a forced-draft and/or induced-draft configuration. The air may be ambient air at a first temperature. At **306**, the process **300** includes changing the temperature of the air, e.g., by heat transfer across the pre-cooler, to create a conditioned air at a second temperature. As described above, this may include cooling the ambient air to a cooler temperature inlet air or warming the ambient air to a warmer temperature inlet air. Various embodiments of the process **300**, the first temperature (e.g., ambient air) may from 0.5 °C, 1 °C, 2 °C, 5 °C, 10 °C, 15 °C, 20 °C, 25 °C, 30 °C, 40 °C, 50 °C, 60 °C, 70 °C, 80 °C, or any temperature or temperature range therebetween, different from the second temperature (e.g., inlet air).

[0032] At **308**, the process **300** includes passing the conditioned air through the air inlet side of the air-cooled heat exchanger tube bundle. This may be accomplished using the same driving force that passed the air to the pre-cooler. At **310**, the process **300** includes removing heat from the process fluid by heat exchange with the conditioned air, thereby creating an exhaust air. As described above, the process **300** may include monitoring various parameters, e.g., the exhaust air temperature, the temperature of the plenum, the inlet and/or outlet temperature of the process fluid and/or pre-cooler medium, and changing system operation using a controller based on the as-monitored monitored conditions. The controller may turn the pre-cooler system on or off, may change the pre-cooler medium from a cooling medium to a warming medium, may increase fan flow rate(s), or make other system changes or alterations.

[0033] While the present techniques may be susceptible to various modifications and alternative forms, the exemplary embodiments discussed herein have been shown only by way of example. However, it should again be understood that the techniques disclosed herein are not intended to be limited to the particular embodiments disclosed. Indeed, the present techniques include all alternatives, modifications, combinations, permutations, and equivalents falling within the scope of the disclosure and appended claims.

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CLAIMS

1. An apparatus for conditioning an inlet air for an air-cooled heat exchanger, comprising:
a pre-cooler tube bundle configured to circulate a cooling medium,
wherein the pre-cooler tube bundle is configured to remove heat from air circulated across the pre-cooler tube bundle,
wherein the pre-cooler tube bundle is configured to be positioned on an air inlet side of the air-cooled heat exchanger in a plenum; and
a controller, wherein the controller is configured to circulate the cooling medium through the pre-cooler tube bundle when an ambient air temperature is above a first preselected temperature and stop circulation of the cooling medium through the pre-cooler tube bundle when the ambient air temperature is below a second preselected temperature.
2. The apparatus of claim 1, wherein the pre-cooler comprises a cooling coil, and wherein the cooling coil is a plain, externally finned, internally finned, continuously finned, or a combination thereof.
3. The apparatus of claim 1 or of claim 2, wherein the pre-cooler comprises a plate pack assembly.
4. An air-cooled heat exchanger system, comprising:
a tube bundle having an air inlet side and an air outlet side;
a fan, wherein the fan is disposed on the air outlet side of the tube bundle for an induced-draft heat exchanger system, and wherein the fan is disposed on the air inlet side of the tube bundle for a forced-draft heat exchanger system;
a pre-cooler disposed on the air inlet side of the tube bundle, wherein the pre-cooler is configured to lower an ambient air temperature to an inlet temperature when a cooling medium is circulated through the pre-cooler, and wherein the air inlet temperature is within a preselected temperature tolerance; and
a controller, wherein the controller is configured to circulate the cooling medium through the pre-cooler when the ambient air temperature is above a first preselected temperature and stop circulation of the cooling medium through the pre-cooler when the ambient air temperature is

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below a second preselected temperature.

5. The system of claim 4, further comprising:

a second tube bundle having an inlet side and an outlet side; and

a second fan,

wherein the second fan is disposed adjacent to the first fan, wherein the first tube bundle and the second tube bundle extend laterally in parallel in a bay, and wherein the first tube bundle is disposed with respect to the second tube bundle such that the air outlet side of the first tube bundle feeds an air inlet side of the second tube bundle.

6. The system of claim 4 or of claim 5, wherein the pre-cooler is further configured to raise the ambient air temperature to a second inlet temperature when a warming medium is circulated through the pre-cooler.

7. The system of claim 4 or of any of claims 5-6, wherein the pre-cooler comprises a cooling coil, and wherein the cooling coil is a plain, externally finned, internally finned, continuously finned, or a combination thereof.

8. The system of claim 4 or of any of claims 5-7, wherein the pre-cooler comprises a plate pack assembly.

9. The system of claim 4 or of any of claims 5-8, wherein the pre-cooler is further configured to raise the ambient air temperature to a second inlet temperature when a warming medium is circulated through the pre-cooler, and wherein the controller is further configured to circulate the warming medium through the pre-cooler when the ambient air temperature is below a third preselected temperature and stop circulation of the warming medium through the pre-cooler when the ambient air temperature is above a fourth preselected temperature.

10. The system of claim 4 or of any of claims 5-9, wherein the air-cooled heat exchanger system does not feed a gas combustion turbine or a vehicle.

11. A method of removing heat from a process fluid, comprising:

circulating a pre-cooler medium through a pre-cooler disposed on the air inlet side of an air-cooled heat exchanger tube bundle;

circulating the process fluid through the air-cooled heat exchanger tube bundle;

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- passing air to the pre-cooler at a first temperature;
- changing the temperature of the air to create a conditioned air;
- passing the conditioned air through the air inlet side of the air-cooled heat exchanger tube bundle;
- removing heat from the process fluid by heat exchange with the conditioned air; and
- circulating the cooling medium through the pre-cooler when an ambient air temperature is above a first preselected temperature and stopping circulation of the cooling medium through the pre-cooler when the ambient air temperature is below a second preselected temperature.
12. The method of claim 11, wherein the temperature of the air is higher than the temperature of the conditioned air.
13. The method of claim 11 or of claim 12, wherein the temperature of the air is lower than the temperature of the conditioned air.
14. The method of claim 11 or of any of claims 12-13, wherein passing the air to the pre-cooler comprises moving the air with a plurality of fans.
15. The method of claim 11 or of any of claims 12-14, wherein the pre-cooler comprises a plate pack assembly or a cooling coil, and wherein the cooling coil is a plain, externally finned, internally finned, continuously finned, or a combination thereof.
16. The method of claim 11 or of any of claims 12-15, wherein the air-cooled heat exchanger tube bundle comprises a plurality of tube bundles arranged in parallel in a bay.
17. The method of claim 11 or of any of claims 12-16, wherein the pre-cooler medium comprises a halocarbon compound.
18. The method of claim 11 or of any of claims 12-17, wherein the pre-cooler medium comprises a vapor.