United States Patent Application Publication	20250257921
Kind Code	A1
Publication Date	August 14, 2025
Inventor(s)	Sheaffer; Bryson Lee

WATER BOX MIXING MANIFOLD

Abstract

A heating, ventilation, air conditioning, and refrigeration (HVAC&R) system includes a heat exchanger with a shell having a first pass configured to place a fluid in a heat exchange relationship with a first refrigerant and a second pass configured to place the fluid in a heat exchange relationship with a second refrigerant. The heat exchanger also includes a water box coupled to the shell and configured to direct the fluid from the first pass to the second pass. The HVAC&R system also includes a fluid mixing manifold disposed within the water box, where the fluid mixing manifold is configured to collect and mix a plurality of flows of the fluid from within the water box to generate a mixed fluid, and a sensor coupled to the fluid mixing manifold, where the sensor is configured to measure a parameter of the mixed fluid.

Inventors: **Sheaffer; Bryson Lee (Mechanicsburg, PA)**

Applicant: **Tyco Fire & Security GmbH** (Neuhausen am Rheinfall, CH)

Family ID: **77491991**

Appl. No.: **19/172447**

Filed: **April 07, 2025**

Related U.S. Application Data

parent US continuation 17802489 20220825 parent-grant-document US 12270586 US continuation PCT/US2021/020071 20210226 child US 19172447
us-provisional-application US 62982582 20200227

Publication Classification

Int. Cl.: **F25B49/02** (20060101); **F25B39/00** (20060101); **F25B39/04** (20060101)

U.S. Cl.:

CPC **F25B49/027** (20130101); **F25B39/00** (20130101); F25B39/04 (20130101); F25B2339/047 (20130101); F25B2700/21161 (20130101)

Background/Summary

CROSS REFERENCE TO RELATED APPLICATIONS [0001] This application is a continuation of U.S. Non-Provisional application Ser. No. 17/802,489, entitled “WATER BOX MIXING MANIFOLD,” filed Aug. 25, 2022, which is a U.S. National Stage Application of PCT International Application No. PCT/US2021/020071, entitled “WATER BOX MIXING MANIFOLD,” filed Feb. 26, 2021, which claims priority from and the benefit of U.S. Provisional Application No. 62/982,582, entitled “WATER BOX MIXING MANIFOLD,” filed Feb. 27, 2020, each of which is hereby incorporated by reference in its entirety for all purposes.

BACKGROUND

[0002] This disclosure relates generally to vapor compression systems, and more particularly, to a system for measuring a fluid temperature in vapor compression systems.

[0003] This section is intended to introduce the reader to various aspects of art that may be related to various aspects of the present disclosure, which are described below. This discussion is believed to be helpful in providing the reader with background information to facilitate a better understanding of the various aspects of the present disclosure. Accordingly, it should be understood that these statements are to be read in this light, and not as admissions of prior art.

[0004] Vapor compression systems, such as chiller systems, utilize a working fluid (e.g., a refrigerant) that changes phases between vapor, liquid, and combinations thereof, in response to exposure to different temperatures and pressures within components of the vapor compression system. The chiller system may place a working fluid in a heat exchange relationship with a conditioning fluid and may deliver the conditioning fluid to conditioning equipment and/or a conditioned environment serviced by the chiller system. In some cases, a heating, ventilation, air conditioning, and/or refrigeration (HVAC&R) system may include multiple chiller systems, and each chiller system may circulate a respective working fluid. Each working fluid may remove heat from a flow of conditioning fluid that is placed in a heat exchange relationship with the respective working fluid via a component (e.g., an evaporator) of the chiller system. In such embodiments, each chiller system may also have a condenser configured to cool heated working fluid. For example, a cooling fluid, such as a water or air flow, may be directed through or across the respective condenser of each chiller system to cool the respective working fluid. The various components of each chiller system may be controlled individually to balance or distribute a load shared by the chiller systems. Unfortunately, variations in the working fluids and/or conditioning fluids at different locations within the chiller systems may complicate effective balancing of the load.

SUMMARY

[0005] In an embodiment of the present disclosure, a heating, ventilation, air conditioning, and refrigeration (HVAC&R) system includes a heat exchanger with a shell having a first pass configured to place a fluid in a heat exchange relationship with a first refrigerant and a second pass configured to place the fluid in a heat exchange relationship with a second refrigerant. The heat exchanger also includes a water box coupled to the shell and configured to direct the fluid from the first pass to the second pass. The HVAC&R system also includes a fluid mixing manifold disposed within the water box, where the fluid mixing manifold is configured to collect and mix a plurality of flows of the fluid from within the water box to generate a mixed fluid, and a sensor coupled to the fluid mixing manifold, where the sensor is configured to measure a parameter of the mixed fluid.

[0006] In another embodiment, a heat exchanger includes a water box configured to direct a fluid from a first pass of the heat exchanger to a second pass of the heat exchanger and a fluid mixing manifold disposed within the water box. The fluid mixing manifold includes a plurality of sampling conduits configured to collect and mix a plurality of flows of the fluid from a respective plurality of locations within the water box, a mixing junction fluidly coupled to each sampling conduit of the plurality of sampling conduits, where the mixing junction is configured to mix the plurality of flows of the fluid to generate a mixed fluid, and a discharge port fluidly coupled to the mixing junction and configured to discharge the mixed fluid into the water box.
[0007] In a further embodiment, a heating, ventilation, air conditioning, and refrigeration (HVAC&R) system includes a heat exchanger having a shell, a water box coupled to the shell, a partition disposed within the shell to define a first volume within the shell and a second volume within the shell, a first subset of tubes disposed within the first volume and configured to direct a fluid into the water box, and a second subset of tubes disposed within the second volume and configured to receive the fluid from the water box. The HVAC&R system also includes a fluid mixing manifold disposed within the water box. The fluid mixing manifold is configured to collect a plurality of flows of the fluid from a respective plurality of locations arrayed along a height of the water box and configured to mix the plurality of flows to generate a mixed fluid. The HVAC&R system further includes a temperature sensor disposed within the fluid mixing manifold and configured to detect a temperature of the mixed fluid.

Description

DRAWINGS
[0008] Various aspects of this disclosure may be better understood upon reading the following detailed description and upon reference to the drawings in which:
[0009] FIG. **1** is a perspective view of an embodiment of a building that may utilize a heating, ventilation, air conditioning, and refrigeration (HVAC&R) system in a commercial setting, in accordance with an aspect of the present disclosure;
[0010] FIG. **2** is a perspective view of an embodiment of a vapor compression system, in accordance with an aspect of the present disclosure;
[0011] FIG. **3** is a schematic of an embodiment of a vapor compression system, in accordance with an aspect of the present disclosure;
[0012] FIG. **4** is a schematic of an embodiment of a vapor compression system of, in accordance with an aspect of the present disclosure;
[0013] FIG. **5** is a schematic of an embodiment of a vapor compression system having multiple refrigerant circuits in a series counter-flow arrangement, in accordance with an aspect of the present disclosure;
[0014] FIG. **6** is a schematic side view of an embodiment of a heat exchanger implemented with two refrigerant circuits of an HVAC&R system, in accordance with an aspect of the present disclosure;
[0015] FIG. **7** is a schematic axial view of an embodiment of a heat exchanger implemented with two refrigerant circuits of an HVAC&R system, in accordance with an aspect of the present disclosure;
[0016] FIG. **8** is a perspective view of an embodiment of a water box having a fluid mixing manifold, in accordance with an aspect of the present disclosure; and
[0017] FIG. **9** is a schematic of an embodiment of a control system for an HVAC&R system having two refrigerant circuits and a fluid mixing manifold, in accordance with an aspect of the present disclosure.
DETAILED DESCRIPTION

[0018] One or more specific embodiments of the present disclosure will be described below. These described embodiments are examples of the presently disclosed techniques. Additionally, in an effort to provide a concise description of these embodiments, all features of an actual implementation may not be described in the specification. It should be appreciated that in the development of any such actual implementation, as in any engineering or design project, numerous implementation-specific decisions must be made to achieve the developers' specific goals, such as compliance with system-related and business-related constraints, which may vary from one implementation to another. Moreover, it should be appreciated that such a development effort might be complex and time consuming, but would nevertheless be a routine undertaking of design, fabrication, and manufacture for those of ordinary skill having the benefit of this disclosure.
[0019] When introducing elements of various embodiments of the present disclosure, the articles “a,” “an,” and “the” are intended to mean that there are one or more of the elements. The terms “comprising,” “including,” and “having” are intended to be inclusive and mean that there may be additional elements other than the listed elements. Additionally, it should be understood that references to “one embodiment” or “an embodiment” of the present disclosure are not intended to be interpreted as excluding the existence of additional embodiments that also incorporate the recited features.
[0020] Embodiments of the present disclosure are directed towards a fluid mixing manifold that may be utilized in a heat exchanger of a vapor compression system, such as a heating, ventilation, air conditioning, and refrigeration (HVAC&R) system. More specifically, present embodiments include a fluid mixing manifold configured to sample fluid from different locations within a heat exchanger and mix the sampled fluids to generate a mixed fluid. The temperature of the mixed fluid may be measured for use in controlling operation of the vapor compression system or other system utilized with the vapor compression system and the heat exchanger.
[0021] For example, the heat exchanger may include a shell and a plurality of tubes disposed within the shell that is configured to direct a cooling fluid or conditioning fluid (e.g., water) therethrough. As the cooling or conditioning fluid is directed through the plurality of tubes, a working fluid (e.g., refrigerant) may be directed through the shell of the heat exchanger, such that heat is transferred between the cooling or conditioning fluid and the working fluid. In some embodiments, the heat exchanger may be a multi-pass heat exchanger. That is, the heat exchanger may be configured to direct the cooling or conditioning fluid along a first pass of the heat exchanger to exchange heat with refrigerant (e.g., a first refrigerant) and to subsequently direct the cooling or conditioning fluid along a second pass of the heat exchanger to exchange heat with refrigerant (e.g., a second refrigerant). To this end, the heat exchanger may include a water box (e.g., cooling fluid box, conditioning fluid box, etc.) that is coupled to the shell and is configured to re-direct the cooling or conditioning fluid from the first pass of the heat exchanger to the second pass of the heat exchanger. The plurality of tubes disposed within the shell may be divided into a first subset of tubes that define the first pass and a second subset of tubes that define the second pass. In operation, cooling or conditioning fluid is directed through the first subset of tubes and into the water box, and the water box directs the cooling or conditioning fluid into the second subset of tubes. In some embodiments, the first subset of tubes may be disposed within a first portion of the shell associated with a first refrigerant circuit of the vapor compression system, and the second subset of tubes may be disposed within a second portion of the shell, fluidly separate from the first portion, associated with a second refrigerant circuit of the vapor compression system. As will be appreciated, it may be desirable to control the vapor compression system based on a temperature of the cooling or conditioning fluid within the water box between the first pass and the second pass.
[0022] The plurality of tubes may be arranged in bundles within the shell such that the tubes are positioned at different locations (e.g., heights) within the shell. Due to variances in individual heat transfer performance of the tubes (e.g., based on a respective location of each tube within the shell), the cooling or conditioning fluid flowing through the tubes may not be homogeneous in

temperature. In other words, the cooling or conditioning fluid exiting one tube of the plurality of tubes may have a different temperature than the cooling or conditioning fluid exiting another tube of the plurality of tubes. For example, the cooling or conditioning fluid directed into the water box via a first tube of the first subset of tubes may have a different temperature than the cooling or conditioning fluid directed into the water box via a second tube of the first subset of tubes. In order to determine an average temperature of the cooling or conditioning fluid within the water box, present embodiments are directed to a fluid mixing manifold configured to sample fluid at different locations within the water box and mix the sampled fluids to generate a mixed fluid. The temperature of the mixed fluid may be measured and may be used to control operation of the vapor compression system. Further, as discussed in detail below, the configuration of the fluid mixing manifold enables more accurate temperature measurements of the fluid for use in controlling operation of the vapor compression system and also enables a reduction in pressure drop of the fluid within the water box compared to traditional systems that are configured to generate a mixed fluid within the water box, such as via baffles disposed within the water box.

[0023] Turning now to the drawings, FIG. **1** is a perspective view of an embodiment of an environment for a heating, ventilation, air conditioning, and refrigeration (HVAC&R) system **10** in a building **12** for a typical commercial setting. The HVAC&R system **10** may include a vapor compression system **14** that supplies a chilled liquid, which may be used to cool the building **12**. The HVAC&R system **10** may also include a boiler **16** to supply warm liquid to heat the building **12** and an air distribution system which circulates air through the building **12**. The air distribution system can also include an air return duct **18**, an air supply duct **20**, and/or an air handler **22**. In some embodiments, the air handler **22** may include a heat exchanger that is connected to the boiler **16** and the vapor compression system **14** by conduits **24**. The heat exchanger in the air handler **22** may receive either heated liquid from the boiler **16** or chilled liquid from the vapor compression system **14**, depending on the mode of operation of the HVAC&R system **10**. The HVAC&R system **10** is shown with a separate air handler on each floor of building **12**, but in other embodiments, the HVAC&R system **10** may include air handlers **22** and/or other components that may be shared between or among floors.

[0024] FIGS. **2** and **3** illustrate embodiments of the vapor compression system **14** that can be used in the HVAC&R system **10**. The vapor compression system **14** may circulate a refrigerant through a circuit starting with a compressor **32**. The circuit may also include a condenser **34**, an expansion valve(s) or device(s) **36**, and a liquid chiller or an evaporator **38**. The vapor compression system **14** may further include a control panel **40** that has an analog to digital (A/D) converter **42**, a microprocessor **44**, a non-volatile memory **46**, and/or an interface board **48**.

[0025] Some examples of fluids that may be used as refrigerants in the vapor compression system **14** are hydrofluorocarbon (HFC) based refrigerants, for example, R-410A, R-407, R-134a, hydrofluoro olefin (HFO), “natural” refrigerants like ammonia (NH3), R-717, carbon dioxide (CO2), R-744, or hydrocarbon based refrigerants, water vapor, or any other suitable refrigerant. In some embodiments, the vapor compression system **14** may be configured to efficiently utilize refrigerants having a normal boiling point of about 19 degrees Celsius (66 degrees Fahrenheit) at one atmosphere of pressure, also referred to as low pressure refrigerants, versus a medium pressure refrigerant, such as R-134a. As used herein, “normal boiling point” may refer to a boiling point temperature measured at one atmosphere of pressure.

[0026] In some embodiments, the vapor compression system **14** may use one or more of a variable speed drive (VSDs) **52**, a motor **50**, the compressor **32**, the condenser **34**, the expansion valve or device **36**, and/or the evaporator **38**. The motor **50** may drive the compressor **32** and may be powered by a variable speed drive (VSD) **52**. The VSD **52** receives alternating current (AC) power having a particular fixed line voltage and fixed line frequency from an AC power source, and provides power having a variable voltage and frequency to the motor **50**. In other embodiments, the motor **50** may be powered directly from an AC or direct current (DC) power source. The motor **50** may include any type of electric motor that can be powered by a VSD or directly from an AC or DC power source, such as a switched reluctance motor, an induction motor, an electronically commutated permanent magnet motor, or another suitable motor.

[0027] The compressor **32** compresses a refrigerant vapor and delivers the vapor to the condenser **34** through a discharge passage. In some embodiments, the compressor **32** may be a centrifugal compressor. The refrigerant vapor delivered by the compressor **32** to the condenser **34** may transfer heat to a cooling fluid (e.g., water or air) in the condenser **34**. The refrigerant vapor may condense to a refrigerant liquid in the condenser **34** as a result of thermal heat transfer with the cooling fluid. The liquid refrigerant from the condenser **34** may flow through the expansion device **36** to the evaporator **38**. In the illustrated embodiment of FIG. **3**, the condenser **34** is water cooled and includes a tube bundle **54** connected to a cooling tower **56**, which supplies the cooling fluid to the condenser **34**.

[0028] The liquid refrigerant delivered to the evaporator **38** may absorb heat from another cooling fluid (e.g., a conditioning fluid), which may or may not be the same cooling fluid used in the condenser **34**. The liquid refrigerant in the evaporator **38** may undergo a phase change from the liquid refrigerant to a refrigerant vapor. As shown in the illustrated embodiment of FIG. **3**, the evaporator **38** may include a tube bundle **58** having a supply line **60**S and a return line **60**R connected to a cooling load **62**. The conditioning fluid of the evaporator **38** (e.g., water, ethylene glycol, calcium chloride brine, sodium chloride brine, or any other suitable fluid) enters the evaporator **38** via return line **60**R and exits the evaporator **38** via supply line **60**S. The evaporator **38** may reduce the temperature of the conditioning fluid in the tube bundle **58** via thermal heat transfer with the refrigerant. The tube bundle **58** in the evaporator **38** can include a plurality of tubes and/or a plurality of tube bundles. In any case, the vapor refrigerant exits the evaporator **38** and returns to the compressor **32** by a suction line to complete the cycle.

[0029] FIG. **4** is a schematic of an embodiment of the vapor compression system **14** with an intermediate circuit **64** incorporated between condenser **34** and the expansion device **36**. The intermediate circuit **64** may have an inlet line **68** that is directly fluidly connected to the condenser **34**. In other embodiments, the inlet line **68** may be indirectly fluidly coupled to the condenser **34**. As shown in the illustrated embodiment of FIG. **4**, the inlet line **68** includes a first expansion device **66** positioned upstream of an intermediate vessel **70**. In some embodiments, the intermediate vessel **70** may be a flash tank (e.g., a flash intercooler). In other embodiments, the intermediate vessel **70** may be configured as a heat exchanger or a “surface economizer.” In the illustrated embodiment of FIG. **4**, the intermediate vessel **70** is used as a flash tank, and the first expansion device **66** is configured to lower the pressure of (e.g., expand) the liquid refrigerant received from the condenser **34**. During the expansion process, a portion of the liquid may vaporize, and thus, the intermediate vessel **70** may be used to separate the vapor from the liquid received from the first expansion device **66**. Additionally, the intermediate vessel **70** may provide for further expansion of the liquid refrigerant due to a pressure drop experienced by the liquid refrigerant when entering the intermediate vessel **70** (e.g., due to a rapid increase in volume experienced when entering the intermediate vessel **70**). The vapor in the intermediate vessel **70** may be drawn by the compressor **32** through a suction line **74** of the compressor **32**. In other embodiments, the vapor in the intermediate vessel may be drawn to an intermediate stage of the compressor **32** (e.g., not the suction stage). The liquid that collects in the intermediate vessel **70** may be at a lower enthalpy than the liquid refrigerant exiting the condenser **34** due to the expansion in the expansion device **66** and/or the intermediate vessel **70**. The liquid from intermediate vessel **70** may then flow in line **72** through a second expansion device **36** to the evaporator **38**.

[0030] As mentioned above, a heat exchanger of the vapor compression system **14** may include a shell having a plurality of tubes disposed therein, where the plurality of tubes is configured to direct a cooling fluid or conditioning fluid (e.g., water) therethrough, and the shell is configured to direct a working fluid (e.g., refrigerant) therethrough to enable heat transfer between the cooling or conditioning fluid and the working fluid. In some embodiments, the heat exchanger may be a multi-pass heat exchanger configured to direct the cooling or conditioning fluid through multiple passes that are defined by different subsets of tubes. In some multi-pass heat exchanger embodiments, each pass of the heat exchanger may be associated with a separate refrigerant circuit that circulates a respective refrigerant therethrough. For example, the vapor compression system **14** may include multiple refrigerant circuits, and condensers of the multiple refrigerant circuits may be packaged together in a common heat exchanger shell and/or evaporators of the multiple refrigerant circuits may be packaged together in a common heat exchanger shell. The heat exchanger further includes a water box configured to direct the cooling or conditioning fluid from the tubes of the first pass to the tubes of the second pass.

[0031] FIG. **5** is a schematic of an embodiment of the vapor compression system **14** with multiple refrigerant circuits **80** (e.g., refrigerant loops). In particular, the illustrated embodiment includes a first refrigerant circuit **82** and a second refrigerant circuit **84** arranged in a series counter-flow arrangement. The first refrigerant circuit **82** includes a first compressor **32**A, a first condenser **34**A, a first expansion device **36**A, and a first evaporator **38**A. The second refrigerant circuit **84** includes a second compressor **32**B, a second condenser **34**B, a second expansion device **36**B, and a second evaporator **38**B. Each of the refrigerant circuits **80** is configured to circulate a respective refrigerant therethrough and is configured to operate in a manner similar to that described above with reference to the vapor compression system **14** shown in FIGS. **2-4**. It should be noted that each of the refrigerant circuits **80** may also include components in addition to those shown in FIGS. **2-4**.

[0032] In the illustrated embodiment, the first and second refrigerant circuits **82** and **84** of the vapor compression system **14** are arranged in a series counter-flow arrangement. Specifically, the first and second evaporators **38**A and **38**B define a portion of a conditioning fluid flow path or circuit **86** that extends from a cooling load **88** (e.g., air handlers **22**), sequentially through the second evaporator **38**B and the first evaporator **38**A, and back to the cooling load **88**. Similarly, the first and second condensers **34**A and **34**B define a portion of a cooling fluid flow path or circuit **90** that extends from a cooling fluid source **92** (e.g., cooling tower **56**), sequentially through the first condenser **34**A and the second condenser **34**B, and back to the cooling fluid source **92**. Thus, conditioning fluid is directed through the vapor compression system **14** first through the second evaporator **38**B and then through the first evaporator **38**A, while cooling fluid is directed through the vapor compression system **14** first through the first condenser **34**A and then through the second condenser **34**B, thereby providing the series counter-flow arrangement.

[0033] As mentioned above, heat exchangers of the multiple refrigerant circuits **80** may be packaged together in a common heat exchanger shell. For example, in some embodiments, the first and second condensers **34**A and **34**B may be packaged in a common heat exchanger shell and/or first and second evaporators **38**A and **38**B may be packaged in a common heat exchanger shell. The common heat exchanger shell may be divided into a first pass and a second pass that are each associated with a respective heat exchanger of one of the refrigerant circuits **80**. The first and second passes of the common heat exchanger shell may direct a cooling fluid or a conditioning fluid sequentially through tubes disposed within the first pass and tubes disposed within the second pass. To this end, the common heat exchanger shell may include a water box configured to re-direct a flow of the conditioning fluid from the tubes of the first pass to tubes of the second pass.

[0034] For example, FIG. **6** is a cross-sectional schematic of a heat exchanger **100** (e.g., packaged heat exchanger, dual circuit heat exchanger, evaporator, condenser, etc.) that may be included in the vapor compression system **14**. The heat exchanger **100** includes a first water box **102** and a second water box **104**. The first water box **102** and the second water box **104** are coupled to a shell **106** of the heat exchanger **100** that has a plurality of tubes **108** disposed therein. The plurality of tubes **108** may be arranged and/or divided into tube bundles. The shell **106**, the first water box **102**, and the second water box **104** may be secured to one another via flanges **110**. While the illustrated embodiment of FIG. **6** shows the flanges **110** having a larger diameter than the shell **106**, the first water box **102**, and/or the second water box **104**, in other embodiments, the flanges **110** may include the same diameter as each of the shell **106**, first water box **102**, and/or second water box **104**. Further, in other embodiments, the shell **106**, the first water box **102**, and/or the second water box **104** may be coupled to one another using another suitable technique (e.g., welding). Additionally, in some embodiments, each of the shell **106**, the first water box **102**, and/or the second water box **104** may be separate components that may be interchanged by coupling and/or removing such components from one another.

[0035] As mentioned above, the plurality of tubes **108** is arranged in one or more tube bundles **112** within the shell **106**. In embodiments of the heat exchanger **100** configured as one or more flooded evaporators, a conditioning fluid (e.g., water, chilled fluid, etc.) is circulated through the plurality of tubes **108**, and heat is transferred from the conditioning fluid to a refrigerant **114** that enters the shell **106** through an inlet **116** at a bottom of the shell **106**. As heat is transferred from the conditioning fluid within the tubes **108** to the refrigerant **114**, the refrigerant **114** evaporates and ultimately exits the shell **106** via an outlet **118** positioned at a top of the shell **106**. It should be appreciated that the techniques disclosed herein may be utilized with heat exchangers **100** having other configurations. For example, the heat exchanger **100** may be a falling film evaporator, a hybrid falling film evaporator, a condenser, or other type of heat exchanger, and thus, the refrigerant **114** may enter and exit the shell **106** of the heat exchanger **100** at locations of the shell **106** other than those shown in FIG. **6**. For example, in an embodiment of the heat exchanger **100** configured as a falling film evaporator, the inlet **116** and the outlet **118** may be positioned at a top of the shell **106**.

[0036] In accordance with present techniques, the heat exchanger **100** may be configured as a multi-pass heat exchanger. More specifically, the plurality of tubes **108** within the shell **106** may be divided into a first subset of tubes and a second subset of tubes, where each subset of tubes is associated with a separate pass of the heat exchanger **100**. In the illustrated embodiment, conditioning fluid **120** (e.g., water) enters the heat exchanger **100** via an inlet **122** of the first water box **102**. However, in other embodiments, a cooling fluid, process fluid, or other fluid may enter the heat exchanger **100** via the inlet **102**. The conditioning fluid **120** is directed from the first water box **102** to a first subset of the plurality of tubes **108**, such that the conditioning fluid **120** flows through a first pass of the heat exchanger **100**, as indicated by arrow **124**. The conditioning fluid **120** exits the first subset of the plurality of tubes **108** and enters the second water box **104**, which directs and/or redirects the conditioning fluid **120** to a second subset of the plurality of tubes **108**, as indicated by arrow **126**. The second subset of the plurality of tubes **108** defines a second pass of the heat exchanger **100**. After the conditioning fluid **120** exits the second subset of the plurality of tubes **108**, the conditioning fluid **120** may flow into the first water box **102** and may exit the first water box **102** via an outlet (not shown). To this end, the first water box **102** may include a partition plate configured to separate the conditioning fluid **120** flowing through the first water box **102** from the inlet **122** to the first subset of the plurality of tubes **108** and the conditioning fluid **120** flowing through the first water box **102** from the second subset of the plurality of tubes **108** to the outlet. The first and second passes of the heat exchanger **100** and the first and second subsets of the plurality of tubes **108** are shown in greater detail in FIG. **7**.

[0037] As mentioned above, embodiments of the present disclosure are directed to a fluid mixing manifold **128** configured to sample and mix fluid flowing through the heat exchanger **100**. More specifically, in the illustrated embodiment, the fluid mixing manifold **128** is positioned within the second water box **104** and is configured to sample conditioning fluid **120** flowing through the second water box **104** at different locations within the second water box **104**. The fluid mixing manifold **128** is further configured to mix the sampled conditioning fluid **120** to generate mixed conditioning fluid **120**. As noted above, the conditioning fluid **120** exiting each tube **108** in the first pass of the heat exchanger **100** may vary in temperature, for example, due to the individual heat transfer efficiency of each tube **108**, among other factors. Thus, by sampling the conditioning fluid

120 at different locations within the second water box **104** and mixing the sampled conditioning fluid **120** to generate the mixed conditioning fluid **120**, the fluid mixing manifold **128** enables efficient detection of an average temperature of the conditioning fluid **120** within the second water box **104** (e.g., between the first pass and the second pass of the heat exchanger **100**). The detected average temperature of the conditioning fluid **120** within the second water box **104** and between the first and second passes of the heat exchanger **100** may be used as feedback to regulate operation of components of a system having the heat exchanger **100**, such as the vapor compression system **14**.
[0038] FIG. **7** is a schematic axial view of the heat exchanger **100**, illustrating a first pass **140** and a second pass **142** of the heat exchanger **100**. As mentioned above, the plurality of tubes **108** disposed within the shell **106** may be divided into a first subset **144** and a second subset **146**. In the illustrated embodiment, the first subset **144** of tubes **108** defines the first pass **140** of the heat exchanger **100**, and the second subset **146** of tubes **108** defines the second pass **142** of the heat exchanger **100**. The first subset **144** of tubes **108** is positioned within a first volume **148** of the shell **106**, and the second subset **146** of tubes **108** is positioned within a second volume **150** of the shell **106**, whereby the first and second volumes **148** and **150** are divided or separated by a partition plate **152** disposed within the shell **106**.
[0039] In some embodiments, the first and second passes **140** and **142** may each be associated with a respective refrigerant circuit configured to circulate a respective refrigerant. Thus, the heat exchanger **100** may be a component of a multi-circuit system (e.g., a two refrigerant circuit chiller). For example, the first pass **140** and the first volume **148** of the shell **106** may be components of the second evaporator **38**B of the second refrigerant circuit **84** shown in FIG. **5**, and the second pass **142** and the second volume **150** of the shell **106** may be components of the first evaporator **38**A of the first refrigerant circuit **82** shown in FIG. **5**. In some embodiments, the first pass **140** and the first volume **148** of the shell **106** may be components of the first condenser **34**A of the first refrigerant circuit **82**, and the second pass **142** and the second volume **150** of the shell **106** may be components of the second condenser **34**B of the second refrigerant circuit **84**. Thus, the heat exchanger **100** of the illustrated embodiment may include two heat exchangers (e.g., two evaporators, two condensers) packaged together in the shell **106**. The following discussion describes operation of the heat exchanger **100** as including two evaporators packaged together in the shell **106**, but it should be appreciated that other embodiments of the heat exchanger **100** may include two condensers packaged together.
[0040] As shown, a first refrigerant **154** is directed into the first volume **148** of the heat exchanger **100** via an inlet **156** of the shell **106**. As described above, conditioning fluid **120** enters the first subset **144** of tubes **108** via the first water box **102**. As the conditioning fluid **120** flows through the first subset **144** of tubes **108** in the first volume **148** (e.g. the first pass **140**), heat is transferred from the conditioning fluid **120** to the first refrigerant **154**, which may cool the conditioning fluid **120** and cause the first refrigerant **154** to evaporate. The evaporated first refrigerant **154** may then exit the first volume **148** of the shell **106** via an outlet **158** of the shell **106** and continue circulating through the refrigerant circuit associated with the first volume **148** and first pass **140** (e.g., second refrigerant circuit **84**).
[0041] Similarly, a second refrigerant **160** is directed into the second volume **150** of the heat exchanger **100** via an inlet **162** of the shell **106**. As mentioned above, the second refrigerant **160** and the first refrigerant **154** may be directed via separate refrigerant circuits (e.g., first and second refrigerant circuits **82** and **84**). Conditioning fluid **120** is directed into the second subset **146** of tubes **108** from the second water box **104**, as described above. As the conditioning fluid **120** flows through the second subset **146** of tubes **108** in the second volume **150** (e.g. the second pass **142**), heat is transferred from the conditioning fluid **120** to the second refrigerant **160**, which may further cool the conditioning fluid **120** and cause the second refrigerant **160** to evaporate. The evaporated second refrigerant **160** may then exit the second volume **150** of the shell **106** via an outlet **164** of the shell **106** continue circulating through the refrigerant circuit associated with the second volume

150 and second pass **142** (e.g., first refrigerant circuit **82**).

[0042] As will be appreciated, it may be desirable to divide or balance a cooling load of the heat exchanger **100** between the two refrigerant circuits. To this end, respective components of the multiple refrigerant circuits may be individually operated to achieve a desired balance of the cooling load between the refrigerant circuits, and operation of the respective components of the multiple refrigerant circuits may be based, at least in part, on an average temperature of the conditioning fluid **120** within the second water box **104** (e.g., the conditioning fluid **120** between the first and second passes **140** and **142**). Thus, present embodiments are directed to the fluid mixing manifold **128**, which enables measurement of an average temperature of the conditioning fluid **120** within the second water box **104** while also mitigating pressure drop of the conditioning fluid **120** within the second water box **104**. As discussed in further detail below, the fluid mixing manifold **128** is configured to sample conditioning fluid **120** within the second water box **104** at different locations (e.g., relative to a height **166** of the heat exchanger **100**) within the second water box **104**. In this way, the fluid mixing manifold **128** is configured to mix portions the conditioning fluid **120** within the second water box **104** to generate mixed conditioning fluid **120**, the temperature of which may be measured to obtain and/or approximate an average temperature of the conditioning fluid **120** within the second water box **104**.

[0043] FIG. **8** is a perspective view of an embodiment of the second water box **104**, illustrating an embodiment of the fluid mixing manifold **128** disposed therein. The second water box **104** has a main body **180** (e.g., dome-shaped main body) and an outer flange **182**, which may be configured to couple to one of the flanges **110** of the shell **106** of the heat exchanger **100**. In an installed configuration, an inner volume **184** of the second water box **104**, which is generally defined by the main body **180**, receives the conditioning fluid **120** from the first subset **144** of tubes **108**, and the main body **180** directs the conditioning fluid **120** to the second subset **146** of tubes **108**. The main body **180** includes an inner surface **186** to which the fluid mixing manifold **128** is coupled (e.g., secured, mounted, affixed, etc.).

[0044] In the illustrated embodiment, the fluid mixing manifold **128** includes a mixing junction **188** and a plurality of sampling conduits **190** that extend from and are fluidly coupled to the mixing junction **188**. Each sampling conduit **190** is configured to receive a flow of the conditioning fluid **120** within the second water box **104** and direct the flow of conditioning fluid **120** to the mixing junction **188** where the different sampled flows of conditioning fluid **120** are mixed to generate mixed conditioning fluid **120**. More specifically, each sampling conduit **190** is configured to sample conditioning fluid **120** at a different location within the second water box **104**, such as at different locations relative to the height **166** of the heat exchanger **100**. For example, a first sampling conduit **192** is configured to receive a first flow of the conditioning fluid **120**, as indicated by arrow **194**, at a first location or height within the second water box **104**, a second sampling conduit **196** is configured to receive a second flow of the conditioning fluid **120**, as indicated by arrow **198**, at a second location or height within the second water box **104**, and a third sampling conduit **200** is configured to receive a third flow of the conditioning fluid **120**, as indicated by arrow **202**, at a third location or height within the second water box **104**. The first, second, and third flows of conditioning fluid **120** mix within the mixing junction **188** to form the mixed conditioning fluid **120**, and the mixed conditioning fluid **120** may be discharged from the fluid mixing manifold **188** via a discharge port **204** of the fluid mixing manifold **128**, as indicated by arrow **206**, that extends from and is fluidly coupled to the mixing junction **188**.

[0045] Each sampling conduit **190** includes a respective inlet port **208** generally facing a first direction **210** (e.g., first lateral direction, first side of the second water box **104**). The inlet ports **208** facing the first direction **210** also face a portion (e.g., a portion of the inner volume **184**) of the second water box **104** that is generally aligned (e.g., relative to a longitudinal axis or length of the heat exchanger **100**) with the first pass **140** and the first subset **144** of tubes **108**. Thus, each sampling conduit **190** is arranged to effectively receive conditioning fluid **120** entering the second water box **104** from the first subset **144** of tubes **108** within the heat exchanger **100**. The discharge port **204**, on the other hand, includes an outlet **212** generally facing a second direction **214** (e.g., second lateral direction, second side of the second water box **104**) opposite the first direction **210**. The discharge port **212** facing the second direction **214** faces a portion (e.g., a portion of the inner volume **184**) of the second water box **104** that is generally aligned (e.g., relative to a longitudinal axis or length of the heat exchanger **100**) with the second pass **142** and the second subset **146** of tubes **108**. Thus, the discharge port **204** effectively directs the mixed conditioning fluid **120** from the fluid mixing manifold **128** towards the second subset **146** of tubes **108** within the heat exchanger **100**.

[0046] The fluid mixing manifold **128** further includes a sensor port **216** extending from the mixing junction **188**. The sensor port **216** is fluidly coupled to the mixing junction **188** and extends through the main body **180** of the second water box **104** to an outer surface **218** of the main body **180**. Accordingly, a sensor (e.g., a temperature sensor) may be inserted into the sensor port **216**, and therefore into the mixing junction **188**, from an exterior of the second water box **104**. In this way, a sensor may be used to detect a temperature or other property of the mixed conditioning fluid **120** within the mixing junction **188**.

[0047] In the illustrated embodiment, the fluid mixing manifold **128** includes generally tubular structures (e.g., sampling conduits **190**) coupled to the second water box **104**. In some embodiments, components of the fluid mixing manifold **128** may be formed from a metallic material, such as carbon steel, a polymeric material, or other suitable material. The mixing junction **188** is coupled to the second water box **104** via the sensor port **216**, and the sampling conduits **190** are coupled to the second water box **104** via support extensions **220**. Thus, the fluid mixing manifold **128** is offset from the inner surface **186** of the second water box **104**. However, other embodiments of the fluid mixing manifold **128** may have other configurations. For example, the fluid mixing manifold **128** may have components directly fixed to the inner surface **186** of the main body **180** to form conduits or channels between the components and the inner surface **186** that are configured to receive flows of the conditioning fluid **120**. In other embodiments, the fluid mixing manifold **128** may be disposed external to the inner volume **184** of the second water box **104** and may have conduits extending through the main body **180** to fluidly couple with the inner volume **184** and receive and/or discharge samples or flows of the conditioning fluid **120** at various locations within the second water box **104**. In any case, the fluid mixing manifold **128** is configured to sample different portions or flows of the conditioning fluid **120** within the second water box **104** (e.g., from various locations along the height **166**) and generate mixed conditioning fluid **120**, the temperature of which may be measured to determine and/or approximate an average temperature of the conditioning fluid **120** within the second water box **104**. Further, embodiments of the fluid mixing manifold **128** may reduce a pressure drop of the conditioning fluid **120** within the second water box **104** compared to traditional components configured to mix the conditioning fluid **120** within water boxes, such as baffles disposed therein. Indeed, as shown in the illustrated embodiment of FIG. **8**, the fluid mixing manifold **128** occupies a relatively small amount of space within the inner volume **184**, which does not impose significant flow restrictions on conditioning fluid **120** within the second water box **104** compared to traditional baffles and other mixing systems.

[0048] FIG. **9** is a schematic of an embodiment of a control system **240** configured to measure and/or approximate an average temperature of the conditioning fluid **120** and control operation of an HVAC&R system (e.g., HVAC&R system **10**, vapor compression system **14**, etc.) based on the determined average temperature. For example, the control system **240** may configured to determine and/or approximate an average temperature of the conditioning fluid **120** within the heat exchanger **100** (e.g., within the second water box **104**) discussed above. The control system **240** may be configured to regulate operation of various components of a first refrigerant circuit **242** (e.g., first refrigerant circuit **82**) and a second refrigerant circuit **244** (e.g., second refrigerant circuit **84**) that are used in conjunction with the heat exchanger **100**.

[0049] The control system **240** includes a controller **246** having a memory **248** and processing circuitry **250**, such as a microprocessor. The memory **248** may include volatile memory, such as random-access memory (RAM), and/or non-volatile memory, such as read-only memory (ROM), optical drives, hard disc drives, solid-state drives, or any other tangible, non-transitory computer-readable medium that includes (e.g., stores) instructions executable by the processing circuitry **250** to operate the HVAC&R system **10**. The processing circuitry **250** may include one or more application specific integrated circuits (ASICs), one or more field programmable gate arrays (FPGAs), one or more general purpose processors, or any combination thereof, configured to execute the instructions stored in the memory **248** to operate the HVAC&R system **10**.

[0050] The controller **246** is configured to receive feedback from one or more sensors **252**. For example, one of the sensors **252** may be used with the fluid mixing manifold **128**. As discussed above, the sensor **252** may be a temperature sensor configured to measure a temperature of mixed conditioning fluid **120** (e.g., within the mixing junction **188** of the fluid mixing manifold **128**). Based on the measured temperature of the mixed conditioning fluid **120**, the controller **246** may adjust operation of one or more components of the first refrigerant circuit **242** and/or the second refrigerant circuit **244** (e.g., any components of the first refrigerant circuit **82** and the second refrigerant circuit **84**). In one embodiment, the controller **246** may adjust operation of the HVAC&R system **10** to balance a cooling load of the HVAC&R system **10** between the first refrigerant circuit **242** and the second refrigerant circuit **244**. As an example, one or more of the sensors **252** may be configured to detect a temperature of the conditioning fluid **120** entering the heat exchanger **100** (e.g., entering the first water box **102** and directed to the first subset **144** of tubes **108**) and to detect a temperature of the conditioning fluid **120** exiting the heat exchanger **100** (e.g., exiting the first water box **102** after flowing through the heat exchanger **100**). Based on the detected temperatures of the conditioning fluid **120** entering and exiting the heat exchanger **100** and the temperature of the mixed conditioning fluid **120** within the second water box **104**, the controller **246** may determine respective temperature differentials of the conditioning fluid across the first pass **140** and second pass **142** of the heat exchanger **100**. The calculated temperature differentials may then be used to adjust operation of components (e.g., compressors, expansion devices, etc.) of the first refrigerant circuit **242** and/or the second refrigerant circuit **244** in order to achieve a desired balance of a cooling load (e.g., cooling load **88**) on the HVAC&R system **10** having the heat exchanger **100**. The controller **246** may also adjust operation of first refrigerant circuit **242**, the second refrigerant circuit **244**, and/or other components of the HVAC&R system **10** to load and/or unload the HVAC&R system **10** in a desirable manner.

[0051] As discussed above, present embodiments are directed to a fluid mixing manifold configured to sample fluid, such as cooling or conditioning fluid, at different locations within a water box of a heat exchanger, such as a heat exchanger incorporated with multiple refrigerant circuits. The fluid mixing manifold mixes the sampled fluids to generate a mixed fluid. The temperature of the mixed fluid may be measured and may be used to control operation of a vapor compression system having the heat exchanger, such as to balance a load shared by the multiple refrigerant circuits. The configuration of the fluid mixing manifold enables more accurate temperature measurements of the fluid for use in controlling operation of the vapor compression system and also enables a reduction in pressure drop of the fluid within the water box compared to traditional systems that are configured to generate a mixed fluid within the water box.

[0052] While only certain features and embodiments of the disclosure have been illustrated and described, many modifications and changes may occur to those skilled in the art, such as variations in sizes, dimensions, structures, shapes and proportions of the various elements, values of parameters, including temperatures and pressures, mounting arrangements, use of materials, colors, orientations, and so forth without materially departing from the novel teachings and advantages of the subject matter recited in the claims. The order or sequence of any process or method steps may be varied or re-sequenced according to alternative embodiments. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit of the disclosure. Furthermore, in an effort to provide a concise description of the exemplary embodiments, all features of an actual implementation may not have been described, such as those unrelated to the presently contemplated best mode of carrying out the disclosure, or those unrelated to enabling the claimed disclosure. It should be noted that in the development of any such actual implementation, as in any engineering or design project, numerous implementation specific decisions may be made. Such a development effort might be complex and time consuming, but would nevertheless be a routine undertaking of design, fabrication, and manufacture for those of ordinary skill having the benefit of this disclosure, without undue experimentation.

[0053] The techniques presented and claimed herein are referenced and applied to material objects and concrete examples of a practical nature that demonstrably improve the present technical field and, as such, are not abstract, intangible or purely theoretical. Further, if any claims appended to the end of this specification contain one or more elements designated as “means for [perform] ing [a function] . . . ” or “step for [perform] ing [a function] . . . ”, it is intended that such elements are to be interpreted under 35 U.S.C. 112 (f). However, for any claims containing elements designated in any other manner, it is intended that such elements are not to be interpreted under 35 U.S.C. 112 (f).

Claims

1. A heating, ventilation, air conditioning, and refrigeration (HVAC&R) system, comprising: a heat exchanger comprising a shell, a first fluid pass extending through the shell, a second fluid pass extending through the shell, and a water box coupled to the shell, wherein the water box is configured to direct a fluid from the first fluid pass to the second fluid pass; and a fluid mixing manifold disposed within the water box, wherein the fluid mixing manifold comprises: a plurality of channels configured to collect a plurality of flows of the fluid from within the water box; and a mixing junction configured to receive the plurality of flows of the fluid from the plurality of channels and generate a mixed fluid via the plurality of flows of the fluid; and a discharge port extending from the mixing junction and configured to discharge the mixed fluid into the water box.

2. The HVAC&R system of claim 1, wherein the fluid mixing manifold comprises a sensor port extending from the mixing junction, and the sensor port is configured to receive a sensor configured to detect a parameter of the mixed fluid.

3. The HVAC&R system of claim 2, wherein the sensor port extends through a body of the water box.

4. The HVAC&R system of claim 1, wherein each channel of the plurality of channels extends from the mixing junction in a respective direction, and the respective directions of the plurality of channels are different from one another.

5. The HVAC&R system of claim 4, wherein: a first channel of the plurality of channels extends from the mixing junction in a first direction, and a second channel of the plurality of channels extends from the mixing junction in a second direction, wherein the first direction and the second direction are opposite one another.

6. The HVAC&R system of claim 5, wherein: a third channel of the plurality of channels extends from the mixing junction in a third direction, and the discharge port extends from the mixing junction in a fourth direction, wherein the third direction and the fourth direction are opposite one another.

7. The HVAC&R system of claim 1, wherein the fluid mixing manifold comprises a plurality of conduits extending from the mixing junction, and each conduit of the plurality of conduits defines a respective channel of the plurality of channels.

8. The HVAC&R system of claim 7, wherein the plurality of conduits is offset from an inner surface of the water box.

9. The HVAC&R system of claim 1, wherein at least one channel of the plurality of channels comprises a respective inlet facing a first direction, the discharge port comprises an outlet facing a second direction, and the first direction and the second direction are opposite one another.

10. The HVAC&R system of claim 1, wherein the water box defines an inner volume, the fluid mixing manifold is disposed within the inner volume, the plurality of channels is configured to collect the plurality of flows of the fluid from a first portion of the inner volume aligned with the first fluid pass of the heat exchanger, relative to a longitudinal axis of the heat exchanger, and the discharge port is configured to discharge the mixed fluid into a second portion of the inner volume aligned with the second fluid pass of the heat exchanger, relative to the longitudinal axis of the heat exchanger.

11. The HVAC&R system of claim 1, wherein: a first channel of the plurality of channels is configured to collect a first flow of the plurality of flows of the fluid at a first height within the water box, a second channel of the plurality of channels is configured to collect a second flow of the plurality of flows of the fluid at a second height within the water box, and a third channel of the plurality of channels is configured to collect a third flow of the plurality of flows of the fluid at a third height within the water box, wherein the first height, the second height, and the third height are different from one another.

12. A heating, ventilation, air conditioning, and refrigeration (HVAC&R) system, comprising: a fluid mixing manifold configured to be disposed within an inner volume of a water box of a heat exchanger, wherein the fluid mixing manifold comprises: a plurality of channels configured to collect a plurality of flows of a fluid from a plurality of locations within the water box; a mixing junction fluidly coupled to each channel of the plurality of channels, wherein the mixing junction is configured to mix the plurality of flows of the fluid received via the plurality to channels to generate a mixed fluid; and a discharge port fluidly coupled to the mixing junction and configured to discharge the mixed fluid into the water box, wherein each channel of the plurality of channels is configured to collect a respective flow of the fluid of the plurality of flows of the fluid from a respective location of the plurality of locations within the water box and direct the respective flow of the fluid to the mixing junction.

13. The HVAC&R system of claim 12, wherein: a first channel of the plurality of channels extends from the mixing junction in a first direction, a second channel of the plurality of channels extends from the mixing junction in a second direction, a third channel of the plurality of channels extends from the mixing junction in a third direction, and the first direction, the second direction, and the third direction are different from one another.

14. The HVAC&R system of claim 13, wherein the discharge port extends from the mixing junction in a fourth direction different from the first direction, the second direction, and the third direction.

15. The HVAC&R system of claim 12, wherein the fluid mixing manifold comprises a plurality of tubular structures extending from the mixing junction, and each tubular structure of the plurality of tubular structures defines a respective channel of the plurality of channels.

16. The HVAC&R system of claim 12, wherein the fluid mixing manifold comprises a sensor port extending from the mixing junction, the sensor port is configured to receive a sensor configured to detect a parameter of the mixed fluid, and the sensor port is configured to extend through a main body of the water box to mount the fluid mixing manifold to the water box and position the plurality of channels within the inner volume and offset from the main body of the water box.

17. The HVAC&R system of claim 16, wherein each channel of the plurality of channels comprises a respective inlet port configured to collect the respective flow of the fluid at the respective location of the plurality of locations, wherein a respective position of each location of the plurality of locations along a height of the water box is different from one another.

18. A fluid mixing manifold for a heat exchanger of a heating, ventilation, air conditioning, and refrigeration (HVAC&R) system, wherein the fluid mixing manifold comprises: a mixing junction; a plurality of sampling conduits extending from the mixing junction, wherein the plurality of sampling conduits comprises: a first sampling conduit comprising a first inlet configured to receive a first flow of fluid from within a water box of the heat exchanger, wherein the first sampling conduit is configured to direct the first flow of fluid to the mixing junction; a second sampling conduit comprising a second inlet configured to receive a second flow of fluid from within the water box, wherein the second sampling conduit is configured to direct the second flow of fluid to the mixing junction; and a third sampling conduit comprising a third inlet configured to receive a third flow of fluid from within the water box, wherein the third sampling conduit is configured to direct the third flow of fluid to the mixing junction; and a discharge port extending from the mixing junction, wherein the mixing junction is configured to mix the first flow of fluid, the second flow of fluid, and the third flow of fluid to generate a mixed fluid, and the discharge port is configured to discharge the mixed fluid into the water box.

19. The fluid mixing manifold of claim 18, comprising: sensor port extending from the mixing junction, wherein the sensor port is configured to receive a sensor configured to detect a parameter of the mixed fluid; and a plurality of support extensions, wherein each support extension of the plurality of support extensions extends from a respective sampling conduit of the plurality of sampling conduits, wherein the sensor port and the plurality of support extensions are configured to couple to a main body of the water box to mount the fluid mixing manifold to the water box and suspend the mixing junction and the plurality of sampling conduits within an inner volume of the water box.

20. The fluid mixing manifold of claim 18, wherein the discharge port and each sampling conduit of the plurality of sampling conduits extends from the mixing junction in respective direction different from one another.