United States Patent	12392919
Kind Code	B2
Date of Patent	August 19, 2025
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Fluid detection systems and methods using the same

Abstract

Fluid detection systems and methods using the same are disclosed. In embodiments the fluid detection systems include a sensor module and an electronics module. The sensor module includes a sensor housing that includes a liquid flow path and a sensor element disposed around at least part of the liquid flow path. The sensor element can detect a capacitance of the liquid flow path and provide a sensor signal to a controller in the electronics module. The electronics module can determine a detected capacitance in the liquid flow path based at least in part on the sensor signal, and can determine whether a wet event has occurred based on a comparison of the detected capacitance to a threshold capacitance. Methods using the fluid detection systems and fluid supply systems including the fluid detection systems are also disclosed.

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Appl. No.: **18/265934**

Filed (or PCT Filed): **December 08, 2021**

PCT No.: **PCT/US2021/062336**

PCT Pub. No.: **WO2022/125618**

PCT Pub. Date: June 16, 2022

Prior Publication Data

Document Identifier	Publication Date
US 20240036226 A1	Feb. 01, 2024

Related U.S. Application Data

continuation-in-part parent-doc US 17115682 20201208 US 12188213 child-doc US 18265934

Publication Classification

Int. Cl.: **G01V3/02** (20060101)

U.S. Cl.:

CPC **G01V3/02** (20130101);

Field of Classification Search

CPC: G01V (3/02)

USPC: 324/686

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS

(1) This application is a U.S. National Stage Application of PCT/US21/62336 filed 8 Dec. 2021, and claims priority to U.S. application Ser. No. 17/115,682, filed Dec. 8, 2020, the entire contents both of which are incorporated herein by reference.

TECHNICAL FIELD

(2) The present disclosure relates to fluid detection systems and methods using the same. In particular, the present disclosure relates to fluid detection systems for use with fluid supply equipment such as backflow prevention devices and relief valves.

BACKGROUND

(3) Fluid supply systems are often configured to convey fluid (e.g., water) from a pressurized source to a destination, such as a building or other structure. For example, buildings often include a water supply system that is configured to receive a pressurized supply of water from a municipal water supply, and to convey water to various outlets such as toilets, faucets, fire prevention systems, etc., within the building. When the water is provided at a sufficient pressure, it will be pressurized against and can flow through the outlets in a forward direction. If pressure is lost or reduced below a threshold amount, however, a “backflow” condition may arise in which the water flows backwards toward the source. As fluid backflow may contaminate the source, technologies such as backflow preventers have been developed to limit or prevent fluid backflow.

(4) FIG. **1** depicts one example of a fluid supply system **100** that includes a backflow preventer. System **100** includes a strainer **101** that is includes an inlet **103** that receives a fluid (e.g., water) from a supply, such as a municipal water supply. Strainer **101** is coupled to an inlet side of backflow preventer **105**. The outlet side of backflow preventer **105** is coupled to a proximal end of a supply pipe **111**. Backflow preventer includes an upstream shutoff valve **107**, a double check valve assembly (DCVA) **108**, and a downstream shutoff valve **109**. The distal end of supply pipe **111** conveys water to a destination, such as a building. Backflow preventer **105** is also coupled to a discharge pipe **113**. In normal operation fluid such as water is conveyed under pressure from the supply to inlet **103**. The pressure from the supply sufficiently biases the fluid in the forward direction to keep the check valves in DCVA **108** open and allow the fluid to flow through pipe **111** to the destination/building in a forward direction. When pressure is lost upstream of backflow preventer **105**, however, one or both of the check valves in DCVA **108** will close to prevent backflow of fluid into the supply.

(5) Backflow preventer **105** may operate in a normal (flow) condition for many years without any backflow events. During that time, mechanical components within backflow preventer **105** may corrode or otherwise degrade such that they might not function as intended during a backflow event. For example, one or more of the double check valves in DCVA **108** may not fully close during a backflow event, resulting in leakage of back flowing fluid. To address that issue backflow preventer **105** is fluidly coupled to a discharge pipe **113**, and is configured to direct fluid leaking through DCVA **108** in a backflow condition to discharge pipe **113** such that the leaking fluid does not enter the supply. While redirecting leaking fluid into discharge pipe **113** can prevent contamination of the supply, the discharge of fluid from discharge pipe **113** may be problematic. For example, fluid discharged from discharge pipe **113** may flood the surrounding environment, which may cause substantial damage—particularly when the outlet of discharge pipe **113** is within a mechanical room of a building.

(6) Systems have been developed to detect fluid flow through a discharge flow path, such as may occur during a backflow event. FIG. **2**. illustrates one such system. System **200** includes a gate valve **201**, a strainer **101**, an automatic valve control **203**, a backflow preventer **105**, a flow sensor **212**, and a controller **217**. Under normal operation, pressurized fluid is provided by a supply and flows/is pressured in a forward direction through the gate valve **201**, strainer **101**, automatic valve control **203**, and backflow preventer **105**. Like system **100**, backflow may occur when pressure is lost upstream of backflow preventer **105**, but such backflow may be stopped or substantially stopped by backflow preventer **105**. Back flowing fluid that that may leak through backflow preventer **105** (i.e., leakage fluid) may be directed into a discharge pipe **113**, where it may flow through an air gap **205**, into a vertical discharge conduit **207**, and then into a horizontal discharge conduit **209**.

(7) System **200** further includes a flow detector **211** coupled in-line with horizontal discharge conduit **209**. Flow detector **211** includes a flow sensor **212** that includes one or more probes **213** that extend into a discharge flow path **215**. Flow sensor **212** is generally configured to monitor the voltage of probes **213** in order to determine whether there is liquid within discharge flow path **215** that is coupled in line with horizontal discharge conduit **209**. If liquid is detected in discharge flow path **215**, controller may cause automatic valve control **203** to actuate one or more gate valves to physically prevent liquid flow toward and/or from the supply, toward and/or from the building, or both.
(8) Although effective, flow detector **211** is not without certain limitations. For example, probes **213** of flow detector **211** must extend into and thus partially obstruct discharge flow path **215**, which may be undesirable. Moreover, due to the nature of probes **213**, flow detector **211** needs to be installed into a horizontal length of discharge flow path **215**. This can impose a meaningful limitation on the manner in which system **200** may be configured within a mechanical room or other confined space. The orientation of probes **213** may also make it difficult for flow detector **211** to detect relatively small flows of fluid within discharge conduit, particularly if the fluid flow is insufficient to cause the fluid to contact probes **213**.
(9) A need therefore remains in the art for improved technologies for detecting fluid within a flow path. The present disclosure is aimed at that need.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) Features and advantages of various embodiments of the claimed subject matter will become apparent as the following Detailed Description proceeds, and upon reference to the Drawings, wherein like numerals designate like parts, and in which:
(2) FIG. **1** is a schematic drawing of a prior art fluid supply system including a backflow preventer;
(3) FIG. **2** is a schematic drawing of a prior art fluid supply system including a backflow preventer and a discharge detection system within a length of horizontal pipe;
(4) FIG. **3** is a schematic drawing illustrating one example of a fluid supply system including a backflow preventer and a fluid detection system consistent with the present disclosure;
(5) FIG. **4** is a block diagram of one example of a fluid detection system consistent with the present disclosure;
(6) FIGS. **5**A-**5**P depict various views of one example of a fluid detection system consistent with the present disclosure;
(7) FIGS. **6**A and **6**B are front and rear perspective views, respectively, of one example of an electronics module for a fluid detection system consistent with the present disclosure;
(8) FIG. **7** is a block diagram of one example of a controller consistent with the present disclosure;
(9) FIGS. **8**A-**8**C are various views of one example of a backflow prevention system including a fluid detection system consistent with the present disclosure; and
(10) FIG. **9** is a flow diagram of one example of a method of detecting fluid, consistent with the present disclosure.
(11) FIGS. **10**A-**10**M depict various views of another example of a fluid detection system consistent with the present disclosure.
(12) FIGS. **11**A-**11**O depict various views of another example of a fluid detection system consistent with the present disclosure.
(13) FIGS. **12**A-**12**O depict various view of another example of a fluid detection system consistent with the present disclosure.
(14) FIG. **13** shows one example of a valve system coupled to a fluid detection system consistent with FIGS. **10**A-**10**M.

(15) FIG. **14** shows one example of a valve system coupled to a fluid detection system consistent with FIGS. **11**A-**100**.
(16) FIG. **15** shows one example of a valve system coupled to a fluid detection system consistent with FIGS. **12**A-**12**O.
(17) Although the following Detailed Description will proceed with reference being made to illustrative embodiments, many alternatives, modifications and variations thereof will be apparent to those skilled in the art.

DETAILED DESCRIPTION

(18) The present disclosure is directed to fluid detection systems, systems including the same, and methods using the same. In embodiments the fluid detection systems include a sensor module that includes a sensor housing. A liquid flow path (also referred to herein as a sensing conduit) extends through the sensor housing from a first inlet opening to a first outlet opening. The sensor module further includes a sensor element that is located outside the liquid flow path and which extends at least partially around a perimeter of the liquid flow path. The sensor element is configured to detect a capacitance within the liquid flow path and to provide a detection signal indicative of a detected capacitance within the liquid flow path. The sensor element is also configured to communicatively couple to a controller within an electronics module.
(19) The sensor modules described herein may optionally include an air flow path that extends through the sensor housing, e.g., from a second inlet opening to a second outlet opening. The air flow path is configured to allow air or another gas to flow, e.g., when the fluid detection system is coupled to another component of a fluid supply system such as a backflow preventer or a relief valve. In embodiments, at least a portion of the liquid flow path and at least a portion of the air flow path extend parallel or substantially parallel to each other.
(20) The sensor modules described herein may also include a sensor channel that is generally configured to house at least a portion of the sensor element. In embodiments the sensor channel is at least partially disposed outside the perimeter of the liquid flow path, and at least a portion of the sensor element is within the sensor channel. In such embodiments the sensor element does not obstruct any part of the liquid flow path due to its position and configuration.
(21) The sensor element may include several parts (or portions), which may be coupled to or integral with one another. For example, the sensor element may include a first portion and a second portion, wherein the first portion is disposed around at least a portion of the perimeter of the liquid flow path. In such embodiments the second portion of the second element may be configured to communicatively couple to the controller, e.g., within the electronics module. Of course, sensor elements with one or greater than two portions may also be used. The liquid flow path may have any suitable shape and the first portion of the sensor element may substantially correspond to that shape. For example, at least a portion of the liquid flow path may have a circular, c shape, or d shape cross section, and the first portion of the sensor element may have a corresponding circular, c shape, or d shape cross section.
(22) In embodiments the fluid detection systems described herein include the electronics module and the controller. In such embodiments the controller may be located within the electronics module, i.e., within a housing of the electronics module (hereinafter, the “electronics housing”). The electronics housing may be configured to physically couple to the sensor housing such that the sensor element is communicatively coupled to the controller. Physical coupling of the electronics module and the sensor housing may be accomplished in any suitable manner. In some embodiments the electronics housing and sensor housing may be integral with one another. In other embodiments, the electronics housing may be detachable from the sensor housing. In such instances the electronics housing may be configured such that the sensor element is communicatively coupled within the controller when the electronics housing and sensor housing are in an assembled state. Physical decoupling of the electronics housing from the sensor housing may, in some embodiments, break communication between the sensor element and the controller.

(23) The controller is generally configured to receive a detection signal from the sensor module and determine whether fluid is present within the liquid flow path based at least in part on the detection signal. In embodiments the sensor signal is indicative of a capacitance within the liquid flow path that is detected by the sensor element, and the controller is configured to determine the capacitance detected by the sensor element (i.e., the detected capacitance) based at least in part on the detection signal. The controller may then compare the detected capacitance to a capacitance threshold and determine whether liquid is present within the liquid flow path based at least in part on that comparison. The controller may record a wet event (e.g., in a memory thereof) when it determines that liquid is present in the liquid flow path. In contrast, the controller may discard a reading and/or record a dry event when it determines that liquid is not present in the liquid flow path. In embodiments, the controller is configured to determine that liquid is present within the liquid flow path when the detected capacitance is at or above the capacitance threshold, and to determine that liquid is not within the liquid flow path when the detected capacitance is above the capacitance threshold. In embodiments the determination of whether a wet event is occurring may depend on whether the controller determines that the detected capacitance within the liquid flow path remains above or below the threshold capacitance for at least a (first) threshold period of time (i.e., for at least a first measurement period).
(24) The controller may also be configured to determine whether a flood event is occurring. The controller may make that determination by comparing a total number of wet events within a (second) measurement period (i.e., a (second) threshold period of time) to a threshold number of wet events for that (second) measurement period. If the comparison indicates that total number of wet events recorded within the (second) measurement period is greater than or equal to the threshold number of wet events for the (second) measurement period, the controller may record a flood event. If the total number of wet events in the (second) measurement period is less than the threshold number of wet events for the (second) measurement period, however, the controller may continue to monitor for the occurrence of wet and/or flood events as previously described.
(25) The fluid detection systems described herein may also include communications circuitry (COMMS). In embodiments the COMMS is located within the electronics housing, though it may be located elsewhere (e.g., in the sensor housing). The COMMS is generally configured to communicate with one or more external devices (e.g., cell phones, smart phones, computers, tablets, combinations thereof, and the like), e.g., via a wired or wireless communication protocol. When the systems described herein include COMMS, the controller may be configured to cause the COMMS to issue an alert (e.g., wet notification and/or flood notification) to an external device via wired or wireless communication, e.g., in response to the detection of a wet event or a flood event, respectively. Alternatively, or additionally, the controller may issue an alert in another form, such as an audio, visual, or audiovisual alert that is configured to notify a user of the occurrence of a wet and/or flood event.
(26) In embodiments the fluid detection systems described herein further include a calibration module that is configured to establish a baseline capacitance within the liquid flow path. The calibration module may be in the electronics module, the sensor module, or another other suitable location. In any case, the controller may be configured to set the capacitance threshold relative to the baseline capacitance, e.g., to improve the controller's ability to accurately detect the occurrence of wet and flood events. For example, the controller may be configured to set the capacitance threshold above the baseline capacitance by a predetermined margin. Alternatively, or in addition to a calibration module, the capacitance threshold may be set by a physical component of the electronics module (e.g., one or more jumpers such as dip switches).
(27) FIG. **3** is a block diagram of one example of a fluid supply system including a backflow preventer and a fluid detection system consistent with the present disclosure. Similar to system **200**, system **300** includes a backflow preventer **105** and a discharge pipe **113**. System **200** can also include can include a gate valve **201**, strainer **101**, and automatic valve control **203**, but such

components are not required. When used, the gate valve **201** includes an inlet that is fluidly coupled to a fluid source such as a municipal water supply. Gate valve **201** further includes a valve (not shown) that may be used to shut off the supply of fluid to system **300**. Strainer **101**, when used, is fluidly coupled to the gate valve **201** (or directly to the fluid source) and is configured to remove solids that may be present within a supplied fluid. Automatic valve control **203**, when used, has an inlet that is fluidly coupled to the strainer **101**, gate valve **201**, and/or the fluid source. Automatic valve control **203** may also have an outlet that is fluidly coupled to an inlet of a backflow preventer **105**. In any case, automatic valve control **203** is configured to control one or more valves, e.g., in backflow preventer **105**, automatic valve control **203**, gate valve **201**, etc., e.g., in response to a control signal.
(28) Backflow preventer **105** includes an inlet and an outlet. The inlet of backflow preventer **105** is fluidly coupled (or configured to be fluidly coupled) to the fluid supply and/or one or more upstream components, such as gate valve **201**, strainer **101**, automatic valve control **203**, or the like. The outlet of backflow preventer **105** is fluidly coupled (or configured to be fluidly coupled) to a destination for a supplied fluid. In this case the outlet of backflow preventer **105** is fluidly coupled to one or more outlets within a building, but backflow preventer **105** may be coupled to any type of destination, such as a storage tank, a fire hydrant, etc. In general, backflow preventer **105** is configured to permit forward fluid flow under normal operating conditions (i.e., when fluid is supplied under adequate pressure), and to limit or prevent backflow of fluid in the event there is a loss of pressure.
(29) Non-limiting examples of suitable backflow preventers that may be used as backflow preventer **105** include backflow preventers produced and sold by WATTS Water Technologies, Inc., such as but not limited to the WATTS 957 RPZ backflow preventer, the WATTS series LF909 reduced pressure zone assembly, the Watts 909 series backflow preventers, combinations thereof, and the like. Of course, such backflow preventers are enumerated for the sake of example only, and any suitable backflow preventer that may be used. In embodiments, backflow preventer **105** includes at least one check valves that is biased in an open position by a fluid when a pressure of the fluid is above a threshold pressure, but which is in a closed position when the pressure of the fluid is below the threshold pressure.
(30) In addition to being fluidly coupled to a fluid source and a fluid destination (e.g., a building), backflow preventer **105** is also fluidly coupled (or configured to fluidly couple) to a discharge pipe **113**. Consistent with the foregoing discussion, discharge pipe **113** generally functions to redirect fluid that may leak through backflow preventer **105** away from the fluid source. The flow of fluid into discharge pipe **113** may be caused by various things, such as a backflow event or a problem with backflow preventer **105** (e.g., a malfunctioning check valve therein). Alternatively, fluid flow into discharge pipe **113** may happen even when backflow preventer **105** is functioning properly. In any case, fluid within discharge pipe **113** (also referred to herein as leakage flow) may flow downstream through fluid detection system **301**, through an air gap **205**, and into a vertical discharge conduit **207**.
(31) As will be described in further detail below fluid detection system **301** includes a sensor module and an electronics module. In embodiments the sensor module includes a sensor housing that includes a liquid flow path (i.e., a sensing conduit) that is configured to receive the leakage flow, and a sensor element disposed at least partially around the liquid flow path. The sensor element is configured to enable detection of fluid within the liquid flow path at least in part by measuring the capacitance within the liquid flow path and providing a detection signal representative of the measured capacitance within the liquid flow path. The detection signal may be provided to a controller, which may be integral with or coupled to the sensor housing in any suitable manner. In embodiments the controller is disposed within the electronics module, which is configured to physically couple to the sensor module.
(32) When the sensor element is in communication with the controller, the controller may

determine the capacitance within the liquid flow path based at least in part on a sensor signal provided by the sensor element. The controller may then determine whether a wet event is occurring within the liquid flow path based at least in part on the determined capacitance. If the controller detects a wet event (i.e., that liquid is present in the liquid flow path), it may further determine whether the wet event is part of a flood event, as described later. In response to a detected wet and/or flood event, the controller may act to alert a user of system **300** to such an event, and may issue control signals (e.g., to optional automatic valve control **203**) that cause one or more valves within system **300** to close.
(33) FIG. **4** is a block diagram of one example of a fluid detection system consistent with the present disclosure. As shown, fluid detection system **301** includes a sensor module **401** and an electronics module **413**. Sensor module **401** includes a sensor housing **403**, and electronics module **413** includes an electronics housing **417**. The electronics housing **417** may be coupled to or integral with the sensor housing **403**.
(34) Sensor module **401** is configured to couple in-line with at least one fluid (e.g., liquid) conduit, such as a discharge pipe or other fluid conduit that may be used in a fluid supply system. Alternatively, or additionally, sensor module **401** is configured to couple in-line to an outlet of an upstream component used in fluid supply equipment, such as a backflow preventer, a pressure relief valve, combinations thereof and the like. In embodiments, sensor housing **403** may be configured to enable sensor module **401** to couple to an end of a fluid conduit such as but not limited to an open end of discharge conduit or pipe. The manner in which sensor module **401** is configured to couple to such a conduit is not limited. In embodiments, sensor housing **403** includes one or more fastening elements (e.g., male/female threads), which are configured to engage with corresponding fastening elements of a fluid conduit. Alternatively, or additionally, sensor housing **403** may be configured to couple to a fluid conduit via adhesive, solder, a mechanical fastener, a mechanical fitting (e.g., a press fit or other mechanical arrangement), combination thereof, and the like. Similar features may be used to couple sensor housing **403** to an outlet of equipment used in a fluid supply system, such as a backflow preventer, a pressure relief valve, or the like.
(35) Sensor housing **403** may be formed of any suitable materials, such as plastics, metals, alloys, composites, and the like. In embodiments, sensor housing **403** is formed from or includes a plastic material, such as but not limited to polyvinylchloride (PVC), chlorinated PVC, cross linked polyethylene, epoxy, fiber reinforced plastic, acrylonitrile butadiene styrene (ABS) combinations thereof, and the like. Alternatively, or additionally, in embodiments sensor housing **403** is formed from or includes one or more metals, such as but not limited to copper, galvanized steel, stainless steel, iron, combinations thereof, and the like. In specific non-limiting embodiments, sensor housing **403** is formed from or includes a polymer coated metal, such as epoxy coated metal.
(36) Sensor module **401** further includes liquid flow path **405**, which may also be referred to as a sensing conduit. In general, liquid flow path **405** is configured to provide a passageway for the flow of a fluid such as water. Accordingly, liquid flow path **405** includes at least one inlet, at least one outlet, and a passageway that extends between the at least one inlet and the at least one outlet. The at least one inlet may be defined at least in part by an opening on an inlet side of sensor module **401** or, more specifically, of sensor housing **403**. The at least one outlet may be defined at least in part by an opening on an outlet side of sensor module **401**. In embodiments, the inlet and outlet sides of sensor module are opposite or substantially opposite one another, and the inlet and outlet openings of liquid flow path **405** are opposite or substantially opposite one another. That is, the inlet and outlet openings may be oriented along corresponding planes that are parallel or substantially parallel (i.e., +/−five degrees of parallel) to one another. In such embodiments the passageway between the inlet and outlet openings of liquid flow path **405** may be straight or substantially straight.
(37) The inlet and outlet openings may of course be arranged differently. For example, when liquid flow path **405** is curved or includes a bend, the inlet and outlet openings may be angled or offset

relative to one another. In embodiments, the inlet and outlet openings are oriented along respective first and second planes, wherein the first and second planes intersect with each other.

(38) The cross sectional shape of liquid flow path **405** is not limited and liquid flow path **405** may have any suitable cross sectional shape. For example, the cross sectional shape of at least a portion of liquid flow path **405** may be a geometric (e.g., circular, ellipsoidal, oval, triangular, quadrilateral, pentagonal, etc.) shape, an irregular shape, or a combination thereof. Without limitation, at least a portion of liquid flow path **405** preferably has a circular, oval, or other geometric cross sectional shape. Still further, in some embodiments liquid flow path **405** has a cross sectional shape that is the same as or complementary to the shape of a flow path in a liquid conduit to which sensor housing **403** is to be coupled.

(39) Liquid flow path **405** is preferably positioned within sensor housing **403** such that when sensor housing **403** is coupled to an outlet of a component used in fluid supply equipment (e.g., a discharge pipe, a backflow preventer, a relief valve, etc.), the inlet of liquid flow path **405** is aligned or substantially aligned with the outlet of the upstream component. In any case, at least a portion of the liquid flow path **405** is defined at least in part by a perimeter **411**. The perimeter **411** may form an edge of an inlet or an outlet of liquid flow path **405**, and/or a portion of a wall of a passageway of flow path **405**. In embodiments, perimeter **411** is formed or otherwise defined at least in part by material of sensor housing **403**, but of course other materials may also be used.

(40) Sensor module **401** further includes a sensor element **407**, which is generally configured to detect a capacitance within liquid flow path **405**. Sensor element **407** may be any suitable sensing structure, such as a capacitance sensor. In embodiments sensor element **407** is a capacitive sensor that is in the form of or includes a conductor, such as a conductive antenna or electrode. In such embodiments the conductor of sensor element **407** may extend at least partially around the perimeter **411** of liquid flow path **405**. Without limitation, sensor element **407** preferably includes at least one conductive antenna that includes or is in the form of one or more wires or strips of conductive material that extend from greater than 0 to 100% of the distance around the perimeter **411** of liquid flow path **405**, such as from greater than or equal to about 25% to about 100%, from greater than or equal to about 25 to about 99%, from greater than or equal to about 40% to about 99%, from greater than or equal to about 50% to about 99% of the distance around perimeter **411**, or even from greater than or equal to about 95% of the distance around perimeter **411**. In specific non-limiting embodiments, sensor element **407** is located outside of liquid flow path **405** (i.e., such that no part of sensor element **407** is present within liquid flow path **405**), and extends around perimeter **411** within the previously noted ranges.

(41) The number of conductive elements used in sensor element **407** is not limited, and any suitable number of conductive elements may be used. For example, sensor element **407** may include 1, 2, 3, 4, 5, 10, 15, 20, or more conductive elements. When multiple elements are used, they may be spaced apart (laterally offset) and extend parallel or substantially parallel to one another. In specific non limiting embodiments, sensor element **407** is in the form of a flat flexible cable (FFC) that includes a plurality of parallel conductors, each conductor of which is laterally offset from one or more adjacent conductors by offset distance that ranges from greater than 0 to about 2.5 millimeters (m), such as from greater than 0 to about 1.5 mm, from greater than 0 to about 1.0 mm, or even from greater than 0 to about 0.5 mm. In a preferred non-limiting embodiment, sensor element **407** is an FFC with **20** parallel conductors, wherein each conductor is offset from one or more adjacent conductors by an offset distance of about 0.5 mm.

(42) Any suitable conductive materials may be used as or in the conductive element(s) of sensor element **407**. Non-limiting examples of suitable conductive materials that may be used in or as such conductive elements include metals such as aluminum, copper, gold, silver, conductive metal alloys, combinations thereof, and the like. Without limitation, in embodiments sensor element **407** includes one or more copper wires or strips that extend around perimeter **411** of liquid flow path **405** within the above noted ranges.

(43) Sensor element **407** may be grounded to provide a common ground reference point that can improve the consistency and reliability of capacitance measurements taken by the element. The manner in which sensor element **407** is grounded is not limited, and any suitable grounding method may be used. For example, sensor element **407** may be connected to an earth ground or a floating ground, e.g., by one or more grounding cables or other types of ground connections.
(44) Sensor module **401** may also include a sensor channel **409** that is configured to house or otherwise support at least a portion of sensor element **407** therein. In embodiments sensor channel **409** may extend completely around the perimeter **411** of liquid flow path **405**. Alternatively, sensor channel **409** may extend at least partially around the perimeter **411** of liquid flow path **405**, e.g., within the ranges noted above for sensor element **407**. In any case sensor channel **409** may be defined at least in part by an inner wall **410** of sensor housing **403** and an outward facing side of perimeter **411**. For example, sensor channel **409** may be in the form of a groove that includes an inner groove wall defined at least in part by an outward facing side of perimeter **411**, an outer groove wall defined by inner wall **410** of sensor housing **403**, and a bottom. In such instances, the groove may have a depth that is greater than or equal to the width and/or thickness of the sensor element **407**, such that all or substantially all (e.g., greater than or equal to 95%) of the sensor element is within the groove.
(45) Sensor element **407** is configured to communicatively couple with a controller. In that regard and as further shown in FIG. **4**, sensor module **401** may further include a second portion **415**, which may be separate from or integral with sensor element **407**. When used, second portion **415** is configured to provide a communications pathway between sensor element **407** and a controller **419** as will be described later. In embodiments, the second portion **415** is in the form of or includes a conductive element (e.g., a conductive wire or stripe) that is configured to provide a physical interface between sensor element **407** and the controller **419**. In such instances the second portion **415** may be coupled to or integral with sensor element **407**. For example, second portion **415** may be in the form of a wire or other conductive element that is coupled to or integral with sensor element **407**.
(46) When second portion **415** is used, sensor element **407** may be understood to correspond to a first portion of a fluid sensor, and second portion **415** may be understood to correspond to a second portion of the fluid sensor. The fluid sensor is of course not limited to two portions, and may include greater (e.g., 3, 4, 5, etc.) or fewer (e.g., 1) portions. In instances where the sensor element includes a single portion (i.e., sensor element **407**), second portion **415** may be omitted and sensor module **401** may be configured such that sensor element **407** can communicate with a controller in any suitable manner. For example, sensor element **407** may be physically connected to a controller (either directly or via one or more intervening components), or it may communicate with the controller via wireless communications—e.g., near field communication, a wireless local area network (WLAN), a ZIGBEE® network, BLUETOOTH®, combinations thereof, and the like. In any case, the sensor element **407** is configured to detect a capacitance within liquid flow path **405**, produce a sensor signal indicative of the detected capacitance, and to provide the sensor signal to a controller to which it is communicatively coupled, as described later.
(47) Sensor module **401** may optionally include an air flow path **423**. In general, air flow path is configured to provide a passageway through sensor housing **403** for the flow of air or another gas. Such may be useful in instances where sensor module **401** is coupled to an outlet of a relief valve, where inflow of air into the relief valve can aid in flow of liquid from the relief valve. This concept will be described later in conjunction in with FIGS. **8**A-**8**C. When used, optional air flow path **423** may be at least partially defined by a perimeter **425**, which may be formed from material of sensor housing **403** and/or other material.
(48) As noted above, electronics module **413** may be integral with or coupled to sensor module **401**. In the former case electronics housing **417** is integral with sensor housing **403**, such that the electronics housing **417** and sensor housing are in one piece. In the latter case, the electronics

module **413** is configured to couple to sensor module **401** in any suitable manner Without limitation, electronics housing **417** is preferably configured to detachably couple to sensor module **401** and, more particularly, to detachably couple to sensor housing **403**. In such instances fluid detection system **301** may be understood to have an assembled state in which electronics module **413** is coupled to sensor module **401**, and a disassembled state in which electronics module **413** and sensor module **401** are separated. Accordingly, FIG. **4** may be understood to depict fluid detection system **301** in an assembled state. In any case, sensor element **407** is configured to communicatively couple to a controller **419** within electronics housing **417**, e.g., by second portion **415** or in another manner as previously described.

(49) Controller **419** is generally configured to determine a detected capacitance within liquid flow path **405** based at least in part on a sensor signal received from sensor element **407**, wherein the sensor signal is indicative of a capacitance detected by the sensor element **407** within liquid flow path **405**. Controller **419** can then use the detected capacitance to determine whether liquid is present within liquid flow path **405** in any suitable manner. For example, controller **419** may determine whether liquid is present within the liquid flow path **405** by comparing the detected capacitance to a capacitance threshold and to record (or not record) a wet event based on that comparison, e.g., in a memory thereof. For example, when the determined capacitance is less than or equal to the capacitance threshold, controller **419** may determine that liquid is present within liquid flow path **405** and record a wet event. Conversely when the determined capacitance is greater than the capacitance threshold, controller **419** may determine that liquid is not present within liquid flow path **405**. In such instances controller may record a dry event, or may discard the determination and continue to monitor the capacitance within liquid flow path **405**.

(50) The capacitance threshold used by controller **419** can be set in any suitable manner. In embodiments, the capacitance threshold is a default capacitance threshold that may be set by the manufacturer of fluid detection system **301**. Such a configuration may be useful when fluid detection system **301** is to be installed in a fluid supply system with a known configuration, i.e., one in which a baseline capacitance of the fluid supply system is known. In other embodiments, the capacitance threshold is set based on a baseline capacitance, which may be set by calibration of fluid detection system **301**, e.g., post installation. Still further, the capacitance threshold may be set by one or more physical components of the controller **419** or an electronics module in which the controller **419** is installed. For example, the capacitance threshold may be set by one or more jumpers (e.g., dip switches) on controller **419** or within electronics module **413**.

(51) In that regard electronics module **413** may optionally include a user interface **421**. In the embodiment of FIG. **4** optional user interface **421** is shown as part of controller **419**, but such a configuration is not required and user interface **421** may be provided at any suitable location. For example, user interface **421** may be provided on or within sensor housing **403**, on or within electronics housing **417**, and/or within controller **419** as shown. In any case, user interface **421** may provide a mechanism for a user to interact with sensor module **401** and/or electronics module **413**. For example, user interface **421** may include a calibration module that is configured to calibrate fluid detection system **301**. More particularly, the calibration module may be configured to establish a baseline capacitance within liquid flow path **405**. The baseline capacitance may be set based at least in part on a capacitance detected by sensor element **407**, e.g., under a known condition. For example, the baseline capacitance may be set based on a capacitance detected by sensor element **407** in response to user interaction with a calibration button or other interactive element of user interface **421**. Alternatively, or additionally, the baseline capacitance may be set based on capacitance readings that are taken by fluid detection system **301** automatically, e.g., a predetermined time or time interval. Still further, the baseline capacitance may be set using jumpers (e.g., dip switches) or another type of electrical control system.

(52) Once the baseline capacitance is determined, controller **419** may set the capacitance threshold based on the baseline capacitance, e.g., with a calibration module, one or more physical elements

(e.g., one or more jumpers such a dip switches), combinations thereof, and the like. For example, controller **419** may set the capacitance threshold to a value that is offset from the baseline capacitance by a predetermined margin. The predetermined margin may be any suitable value, and in some instances is equal to about 25%, about 50%, about 100%, about 150%, or even about 200% of the baseline capacitance value or more. In embodiments, controller **419** is configured to set the capacitance threshold above the baseline threshold by the predetermined margin. In embodiments, the sensor element may have a sensitivity range of 100 picofarads (pF), the range of capacitance in the typical system may range from 5 to 20 pF, and the controller may set the threshold capacitance to 10-15 pF, such as about 12 pF.

(53) The controller may be further configured to determine that a wet event has occurred when a detected capacitance is less than or equal to the threshold capacitance for a (first) time period, i.e., a first measurement period. The length of the first measurement period is not limited and the first measurement period may be set to any suitable length of time. In embodiments, the first measurement period ranges from greater than 0 to about 5 seconds, such as from greater than 0 to about 2.5 seconds. The first measurement period may of course be set to a longer of shorter period of time. In general, use of the first measurement period can limit or prevent controller **419** from determining that a wet event has occurred due to drips or other short leaks that cause liquid to be present within the liquid flow path **405** for a very short period of time. This may improve the accuracy of controller **419** and the user experience by preventing controller **419** from falsely reporting small leaks, drips, and other minor transient events as wet events that may need attention from a user.

(54) Controller **419** may be further configured to determine whether a flood event is occurring within liquid flow path **405**. In embodiments, controller **419** may determine whether a flood event is occurring by monitoring the detected capacitance within liquid flow path **405** during a (second) measurement period, determining a total number of wet events occurring within the (second) measurement period, and comparing the total number of wet events within the (second) measurement period to a threshold number of wet events set for the (second) measurement period. The second measurement period may be used independently or in conjunction with the first measurement period, and may be set to any suitable length of time. For example, the second measurement period and may range from greater than 0 seconds to several minutes or more. In embodiments the second measurement period ranges from greater than 0 to about 10 minutes (600 seconds), such as from greater than 0 to about 5 minutes (300 seconds), from greater than 0 to about 2 minutes (120 seconds), or even from greater than 0 to about 90 seconds. In those or other embodiments, controller **419** may be configured such that the second measurement period begins at the end of a first measurement period in which a wet event is detected.

(55) When the total number of wet events meets or exceeds the threshold number of wet events in the (second) measurement period, controller **419** may determine that a flood event is occurring within liquid flow path **405**, and may record the occurrence of that flood event accordingly (e.g., in a memory thereof). Upon detection of a flood event, controller **419** may be configured to cause the issuance of an alert. The alert may be in the form of an audio, visual, or audiovisual alert (e.g., a light and/or siren), a notification message to an external device, combinations thereof, and the like. For example, controller **419** issue a control signal that is configured to cause communications circuitry (not shown) within or communicatively coupled to fluid detection system **301** to issue a notification message to an external device via a wired or wireless communication protocol, wherein the notification message is indicative of the occurrence of a flood event. In addition, controller **419** may cause an alert light and/or an alert siren to activate to provide an audio visual notice of a detected flood event.

(56) In embodiments controller **419** may be configured to delay issuance of an alert/notification for a delay time following detection of a wet and/or flood event. During the delay time, controller **419** may continue to monitor the detected capacitance in the liquid flow path. If the controller

determines that the detected capacitance returns to above the capacitance threshold during the delay time (i.e., returns to a capacitance indicative of normal operation), controller **419** may not issue a notification/alert as described above. If the detected capacitance remains at or below the capacitance threshold during the delay time, however, controller **419** may issue a notification/alert as described above. As may be appreciated, use of the delay time may limit reporting of transient wet/flood events that may not require service. The delay time may be any suitable length. For example, in embodiments the delay time ranges from greater than 0 to about 300 seconds (5 minutes), greater that 0 to about 180 seconds (3 minutes), even greater than 0 to about 60 seconds (1 minute), or even greater than 0 to about 30 seconds. The delay time may be set in any suitable manner, such as via a user interface of controller **419**, a calibration module within controller **419**, one or more physical elements of electronics module **413** (e.g., one or more dip switches), combinations thereof, and the like.
(57) When the total number of wet events is below the threshold number of wet events for the (second) measurement period, controller **419** may determine that a flood event is not occurring within liquid flow path **405**. In such instances controller **419** may continue to monitor the capacitance within the liquid flow path **405** for occurrence of wet and/or flood events. Controller **419** may also issue a control signal that is configured to cause communications circuitry to issue a notification message to an external device as noted above, wherein the notification message is indicative of the occurrence of the wet event(s) occurring within the measurement period, either alone or along with an indication that a flood event has not been detected.
(58) Any suitable type of controller may be used as controller **419**. With that in mind, FIG. **7** is a block diagram of one example of a controller that may be used as controller **419** in accordance with the present disclosure. Controller **419** includes a processor **701**, memory **703**, and communications circuitry (COMMS) **705**, which are communicatively coupled to one another via a bus **707**. Controller **419** may optionally further include a user interface **421**, as discussed above.
(59) Processor **701** may be any suitable general-purpose processor or application specific integrated circuit. Without limitation, in embodiments processor **701** is one or more single or multicore processors produced by INTEL® corporation, APPLE® corporation, AMD® corporation, SAMSUNG® corporation, NVIDIA® corporation, Advanced Risc Machines (ARM®) corporation, combinations thereof, or the like. While FIG. **7** depicts the use of a single processor **701**, it should be understood that multiple processors can be used.
(60) Memory **703** may be any suitable type of computer readable memory. Examples of memory types that may be used as memory **703** include but are not limited to: programmable memory, non-volatile memory, read only memory, electrically programmable memory, random access memory, flash memory (which may include, for example NAND or NOR type memory structures), magnetic disk memory, optical disk memory, phase change memory, memristor memory technology, spin torque transfer memory, combinations thereof, and the like.
(61) Additionally, or alternatively, memory **703** may include other and/or later-developed types of computer-readable memory.
(62) COMMS **705** may include hardware (i.e., circuitry), software, or a combination of hardware and software that is configured to allow system controller **419** (or fluid detection system **301**) to transmit and receive messages via wired and/or wireless communication from an external device **711**. Communication between COMMS **705** and an external device **711** may occur, for example, over a wired or wireless connection using one or more currently known or future developed communication standards. COMMS **705** may include hardware to support such communication, e.g., one or more transponders, antennas, BLUETOOTH™ chips, personal area network chips, near field communication chips, wired and/or wireless network interface circuitry, combinations thereof, and the like. As shown, COMMS **705** may be communicatively coupled to sensor element **407**, e.g., via wired or wireless communication. In embodiments COMMS **705** is communicatively coupled with sensor element **407** when fluid detection system **301** is in an assembled state, and is

configured to receive sensor signals from sensor element **407**.

(63) Controller **419** further includes a control module **709**. In this specific context, the term “module” refers to software, firmware, circuitry, and/or combinations thereof that is/are configured to perform one or more operations consistent with the present disclosure. Software may be embodied as a software package, code, instructions, instruction sets and/or data recorded on non-transitory computer readable storage mediums. Firmware may be embodied as code, instructions or instruction sets and/or data that are hard-coded (e.g., nonvolatile) in controller **419**, e.g., within memory **703** or other storage. In embodiments, control module **709** is in the form of logic that is implemented at least in part in hardware to perform operations consistent with the present disclosure.

(64) For example, control module **709** may be configured to cause controller **419** to establish a capacitance threshold based on a baseline capacitance as discussed previously. Control module **709** may also be configured to cause controller **419** to determine a detected capacitance within liquid flow path **405**, e.g., based on a sensor signal provided by sensor element **407**. Control module **709** may further be configured to cause controller **419** to determine whether liquid is present within the liquid flow path **405** based at least in part on a comparison between the detected capacitance and the capacitance threshold as previously described. Moreover, control module **709** may be configured to cause controller **419** to determine whether a flood event is occurring with liquid flow path **405** as discussed above. When a wet event and/or a flood event is detected, control module **709** may cause controller **419** (or more specifically, COMMS **705**) to issue a notification message to an external device **711**, e.g., via wired or wireless communication. Finally, control module **709** may be configured to cause controller **419** to perform calibration operations consistent with the present disclosure, e.g., at a predetermined time, at a predetermined interval, and/or in response to user interaction with a calibration button, e.g., on user interface **421**, and/or in response to a position of a calibration jumper within controller **419**. Pursuant to such calibration operations, control module **709** may cause controller to set a baseline capacitance and to set the capacitance threshold based on the baseline capacitance as discussed above.

(65) FIGS. **5**A-**5**P depict various views of another example of a fluid detection system consistent with the present disclosure. As shown, fluid detection system **500** includes a sensor module **401** and an electronics module **413**. The nature and function of sensor module **401** and electronics module **413** is the same as described above in connection with FIG. **4**, and so will not be reiterated in detail.

(66) As best shown in FIGS. **5**A and **5**J and **6**A and **6**B, electronics module **413** is separable from sensor module **401**. That is electronics module **413** may be physically connected and separated from sensor module **401**, such that fluid detection system **500** is in an assembled or disassembled state, respectively. In the assembled state, controller terminals **525** (best shown in FIG. **6**B) on electronics module **413** are coupled to corresponding receiving terminals **523** (shown in FIG. **5**I) on a printed circuit board (PCB) **521** of sensor module **401**, and at least one sensor terminal **519** of a sensor element **515** (best shown in FIGS. **5**H, **5**I, **5**K and **5**P) is also coupled to sensor PCB **521**. In that state, sensor PCB **521** communicatively couples the sensor element **515** to the controller **419**.

(67) With further reference to FIGS. **5**A-**5**P—sensor module **401** includes a sensor cover **501** and a sensor base **503**, which together form a sensor housing consistent with sensor housing **403** as described above in connection with FIG. **4**. As best shown in FIG. **5**J, sensor cover **501** and sensor base **503** are detachable from one another and form corresponding upper and lower portions of a sensor housing **403**. The manner in which sensor cover **501** and sensor base **503** can be coupled to one another is not limited. In embodiments and as shown in FIG. **5**J, sensor cover **501** may include one or more tabs (shown but not labeled) that are configured to be inserted into and engage with corresponding slots within sensor base **503**. Sensor module **401** further includes a sensor element **515**, which is functionally similar to sensor element **407** described previously.

(68) As best shown in FIGS. **5**A-**5**K, sensor module **401** includes a liquid flow path **405** that

extends through the sensor housing formed by sensor cover **501** and sensor base **503**. Like the liquid flow path in system **300**, the liquid flow path **405** in fluid detection system **500** is defined at least in part by a perimeter **411**. In the embodiment illustrated in FIGS. 5A-5P, perimeter **411** is D-shaped and defines at least a portion of the inlet **536** of liquid flow path **405**. The shape of perimeter **411** and the inlet **536** of liquid flow path **405** is not limited to that configuration, and such components may have any suitable shape as discussed above. In this embodiment, liquid flow path **405** extends from inlet **436** on a first side of sensor module **401** to outlet **537** on a second side of sensor module **401**, wherein the first and second sides are opposite to one another. Consequently, a passageway within liquid flow path **405** extends straight or substantially straight between the inlet **536** and the outlet **537**. Of course, inlet **536** and outlet **537** of liquid flow path **405** may be sized and positioned differently, with a corresponding difference in the shape of the passageway there between.

(69) In system **500**, sensor module **401** further includes air flow path **423**. Air flow path **423** includes an inlet **538** and an outlet **539**, and is at least partially defined by a perimeter **425**. In embodiments fluid detection system **500** is configured such that liquid can move through liquid flow path **405** in a first flow direction and air can move through air flow path in **423** in a second flow direction that is opposite the first flow direction. Thus, inlet **538** may be on the same side of sensor module **401** as outlet **537**, and outlet **539** may be on the same side of sensor module **401** as inlet **536**. In this case the perimeter **425** defines at least a portion of a D-shape outlet **539** of air flow path **423**. Of course, outlet **539** and air flow path **423** are not limited to such a configuration and may have any suitable shape, such as but not limited to the cross sectional shapes noted herein for liquid flow path **405**.

(70) As best shown in FIG. 5K, 5L, 5M, one or both of liquid flow path **405** and air flow path **423** may be completely defined by sensor cover **501**. For example, sensor cover **501** may include first and second extensions that extend inwardly from a top surface **502** of sensor cover **501** towards sensor base **503**, and which respectively define at least a portion of liquid flow path **405** and air flow path **423**. The first extension may include an inner wall **530** that defines at least a portion of an inward facing side of the liquid flow path **405**, and a corresponding outer wall **531**. Similarly, the second extension may include an inner wall **532** that defines at least a portion of an inward facing side of the air flow path **423**, and a corresponding outer wall **534**.

(71) As best shown in FIGS. 5A and 5L, sensor cover **501** may include a groove **513**. In the embodiment of FIGS. 5A-5P, groove **513** extends fully around liquid flow path **405**, with one side of groove **513** defined by the outer wall **531** of the first extension that defines liquid flow path **405**. That configuration is not required, however, and groove **513** may be configured differently. For example, groove **513** may be configured to extend partially around the inlet opening of liquid flow path **405**. Regardless of its configuration, groove **513** may be configured to facilitate in-line coupling of the inlet side of sensor module **401** to another component, such as an outlet of a discharge pipe, a backflow preventer, a relief valve or the like. Groove **513** may be configured to house or otherwise support a sealing element (e.g., an O-ring or other type of gasket) therein, wherein the sealing element is configured to form a seal between the inlet side of sensor module **401** and a corresponding surface of a component to which the inlet side is coupled, such as the outlet of a discharge pipe, a backflow preventer, etc.

(72) Sensor cover **501** may include one or a plurality of cover spacers **529**, as best shown in FIGS. 5K and 5M. When used, the cover spacers **529** may be in the form of a projection that extends from an underside **504** of sensor cover **501**. The cover spacers **529** may extend from and be spaced apart from outer walls **531**, **534** by a gap. The gaps between each of the cover spacers may collectively form a first sensor channel **533**. The first sensor channel **533** may be sized to receive at least a portion of sensor element **515** and optionally at least a portion of a spacer element **517**. In embodiments, cover spacers **529** are each sized and configured such that they are adjacent to or abut a corresponding portion of an inward facing side **542** (shown in FIG. 5N) of sensor base **503**

when sensor module **401** is in an assembled state.
(73) Sensor cover **501** may further include a second sensor channel **535** between liquid flow path **405** and air flow path **423**. As best shown in FIG. 5M, the second sensor channel **535** may extend across the sensor cover **501** to at least partially separate liquid flow path **405** from air flow path **423**. In embodiments the second sensor channel **535** is sized and configured to receive at least a portion of sensor element **515** and optionally at least a portion of spacer element **517** therein. As may be appreciated, the first sensor channel **533** and second sensor channel **535** can receive and support sensor element **515** and optionally spacer element **517** when sensor module is in an assembled state.
(74) As best shown in FIGS. 5H, 5I, 5N and 5O, sensor base **503** includes one or more fastener openings **505**. In general, fastener openings **505** may function to facilitate coupling of sensor base **503** to sensor cover **501** and/or another structure, e.g., with one or more fasteners. The number of fastener openings **505** is not limited, and such openings may be omitted.
(75) As further shown in FIGS. 5H, 5I, 5N, and 5O, sensor base **503** includes a cross support **527**. In general, cross support **527** functions to support a portion of a sensor element **515** within sensor module **401**. In that regard, cross support **527** and cover spacers **529** similarly function to support and maintain the position of the sensor element **515** within sensor module **401**. In embodiments, cross support **527** and second sensor channel **535** are sized and positioned such that they extend parallel or substantially parallel to one another when sensor module **401** is in an assembled state.
(76) In an assembled state sensor cover **501** and sensor base **503** form a receptacle for receiving or otherwise coupling to electronics module **413**. For example, and as best shown in FIGS. 5M and 5N, sensor cover **501** includes a first cavity **522** and sensor base **503** includes a second cavity **524**. The first and second cavities **522**, **524** form respective first and second portions of a receptacle for receiving or otherwise coupling to electronics module **413** when sensor cover **501** is coupled to sensor base **503**. In embodiments the first cavity **522** and second cavity **524** form respective halves of a receptacle for electronics module **413**. Of course, sensor module **401** need not be configured in that manner, and the receptacle for the electronics module **413** may be configured differently. For example, the receptacle for the electronics module **413** may be positioned entirely on sensor cover **501** or entirely on sensor base **503**.
(77) Sensor element **515** is generally configured to detect the capacitance within liquid flow path **405**. In that regard, sensor element **515** may be configured to function in the same manner and be formed from the same materials noted above in connection with sensor element **407**. That is, sensor element **515** is configured to detect capacitance within liquid flow path **405** and to output a sensor signal indicative of a detected capacitance, e.g., to controller **419**.
(78) In embodiments, sensor element **515** is in the form of one or more conductive strips and/or wires, which may be formed from copper or any other suitably conductive materials. Without limitation, in embodiments sensor element **515** is in the form of or includes or plurality of conductive strips or wires, such as copper wires or strips, which may be in the form of one or more open circuit conductors (antennas). The number of wires or strips may vary and is not limited. In embodiments, the number of wires or strips is greater than or equal to 1, such as ≥2, ≥3, ≥4, ≥5, ≥10, ≥20, or more. In specific non limiting embodiments, sensor element **515** is in the form of a flat flexible cable (FFC) that includes a plurality of parallel conductors, each conductor of which is laterally offset from one or more adjacent conductors by offset distance that ranges from greater than 0 to about 2.5 millimeters (m), such as from greater than 0 to about 1.5 mm, from greater than 0 to about 1.0 mm, or even from greater than 0 to about 0.5 mm. In a preferred non-limiting embodiment, sensor element **515** is an FFC with **20** parallel conductors, wherein each conductor is offset from one or more adjacent conductors by an offset distance of about 0.5 mm.
(79) In embodiments system **500** and sensor element **515** are physically configured to facilitate detection of the capacitance of liquid flow path **405** and, more particularly, a change in the capacitance of liquid flow path **405** due to the presence of liquid. In that regard, the perimeter **411**

may be defined by a wall that is configured to space sensor element **515** from an inward facing side of liquid flow path **405** by a distance R, which may also be referred to herein as a radial distance. This concept is best shown in FIG. **5**H, which illustrates an embodiment in which the distance R is equivalent to the thickness of the wall defining perimeter **411**. It should be understood that such illustration is for the sake of example only, and that distance R need not be equivalent to the thickness of the wall defining perimeter **411**. In any case, the distance R may be any suitable thickness, and embodiments R ranges from greater than 0 to about 25.4 mm (1 inch), such as from greater than 0 to about 12.7 mm (½ inch).

(80) In embodiments the sensor element **515** (or each conductive element therein) may also be configured to facilitate detection of the capacitance within liquid flow path **405**. For example, and as best shown in FIG. **5**J, sensor element **515** may be in the form of or include one or more conductive strips, wherein each of the conductive strips has an axial width W. In this context, the term axial width means a width in the direction of the conductive element that is parallel an axis extending through liquid flow path **405**. W may be any suitable axial width, and in embodiments W ranges from greater than 0 to 127 mm (5 inch), such as from greater than 0 to 63.5 mm (2.5 inches), or even from greater than 0 to about 25.4 mm (1 inch).

(81) The ratio of the axial width W to the distance R can impact the ability of sensor element **515** to detect the capacitance of liquid flow path **405**. In embodiments, the ratio of W:R ranges from greater than or equal to about 2:1 to about 10:1, such as from greater than or equal to about 2:1 to about 5:1. In non-limiting preferred embodiments, the ratio of W:R is about 5:1. While smaller ratios and higher ratios are possible, it is noted that performance of sensor element **515** may decrease at a W:R ratio of less than 2:1 and that increasing the ratio beyond 5:1 was not observed to produce significant performance gains relative to a ratio of 5:1. In specific non-limiting embodiments, the ratio of W:R is about 5:1, R is about 12.7 mm (½ inch), and W is about 63.5 mm (2.5 inches).

(82) When a plurality of open circuit conductors (antennas) are used, they may be arranged such that they each extend parallel to one another and are disposed around at least a portion of the liquid flow path **405**. Notably, use of a plurality of parallel open circuit conductors can improve the sensitivity of sensor element **515**, e.g., allowing sensor element **515** to sense relatively low capacitance values within liquid flow path **405**. Pragmatically speaking, this means that sensor element **515** may be able to sense deviations from a relatively low baseline capacitance (e.g., detected within liquid flow path **405** during calibration), without requiring the use of specialize tooling or equipment to produce.

(83) As best shown in FIGS. **5**I and **5**K, sensor element **515** extends around substantially all (≥95%) of perimeter **411** of liquid flow path **405**. With reference to FIG. **5**P, at least a portion of sensor element **515** may have a shape that substantially corresponds to a shape of the liquid flow path **405** or, more specifically, the shape of the side of outer wall **531**. For example, when liquid flow path **405** or outer wall **531** have a D-shape, at least a portion of sensor element **515** has a D-shape as best shown in FIGS. **5**I, **5**K, and **5**P. When liquid flow path **405** or outer wall **531** have another shape (e.g., a C shape, quadrilateral shape, a single sided (e.g., circular) shape etc.), at least a portion of sensor element **515** may have a corresponding shape. In any case, sensor element **515** is configured such that it can be disposed around the outside of the perimeter **411** of liquid flow path **405**, e.g., within the first sensor channel **533** and the second sensor channel **535** noted above. In that regard, cross support **527** of sensor base **503** functions to support the section of sensor element **515** that extends within the second sensor channel **535**. Notably, no portion of sensor element **515** is present within liquid flow path **405**.

(84) As best shown in FIG. **5**K, sensor module further includes a spacer element **517**. In general, spacer element **517** functions to maintain the position of sensor element **515** within first and second sensor channels **533**, **535**, and in some cases to insulate sensor element from other components of sensor module **401**—such as outer walls **531**, **534**, and/or cover spacer(s) **529**. To that end, spacer

element **517** may be formed from any suitable material. In embodiments, spacer element **517** is formed from or includes an insulating material, such as but not limited to an insulating foam. Non-limiting examples of insulating foams that can be used include open or closed cell foams, such as open or closed cell neoprene foam, ethylene propylene diene monomer (EPDM) foam, styrene butadiene rubber (SBR) foam, combinations thereof and the like. Without limitation, spacer element **517** is preferably a closed cell insulating foam.

(85) As best shown in FIG. 5P, sensor element **515** has a proximal end **543** and a distal end **544**. The proximal end **543** is coupled to a sensor terminal **519**. In general, sensor terminal **519** functions to communicatively couple sensor element **515** to a corresponding input terminal on sensor PCB **521**. As noted previously, sensor PCB **521** generally functions to communicatively couple sensor element **515** to controller **419**. In that regard, sensor PCB **521** includes receiving terminals **523** that are configured to couple to corresponding controller terminals **525** when fluid detection system **500** is in an assembled state, i.e., when electronics module is disposed within a receptacle formed by sensor cover **501** and sensor base **503** and controller terminals **525** are coupled to receiving terminals **523** on sensor PCB **521**.

(86) FIGS. **6**A and **6**B depict front and back views, respectively, of one example of an electronics module **413** consistent with the present disclosure. As shown electronics module **413** includes an electronics base **507** and electronics cover **509**. Electronics base **507** and electronics cover **509** are configured to detachably couple to one another in any suitable manner, such as by a mechanical fastener, a form locking connection, a snap fit connection or the like. When so coupled, the electronics base **507** and electronics cover **509** define an electronics housing that includes a cavity for housing a controller **419** and an optional user interface **421**, as shown in FIG. **6**A. The nature and function of controller **419** and user interface **421** are the same as described above in connection with FIG. **4**, and so are not reiterated. As best shown in FIG. **6**B, electronics module **413** includes controller terminals **525** that are configured to communicatively couple controller **419** to sensor PCB **521**, as described above. While FIG. **6**B depicts controller terminals **525** in the form of two prongs, any type and shape of terminals may be used.

(87) Electronics module **413** further includes a cable **511**, as best shown in FIGS. **6**A and **6**B. Cable **511** is generally configured to provide power to the components of electronics module **413**, and to provide a wired connection to a communications system (not shown) that may be used to send notification messages in response to a detected wet and/or flood event. In embodiments, cable **511** may also provide a connection to earth ground for sensor element **515**. However, sensor element **515** may be ground in another manner as discussed above in connection with sensor element **407**.

(88) As noted above, when sensor module **401** includes a receptacle for receiving and coupling to electronics module **413**. With that in mind, electronics module **413** may be sized and configured such that it can detachably couple the receptacle provided by sensor module **401**, such that sensor module **401** is communicatively coupled to electronics module **413** (e.g., such that controller terminals **525** couple to receiving terminals **523** of sensor PCB **521**).

(89) In use, sensor module **401** may be coupled in-line with the outlet of another component, such as the outlet or inlet of a discharge pipe (or other fluid conduit), an outlet or inlet of a backflow preventer, an outlet or inlet of a check or relief valve, or the like. In any case, sensor element **515** may sense the capacitance within liquid flow path **405** and produce a sensor signal indicative of the detected capacitance. When the electronics module **413** is communicatively coupled to the sensor module **401** (e.g., as shown in FIG. 5A), the sensor signal may be provided to controller **419** via sensor terminal **519**, sensor PCB **521**, receiving terminals **523**, and controller terminals **525**. In any case, the controller **419** may determine a detected capacitance within liquid flow path **405** based at least in part on the sensor signal. Controller **419** may then determine whether a wet condition, a dry condition, and/or a flood condition is occurring based on the detected capacitance and a capacitance threshold, as previously described in association with FIG. **4**. The baseline capacitance may be determined based on a capacitance of liquid flow path **405** measured during a calibration

operation, e.g., in response to actuation of a calibration button or another interface element of user interface **421**. If one or more of such conditions are detected, the controller **419** may cause a notification message to be sent to an external device, e.g., via communications circuitry that is communicatively coupled to controller **419**. Such communications circuitry may be within sensor module **401**, electronics module **413**, and/or within a separate component that is communicatively coupled to controller **419** in any suitable manner.

(90) While the present disclosure focuses on the use of the disclosed fluid detection systems in conjunction with the detection of fluid flow from an outlet of a relief valve or a backflow preventer, the fluid detection systems are not limited to such end uses. Indeed, the fluid detection systems described herein can be used to detect fluid that is passing through an outlet of any suitable fluid conduit, such as may be used in a fluid (e.g., water) supply system, a hot water heater, a recreational vehicle water system, or the like. For example, the fluid detection systems described herein may be used to couple to and detect fluid flow from one or more valves, pipes, conduits, low pressure regions, combinations thereof, and the like.

(91) With the foregoing in mind and for the sake of illustration of one example end use, FIGS. **8**A-**8**C depict one example of a relief valve leak detection system that includes a fluid detection system **500** consistent with the present disclosure. As shown, relief valve leak detection system **800** includes relief valve **801**, fluid detection system **500**, and an air gap **803**. As best shown in FIG. **8**C (which is a cross sectional diagram along plane B shown in FIG. **8**B), relief valve includes a liquid flow path **805** with a liquid flow outlet **809**, and an air flow path **807** with an air flow inlet **810**. The liquid flow path **805** is configured to convey a liquid flow **806** to liquid flow outlet **809**, and the air flow path **807** is configured to receive an air flow **808** via air flow inlet **810**. As further shown in FIG. **8**C, fluid detection system **500** is coupled to relief valve **801** such that liquid flow path **405** is fluidly coupled to liquid flow outlet **809**, and air flow path **423** is fluidly coupled to air flow inlet **810**. The outlet side of fluid detection system **500** is coupled to a proximal end of air gap **803**, and a discharge pipe (not shown) may be coupled to a distal end of air gap **803**.

(92) In operation, relief valve **801** may regulate the pressure within a component of a liquid supply system, such as a water supply system. Under normal operating conditions liquid may flow through relief valve **801** to a downstream component at a pressure that is less than a threshold pressure of relief valve **801**. Under such conditions, liquid will typically not flow through liquid flow path **805** and liquid flow outlet **809**. If the pressure within relief valve exceeds threshold pressure or if relief valve malfunctions, however, liquid may flow through liquid flow outlet **809** and through liquid flow path **405**, which flow may be facilitated by the flow of air into air flow inlet **810** and into air flow path **807**.

(93) Consistent with the foregoing disclosure, fluid detection system **500** may monitor the capacitance of liquid flow path **405** to determine whether liquid is present within the liquid flow path, which may be indicative of an overpressure or other faulty condition of relief valve **801**. To accomplish that function, when fluid detection system **500** is installed as shown in FIG. **8**A, a calibration operation may be executed to establish a baseline capacitance within liquid flow path **405**. Alternatively, the baseline capacitance may be pre-set. In any case, the sensor element within fluid detection system **500** may monitor the capacitance of liquid flow path **405** and provide a sensor signal indicative of that capacitance to a controller, e.g., with electronics module **413**. The controller may then determine the detected capacitance in the liquid flow path **405**, and determine whether a wet, dry, and/or flood event is occurring in liquid flow path **405** based at least in part on the detected capacitance as previously described. When a wet event is detected (e.g., when the detected capacitance is at or above a capacitance threshold, either independently or for greater than or equal to a (first) measurement period), the controller may record the wet event, and may optionally determine whether a flood event is occurring. The controller may make that determination, for example, based at least in part on a comparison of a total number of wet events occurring within a (second) measurement period and a threshold number of wet events for that

(second) measurement period. For example, if the total number of wet events in the (second) measurement period meets or exceeds the threshold number of wet events for that (second) measurement period, the controller may determine that a flood event is occurring. Conversely, if the total number of wet events is less than the threshold number of wet events for the (second) measurement period, the controller may determine that a flood event is not occurring.

(94) Reference is now made to FIG. **9**, which is a flow diagram of one example of a method for detecting a fluid (e.g., with a fluid detection system) consistent with the present disclosure. As shown, method **900** begins with start block **901**. The method may then proceed to optional block **903**, pursuant to which a determination may be made as to whether a calibration of a fluid detection system consistent with the present disclosure needs to be updated. When such operations are performed the outcome of block **903** may depend on various such the length of time since the calibration of the fluid detection system was last set, whether a calibration button has been pressed on a user interface of the system, etc.

(95) If the calibration is to be updated the method may proceed from block **903** to block **905**, pursuant to which calibration operations consistent with the present disclosure are performed. In embodiments such calibration operations include measuring a capacitance within a liquid flow path with a sensor element, conveying a sensor signal indicative of that capacitance to a controller, determining the detected capacitance with the controller, and setting a baseline capacitance value to the detected capacitance. The calibration operations may also include setting a threshold capacitance value relative to the baseline capacitance value. For example, the threshold capacitance value may be set to a capacitance value that is offset above the baseline capacitance value by a predetermined margin, such as about 1, 5, 10, 15, 20, 25, 30, 35, 40, or even 50% of the baseline capacitance value.

(96) Once calibration operations are performed or if the operations of block **903** are omitted the method may proceed to block **907**, pursuant to which a capacitance of a liquid flow path is measured. Consistent with the foregoing discussion, the capacitance of a liquid flow path may be measured at least in part with a sensor element that is disposed at least partially around the liquid flow path. More specifically, the sensor element may sense the capacitance within the liquid flow path and output a sensor signal indicative of the capacitance to a controller. The controller may then determine the detected capacitance within the liquid flow path based at least in part on the sensor signal.

(97) The method may then proceed to block **909**, pursuant to which a determination may be made (e.g., by a controller) as to whether a wet event has occurred based at least in part on the detected capacitance in the liquid flow path as noted above. If not, the method may loop back to block **907**. But if so, the method may proceed to block **911**, pursuant to which the controller records a wet event (or "hit), e.g., in a memory thereof. The method may then proceed to optional block **913**, pursuant to which a hit/wet event notification may be sent, e.g., to an external device. For example, and consistent with the above description, in response to detection of a hit/wet event, the controller may cause communications circuitry to issue a notification message indicative of that event to an external device, via wired or wireless communication.

(98) Following block **913** or if the operations of block **913** are omitted, the method may proceed to block **915**, pursuant to which a determination may be made (e.g., by a controller) as to whether a (second) measurement period has expired. The (second) measurement period may be set to any desired amount of time and may fall within the second measurement period ranges described above. If the measurement period has not expired the method may loop back to block **907**. If the measurement period has expired, however, the method may proceed to block **917**.

(99) Pursuant to block **917** a determination may be made (e.g., by a controller) as to whether a flood event is occurring within the liquid flow path. To that end a controller may perform flood event detection operations consistent with the present disclosure, wherein such operations include determining a total number of wet events detected in a (second) measurement period, comparing

the total number of wet events to a threshold number of wet events for the (second) measurement period, and determining whether a flood event has occurred based on that comparison. When the total number of wet events in the (second) measurement period is less than the threshold number of wet events for that (second) measurement period, a determination is made that a flood event has not occurred and the method may loop back to block **907**. When the total number of wet events for the (second) measurement period meets or exceeds the threshold number of wet events for that (second) measurement period, however, determination is made that a flood event has occurred and the method proceeds to block **919**, pursuant to which a flood event may be recorded by the controller, e.g., in a memory thereof. The method may then proceed to optional block **921**, pursuant to which a flood notification message may be issued in the same manner as the hit/wet notification message described above in connection with block **913**.
(100) Once a flood notification message has been sent or if the operations of block **921** are omitted the method may proceed to block **923**, pursuant to which a determination may be made (e.g., by a controller) whether the leak detection method is to continue. If so, the method loops back to block **907**. But if not, the method proceeds to block **925** and ends.
(101) FIGS. **10**A-**10**M illustrate another example of a fluid detection system consistent with the present disclosure. As shown, fluid detection system **1000** includes a sensor module **401** and an electronics module **413**. The function of sensor module **401** and electronics module **413** are largely the same as described above in connection with FIG. **4**, and so will not be reiterated in detail. This embodiment is also functionally similar to system **500** described above but lacks an air flow path **423**. As may be appreciated, fluid detection system **1000** may be particularly useful to detect leaks from smaller water systems, such as residential water systems, recreational vehicle water systems, hot water heaters, and the like.
(102) As best shown in FIGS. **10**A, **10**C, and **10**M, electronics module **413** is separable from sensor module **401**. That is, electronics module **413** may be physically connected and disconnected from sensor module **401**, such that fluid detection system **1000** is in an assembled or disassembled state. In the assembled state a controller (e.g., a controller **419** as described above in connection with FIG. **4**) is present within electronics module **413** and is communicatively coupled to a sensor element **1015** in sensor module **401**. The controller within electronics module **413** may be communicatively coupled to sensor element **1015** in any suitable manner. For example, and as will be described later, when system **1000** is in an assembled state, sensor element **1015** is communicatively coupled to a controller in electronics module **413** by one or more contacts, such as one or more spring-loaded pins.
(103) As best shown in FIG. **10**C, sensor module **401** includes a sensor cover **1002**, a sensor base **1003**, a conduit part **1004**, and a sensor element **1015**. The sensor cover **1002** and sensor base **1003** are separable from one another. When sensor cover **1002** and sensor base **1003** are coupled to one another they form a sensor housing, as best shown in FIG. **10**B. The way sensor cover **1002** and sensor base **1003** can be coupled to one another is not limited. In embodiments, sensor cover **1002** and sensor base **1003** are coupled by one or more fasteners (e.g., screws), a weld, an interference fit between corresponding parts of sensor cover **1002** and sensor base **1003**, combinations thereof, and the like. To that end, sensor cover **1002** and sensor base **1003** may include one or more fastener openings **1005** that are configured facilitate coupling of sensor cover **1002** to sensor base **1003** and/or another structure, e.g., with one or more fasteners. The number of fastener openings **1005** is not limited, and any or all such openings may be omitted.
(104) As shown in FIGS. **10**B-**10**D, sensor cover **1002** includes a cover body that includes a first cover cavity **1055** and a second cover cavity **1056**. The first cover cavity **1055** is generally configured to receive or otherwise couple to electronics module **413**. The way sensor cover **1002** (and, more particularly, first cover cavity **1055**) couples to electronics module **413** is not limited, and such components may be coupled in any suitable manner. For example, sensor cover **1002** may couple to electronics module **413** via one more fasteners, an adhesive, a weld, an interference fit, or

the like. In embodiments, sensor cover **1002** is configured to couple to electronics module **413** using one or more fasteners that extend through one or more fastener openings **1005**, e.g., within first cover cavity **1055**. At least some of the fastener openings **1005** of the sensor cover **1002** may be positioned to align with corresponding fastener openings **1005** of electronics module **413**, such that a fastener may be placed therein to couple sensor cover **1002** with electronics module **413**. Regardless of how sensor cover **1002** is coupled to electronics module **413**, it may include an opening **1062** that facilitates coupling of a controller in electronics module **413** with sensor element **1015**, as described in more detail later.
(105) Second cover cavity **1056** is generally configured to form part of a passageway within sensor module **401** through which conduit part **1004** extends when sensor module **401** is in an assembled state. In that regard, second cover cavity **1056** includes opposing first and second cover sidewalls **1058**, **1059**, which respectively include a first cover receptacle **1060** and a second cover receptacle **1061**. As will be described layer, first and second cover receptacles **1060**, **1061** are configured to form part of a passageway through which conduit part **1004** can extend when sensor cover **1002** is coupled to sensor base **1003**.
(106) In embodiments and as shown in FIGS. **10**D and **10**E, second cover cavity **1056** may be positioned substantially opposite at least a portion of first cover cavity **1055**, with a cover divider wall **1057** therebetween. In embodiments, cover divider wall **1057** preferably defines at least a portion of both first cover cavity **1055** and second cover cavity **1056**. For example, and as shown in FIGS. **10**D and **10**E, cover divider wall **1057** may form at least part of a bottom wall of first cover cavity **1055** and may also form at least part of a top wall of second cover cavity **1056**. In any case, an opening **1062** may be formed through cover divider wall **1057** to facilitate coupling of a controller in electronics module **413** with sensor element **1015**.
(107) As best shown in FIGS. **10**F and **10**G, sensor base **1003** includes a base body that defines a base cavity **1063**. Like second cover cavity **1056**, base cavity **1063** is generally configured to form part of a passageway within sensor module **401** through which conduit part **1004** extends when sensor module **401** is in an assembled state. Base cavity **1063** is defined at least in part by one or more sidewalls of the base body. For example, and as best shown in FIG. the base body includes opposing first and second base sidewalls **1064**, **1065**, which respectively include first and second base receptacles **1066**, **1067**—which are configured to form part of a passageway through which conduit part **1004** can extend when sensor base **1003** and is coupled to sensor cover **1002**.
(108) As noted above, sensor base **1003** is configured to couple to sensor cover **1002** to form a passageway for conduit part **1004**. The way sensor base **1003** couples to sensor cover **1002** is not limited, and such components may be coupled in any suitable manner. For example, sensor base **1003** may couple to sensor cover **1002** via one more fasteners, an adhesive, a weld, an interference fit, or the like. In embodiments, sensor base **1003** is configured to couple to sensor cover **1002** using one or more fasteners that extend through one or more fastener openings **1005** on sensor base **1003** and sensor cover **1002**, as best shown in FIGS. **10**A and **10**C. In such instances, at least some fastener openings **1005** of sensor base **1003** may be positioned to align with corresponding fastener openings **1005** of sensor cover **1002**, such that a fastener may be placed therein to couple sensor base **1003** to sensor cover **1002**.
(109) Conduit part **1004** is configured to provide a liquid flow path through which a liquid may flow when system **1000** is in use. Conduit part **1004** is also configured to support and/or position sensor element **1015** relative to the liquid flow path, such that sensor element **1015** can detect a capacitance within the liquid flow path. With that in mind and as best shown in FIGS. **10**A and **10**H-**10**K, conduit part **1004** has a conduit part body that includes a liquid flow path **405** defined at least in part by an inner wall **1030** of the conduit part body, and which extends from an inlet **1036** to an outlet **1037**. In the embodiment illustrated in FIGS. **10**A-**10**M, inlet **1036** and outlet **1037** form have a circular-shaped perimeter **1012**, but such openings may have any suitable shape. In the illustrated embodiment inlet **1036** and outlet **1037** are also substantially opposite to one another,

such that the course liquid flow path **405** between the inlet and outlet **1036**, **1037** is substantially straight. Inlet **1036** and outlet **1037** of liquid flow path **1035** can be sized and positioned differently, resulting in a corresponding difference in the shape and course of the passageway therebetween.

(110) As best shown in FIG. **10**J, conduit part **1004** includes a groove **1014** (which may also be referred to as a sensor channel) that extends at least partially (and preferably fully) around the outer wall **1031**. The groove **1014** includes at least one groove sidewall and a bottom defined at least in part by outer wall **1031**. The depth of groove **1014** (i.e., the height of one or more of the groove sidewalls) is not limited, and in some embodiments is greater than or equal to the thickness of sensor element **1015**. In embodiments and as also shown in FIG. **10**J, at least one of the sidewalls of the groove **1014** is or is adjacent to a ridge **1032** that extends radially outward from the surface of outer wall **1031**. Regardless of its configuration, groove **1014** is configured to position sensor element **1015** at a desired location. In embodiments, ridge **1032** is configured to align sensor element **1015** within the sensor housing, e.g., to facilitate coupling of sensor element **1015** with a controller **419** in electronics module **413** via an electronics terminal **1025**. Conduit part **1004** also includes first and second alignment rings **1068**, **1069**, as shown in FIG. **10**J. In general, first alignment ring **1068** is positioned and configured to receive at least a portion of an edge of first cover receptacle **1060** and first base receptacle **1066** when fluid detection system **1000** is in an assembled state. Similarly, second alignment ring **1069** is positioned and configured to receive at least a portion of an edge of second cover receptacle **1061** and second base receptacle **1067** when fluid detection system **1000** is in an assembled state. In that way, first and second alignment rings **1068**, **1069** can facilitate alignment of sensor element **1015** within the sensor housing.

(111) The function of sensor element **1015** is the same as sensor elements **407** and **515** described above, and so is not reiterated in detail. That is, sensor element **1015** is generally configured to detect the capacitance within liquid flow path **405** of conduit part **1004**. As shown in FIG. **10**I, sensor element **1015** may be a band that is formed from or includes a conductive material, such as copper, aluminum, gold, or any other suitably conductive material. In any case, sensor element **1015** is configured to extend around the outer wall **1031** of conduit part **1004**, e.g., within groove **1014**.

(112) Groove **1014** and outer wall **1031** may be configured to position sensor element **1015** such that sensor element **1015** can detect the capacitance (or a change in capacitance) within liquid flow path **405**. More specifically, the groove **1014** and outer wall **1031** may be configured such a thickness R**1** is defined between outer wall **1031** within groove **1014** and inner wall **1030** of liquid flow path **405** (best shown in FIG. **10**K), wherein R**1** is selected to space sensor element **1015** at a desired distance from the inner wall **1030**. That concept is best shown in FIG. **10**K, which illustrates an embodiment in which the distance R**1** is equivalent to the thickness between inner wall **1030** and the surface of outer wall **1031** within groove **1014**. The value of R may vary depending on the size of liquid flow path **405**, the size of sensing element **1015**, and other parameters. In embodiments, R**1** is in a range of about 0.1 inches (2.5 millimeters (mm)) to about 0.5 inches (12.7 mm), such as about 0.15 inches (3.8 mm) to about inches (7.6 mm), or even about 0.2 inches (5.1 mm) to about 0.25 inches (6.4 mm) Without limitation, R**1** is preferably about 0.2 to 0.3 inches (5.1-7.6 mm) when an when an internal diameter (ID**1**) of liquid flow path **405** is about 1 inch (25.4 mm) Of course, R**1** is not limited to such ranges and liquid flow path **405** may have any suitable internal diameter.

(113) As best shown in FIGS. **10**H and **10**I, sensor element **1015** preferably extends around substantially all (≥95%) of outer wall **1031**. With reference to FIG. **10**I, at least a portion of sensor element **1015** has a shape that substantially corresponds to a shape of the liquid flow path **1035** or, more specifically, the shape of the side of outer wall **1031** within groove **1014**. For example, when liquid flow path **1035** or outer wall **1031** has a circular cross-sectional shape, a D shape, a C-shape, a 4 or more-sided shape, or the like, at least a portion of sensor element **1015** may have a corresponding shape. Notably, no portion of sensor element **1015** is present within liquid flow path

405.

(114) In this embodiment electronics module **413** includes an electronics cover **1071** that is configured to couple to sensor cover **1002**, e.g., via one or more fasteners as described above. Electronics module **413** further includes electronics circuitry **1073** (e.g., a controller), which is configured to be disposed between electronics cover **1071** and sensor cover **1002**, e.g., within first cover cavity **1055**. As best shown in FIG. **10**M, electronics module **413** further includes an electronics terminal **1025** that is configured to communicatively couple a controller within electronics module **413** to sensor element **1015** when fluid detection system **1000** is in an assembled state. Electronics terminal **1025** may have any suitable configuration and may be formed of or include any suitable electrically conductive material (e.g., metals such as copper, aluminum, gold, and the like). In embodiments, electronics terminal **1025** is in the form of a pin that is configured to extend through opening **1062** within cover divider wall **1057**, such that a first end of the pin electrically contacts electronics circuitry **1073** and a second end of the pin electrically contacts a portion of sensor element **1015**. Without limitation, electronics terminal **1025** is preferably biased towards sensor element **1015**, e.g., with a spring or other biasing mechanism. In such instances, electronics terminal **1025** may be referred to as a spring-loaded pin.

(115) In an assembled state (as shown in FIG. **10**A), sensor base **1003** and sensor cover **1002** are coupled to one another and define a passageway through which conduit part **1004** extends. An edge of first cover receptacle **1060** and an edge of first base receptacle **1066** are disposed within first alignment ring **1068**, and an edge of second cover receptacle **1061** and an edge of second base receptacle **1067** are disposed within second alignment ring **1069**. When conduit part **1004** is so positioned, at least a portion of sensor element **1015** within groove **1014** is aligned with the opening **1062** in cover divider wall **1057**. Electronics module **413** is coupled to sensor cover **1002** via one or more fasteners as described above. When electronics module **413** is so coupled, electronics terminal **1025** (e.g., a spring-loaded pin) extends through opening **1062** to contact a portion of the surface of sensor element **1015** as described above. In that way, sensor element **1015** is communicatively coupled to the controller within electronics module **413** by electronics terminal **1025**. The fluid sensor system **1000** may then be used to detect the presence or absence of fluid in liquid flow path **405**, e.g., in the same manner as described above connection with fluid detection systems **400**, **600**, and **800**.

(116) Although not shown, fluid detection system **1000** may include a cable, e.g., for providing power to the components of electronics module **413**, and optionally to provide a wired connection to a communications system that may be sued to send notifications in response to a detected wet and/or flood event. The cable may also provide a connection to earth ground for sensor element **1015**. However, sensor element **1015** may be ground in another manner as discussed above in connection with sensor element **407**.

(117) FIG. **13** depicts one example of a valve leak detection system that includes a fluid detection system **1000** consistent with the present disclosure. As shown, valve leak detection system **1400** includes a fluid detection system **1000** coupled to a valve system **1301**. In this case valve system **1301** is in the form of a temperature and pressure (T & P) relief valve that includes a thermal actuator **1303**, e.g., as described in U.S. Pre-Grant Publication No. 2020/0141773, which is incorporated herein by reference. More particularly, valve system includes and inlet proximate to thermal actuator **1303**, an outlet fluidly coupled to fluid detection system **1000**, and a control valve (not shown) that is located between the inlet and the outlet and is configured to fluidly couple the inlet to the outlet upon the detection of at least one fluid condition, such as a fluid overpressure or over temperature condition. In operation, the inlet of valve system **1301** may be coupled to a water storage device, such as a water heater, such that thermal actuator **1303** extends into the water storage device. So connected, valve system **1301** may monitor fluid conditions within the water storage device, such as fluid pressure and fluid temperature. When fluid conditions are within acceptable parameters, a control valve within valve system **1301** may be in a closed state,

preventing a flow of fluid from the inlet of valve system **1301** to the outlet of valve system **1301** and thus, preventing the flow of fluid into the liquid flow path **405** of fluid detection system **1000**. When fluid conditions are outside acceptable parameters (e.g., in an over pressure or over temperature condition), the control valve within valve system **1301** may move to an open state, fluidly coupling the inlet and outlet of valve system **1301**. In that state, fluid may flow through valve system **1301** and into the liquid flow path **405** fluid detection system **1000**.

(118) Consistent with the foregoing disclosure, fluid detection system **1000** may monitor the capacitance of liquid flow path **405** to determine whether liquid is present within the liquid flow path—which may be indicative of a faulty condition of valve system **1301** or fluid conditions within the water storage device that are out of specification. To accomplish that function, when fluid detection system **1000** is installed as shown in FIG. **13**, a calibration operation may be executed to establish a baseline capacitance within liquid flow path **405**. Alternatively, the baseline capacitance may be pre-set. In any case, the sensor element **1015** within fluid detection system **1000** may monitor the capacitance of liquid flow path **405** and provide a sensor signal indicative of that capacitance to a controller, e.g., within electronics module **413**. The controller may then determine the detected capacitance in the liquid flow path **405**, and determine whether a wet, dry, and/or flood event is occurring in liquid flow path **405** based at least in part on the detected capacitance as previously described. The controller may also perform recording and reporting operations as previous described.

(119) FIGS. **11**A-**11**O illustrate another example of a fluid detection system consistent with the present disclosure. As shown, fluid detection system **1100** includes a sensor module **401** and an electronics module **413**. A liquid flow path **405** extends through the sensor module **401**. The function of sensor module **401** and electronics module **413** are largely the same as described above in connection with FIG. **4**, and so are not reiterated. This embodiment is also functionally similar to system **500** described above, but lacks an air flow path **423**. Like fluid detection system **1000**, fluid detection system **1100** may be particularly useful for detecting leaks from smaller water systems, such as residential and RV water systems, hot water heaters, and the like.

(120) As best shown in FIGS. **11**A and **11**O, electronics module **413** is separable from sensor module **401**. That is, electronics module **413** may be physically connected and disconnected from sensor module **401**, such that fluid detection system **1100** is in an assembled state (FIG. **11**A) or in a disassembled state (FIG. **11**O). In the assembled state a controller (e.g., a controller **419** as described above in connection with FIG. **4**) is present within electronics module **413** and is communicatively coupled to a sensor element **1115** in sensor module **401**. The controller within electronics module **413** may be communicatively coupled to sensor element **1115** in any suitable manner. For example, and as will be described later, when system **1100** is in an assembled state, a proximal portion **1143** of sensor element **1115** may be communicatively coupled to a controller in electronics module **413** by at least one electronics terminal **1125** that couples to electronics circuitry **1173** in electronics module **413**.

(121) As best shown in FIGS. **11**A-**11**H, sensor module **401** includes a sensor cover **1102** and a sensor base **1103**, which are separable from one another. When assembled as shown in FIGS. **11**B-**11**H, the sensor cover **1102** and sensor base **1103** form a sensor housing **1104**. The way sensor cover **1102** and sensor base **1103** can be coupled to one another is not limited. In embodiments, sensor cover **1102** and sensor base **1103** are coupled by one or more fasteners (e.g., screws), a weld, an interference fit between corresponding parts of sensor cover **1102** and sensor base **1103**, combinations thereof, and the like. As best shown in FIG. **10**H, sensor cover **1002** and sensor base **1003** may include one or more fastener openings **1105** that are configured facilitate coupling of sensor cover **1102** to sensor base **1103** and/or another structure, e.g., with one or more fasteners. The number of fastener openings **1105** is not limited, and any of such openings may be omitted.

(122) As shown in FIG. **11**I, sensor cover **1102** includes a cover body (not labeled) that includes a cover inner wall **1130**, a cover outer wall **1131**, a first cover cavity **1155**, and a second cover cavity

1156. The first cover cavity **1155** is generally configured to receive or otherwise couple to electronics module **413**. The way sensor cover **1102** (and, more particularly, first cover cavity **1155**) couples to electronics module **413** is not limited, and such components may be coupled in any suitable manner. For example, sensor cover **1102** may couple to electronics module **413** via one more fasteners, an adhesive, a weld, an interference fit, or the like. In embodiments, electronics module **413** includes an electronics base **1107** that is configured to receive first cover cavity **1155**, or to plug into first cover cavity **1155** and be retained therein. In either case, the electronics base **1107** and first cover cavity **1155** may be coupled to one another via an interference fit between corresponding components thereof. A seal **1106** may be provided in a channel around sensor cover **1102** and sensor base **1103**, and may function to form a fluid tight seal with electronics module **413** with system **1100** is in an assembled state.

(123) In embodiments at least a portion of second cover cavity **1156** is positioned substantially opposite at least a portion of first cover cavity **1155**. The first and second cover cavities **1155**, **1156** are preferably separated from each other by first and second cover dividers **1171**, **1172**, which in the illustrated embodiment extend inwardly from cover outer wall **1131**. The first and second cover dividers each preferably define at least a portion of both first cover cavity **1155** and second cover cavity **1156**. For example, and as shown in FIG. **11**I, first and second cover dividers **1171**, **1172** each form at least part of a wall of first cover cavity **1155** and second cover cavity **1156**. In any case, first and second dividers may include or be spaced from one another such that an opening **1162** is provided to allow a portion of sensor element **1115** to extend into the first cover cavity **1155**, facilitating coupling of the sensor element **1115** to a controller in electronics module **413** as described in more detail later.

(124) Sensor cover **1102** is configured to receive at least a portion of sensor base when fluid sensor system **1100** is in an assembled state. As shown in FIG. **11**I, sensor cover **1102** includes a cover neck portion **1181** and a cover conduit portion **1183**. An outer cover shoulder **1176** is defined at least in part by an inward facing surface **1147** of cover outer wall **1131**, and extends around the cover neck portion **1181** and cover conduit portion **1183**. The outer cover shoulder **1176** is configured to receive a corresponding base shoulder **1167** (extending around base neck portion **1185** and a base conduit portion **1186**) when sensor housing **1104** is in an assembled state. In any case, cover inner wall **1130** at least partially defines a portion of liquid flow path **405** extending through sensor cover **1102**. For example, liquid flow path **405** is at least partially defined by the inward facing surface **1145** of cover inner wall **1130**. The outward facing surface **1146** of cover inner wall **1130** tapers on one end of liquid flow path **405** to form an inner cover shoulder, in which a seal **1149** (e.g., an O-ring) is placed. The inner cover shoulder and seal **1149** are configured to be received by and form a seal with sealing surface **1165** of sensor base **1103** (best shown in FIG. **11**K) when sensor module **401** is in an assembled state.

(125) Returning to FIG. **11**I, cover outer wall includes an inward facing surface **1147** and an outward facing surface **1148**. A groove **1114** (which may also be referred to as sensor channel) is defined between an inward facing surface **1147** of cover outer wall **1131** and the outward facing surface **1146** of cover inner wall **1130**. In general, groove **1114** is configured to support and maintain the position of a sensor element **1115** within sensor cover **1102**. For example, a distal portion **1144** of sensor element **1115** may extend within groove **1114**, and a proximal portion **1143** of sensor element **1115** may extend through an opening **1162** between first and second cover dividers **1171** and **1172** and into second cover cavity **1156**. For example, and as shown in FIGS. **11**I and **11**J, the proximal portion **1143** of sensor element **1115** may include a first bend **1138** (e.g., within first cavity **1155**) and a second bend **1139** (e.g., within second cover cavity **1156**). The first bend **1138** is configured to facilitate passage of sensor element **1115** through opening **1162**. The second bend **1139** is configured to provide a contact portion of sensor element **1115**, e.g., for coupling to one or more electronics terminals **1125** of electronics module **413** as shown in FIG. **11**M. In embodiments and as shown in FIG. HI, a plurality of standoffs **1129** may be provided to

position sensor element **1115** within groove **1114**.

(126) Liquid flow path **405** is generally configured to provide a passageway for a flow of fluid through sensor cover **1102** and sensor housing **1104**. For the sake of illustration liquid flow path **405** is illustrated in FIG. **11**I with a circular cross sectional shape, but liquid flow path **405** may have any suitable shape. Moreover, in this embodiment liquid flow path **405** includes an inlet **1136** and an outlet **1137** that are positioned substantially opposite one another. Consequently, the course of liquid flow path **405** in this embodiment extends substantially straight between inlet **1136** and outlet **1137**. Of course, inlet **1136** and outlet **1137** of liquid flow path **405** may be sized and positioned differently, with a corresponding difference in the shape and course of the passageway there between.

(127) Cover inner wall **1130** and (optionally) standoffs **1129** may be configured to space the distal portion **1144** of sensor element **1115** a desired distance from liquid flow path **405** when distal portion **1144** is disposed within groove **1114**. In that regard, the portion of cover inner wall proximate to (e.g., abutting, or adjacent to) sensor element **1115** may have a thickness R**2** between outward facing surface **1146** and inward facing surface **1145** of cover inner wall **1130**, as shown in FIG. HI. The value of R**2** may vary depending on the size (e.g., internal diameter) of liquid flow path **405**, the size of sensing element **1115**, and other parameters. In embodiments, R**2** is in a range of about 0.05 to about 0.5 inches (about 1.3 to about 12.7 millimeters (mm)), such as about 0.07 to 0.3 inches (about 1.8 to about 7.6 mm), or even 0.08 to about 0.1 inches (about 2.0 to about 2.5 mm) Without limitation, R**2** is preferably about 0.08 inches (about 2.0 mm) when an internal diameter (ID**2**) of liquid flow path **405** is about 0.75 inches (about 19 mm) Of course, R**2** is not limited to such ranges and liquid flow path **405** may have any suitable internal diameter.

(128) Sensor base **1103** is generally configured to mate with sensor cover **1102** and to form at least a portion of liquid flow path **405**. As noted above, sensor base **1103** includes a base neck portion **1185** and a base conduit portion **1186**, which are configured to couple with corresponding portions of sensor cover **1102** (i.e., cover neck portion **1181** and cover conduit portion **1183**). The base neck portion **1185** includes a base cavity **1163** which, together with first cover cavity **1155** forms a receptacle for receiving a portion of electronics base **1107** when sensor housing **1104** is in an assembled state. Sensor base **1103** further includes a base wall **1164**, which at least partially defines base cavity **1163**. The base wall **1164** may include substantially linear elements within base neck portion **1185**, and one or more curvilinear elements in base conduit portion **1186**. At least a portion of base wall **1164** defines a sealing surface **1165** within base conduit portion **1186**. As noted above, the sealing surface **1165** is configured to receive a seal **1149** and a portion of cover inner wall **1130** therein when sensor housing **1104** is in an assembled condition. Sensor base **1103** further includes a base rim **1166**, which extends around most of the perimeter of sensor base **1103**, except for the portion of the perimeter that defines part of base cavity **1163**. The base rim **1166** extends upwardly from the body of sensor base **1103** to define a base shoulder **1167**, which is configured to mate with (e.g., be received within) an outer cover shoulder **1176** of sensor cover **1102** when sensor housing **1104** is in an assembled state.

(129) When sensor module **401** is in an assembled state, sensor cover **1102** and sensor base **1103** form a receptacle for receiving or otherwise coupling to electronics module **413**. More specifically, and as best shown in FIGS. **11**H and **11**O, the first cover cavity **1155** of sensor cover **1102** and the base cavity **1163** of sensor base **1103** form first and second portions of a receptacle that can plug into or otherwise couple to a corresponding receptacle in electronics base **1107**. Of course, sensor module **401** need not be configured in that manner, and the receptacle for the electronics module **413** may be configured differently and/or defined by other portions of the sensor cover **1102** and/or sensor base **1103**. For example, the receptacle for the electronics module **413** in sensor module **401** may be configured to receive a portion of electronics base therein.

(130) The function of sensor element **1115** is the same as sensor elements **407**, **515**, and **1015** described above, and so is not reiterated in detail. Like those previously described elements, sensor

element **1115** is generally configured to detect the capacitance within liquid flow path **405**. As best shown in FIG. **11**J, sensor element **1215** may include a proximal portion **1143** and a distal portion **1144**, both of which may be formed from or include a band of conductive material such as copper, aluminum, gold, or the like. As discussed above, distal portion **1144** of sensor element **1115** is configured to be disposed within groove **1114** in sensor cover HI. As best shown in FIG. **11**N, proximal portion **1143** may be coupled to electronics circuitry **1173** via electronics terminal **1125** (e.g., a spring loaded pin). As best shown in FIG. H, in embodiments at least a portion of proximal portion **1143** of sensor element **1115** includes a substantially flat region of conductive material, which can contact electronics terminal **1125** when electronics module **413** is coupled to sensor module **401**.

(131) In this embodiment and as shown in FIGS. **11**A, **11**L-**11**O, electronics module **413** includes electronics base **1107**, electronics cover **1109**, and cable **1111**. The electronics base **1107** and electronics cover **11099** are detachably coupled to one another, e.g., via one or more fasteners. Electronics module **413** further includes electronics circuitry **1173** (e.g., a controller), which is configured to be disposed in an electronics cavity defined by electronics base **1107** and electronics cover **1109**. As best shown in FIG. **11**M, electronics base **1107** includes an opening **1198** through which an electronics terminal **1125** extends. The electronics terminal **1125** is configured to contact proximal portion **1143** of sensor element **1115** when fluid detection system **1100** is in an assembled state, thereby communicatively coupling sensor element **1115** with the controller in electronics module **413**. Electronics terminal **1125** may have any suitable configuration and may be formed of or include any suitable electrically conductive material (e.g., metals such as copper, aluminum, gold, and the like). In embodiments, electronics terminal **1125** is/are in the form of one or more pins or pads that is/are configured to extend into first cover cavity **1155** such that it/they contact proximal portion **1143** of sensor element **1115**. Without limitation, electronics terminal **1125** is preferably biased towards proximal portion **1143**, e.g., with a spring or other biasing mechanism. In such instances, electronics terminal **1125** may be referred to as a spring-loaded terminal or a spring-loaded pin.

(132) In an assembled state (as shown in FIG. **11**A), sensor base **1103** and sensor cover **1102** are coupled to one another to form a sensor housing, with distal portion **1144** of sensor element **1115** disposed in groove **1114**. The proximal portion **1143** of sensor element **1115** extends through opening **1162**. A receptacle formed by electronics base **1109** receives the receptacle formed by the first cover cavity **1155** and base cavity **1163**, such that electronics terminal **1125** contacts proximal portion **1143** of sensor element **1115**. In that way, sensor element **1115** is communicatively coupled to the controller within electronics module **413** by electronics terminal **1125** and proximal portion **1143** of sensor element **1115**. The fluid sensor system **1100** may then be used to detect the presence or absence of fluid in liquid flow path **405**, e.g., in the same manner as described above connection with fluid detection systems **400**, **600**, **800** and **1000**.

(133) FIG. **14** depicts one example of a valve leak detection system that includes a fluid detection system **1100** consistent with the present disclosure. As shown, valve leak detection system **1400** includes a valve system **1401**, fluid detection system **1100**, and an air gap **1403**. Similar to system **800**, valve system **1401** includes a liquid flow path that includes an outlet coupled to the inlet **1136** of fluid detection system **1100**. The outlet **1137** of fluid detection system **1100** is coupled to air gap **1403**. The liquid flow path from valve system **1401** is configured to convey a liquid flow to the inlet **1136**. In operation, valve system **1401** may regulate the flow of fluid in a liquid supply system, such as a water supply system. Under normal operating conditions liquid may flow through valve system **1401**. Under certain conditions or if valve system **1401** fails, however, liquid may flow through the liquid flow path **405** in fluid detection system **1100**, which, which flow may be facilitated by a flow of air provided by air gap **1403**.

(134) Consistent with the foregoing disclosure, fluid detection system **1100** may monitor the capacitance of liquid flow path **405** to determine whether liquid is present within the liquid flow

path—which may be indicative of a faulty condition of valve system **1401**. To accomplish that function, when fluid detection system **1100** is installed as shown in FIG. **14**, a calibration operation may be executed to establish a baseline capacitance within liquid flow path **405**. Alternatively, the baseline capacitance may be pre-set. In any case, the sensor element **1115** within fluid detection system **1100** may monitor the capacitance of liquid flow path **405** and provide a sensor signal indicative of that capacitance to a controller, e.g., within electronics module **413**. The controller may then determine the detected capacitance in the liquid flow path **405**, and determine whether a wet, dry, and/or flood event is occurring in liquid flow path **405** based at least in part on the detected capacitance as previously described. The controller may also perform recording and reporting operations as previous described.

(135) FIGS. **12**A-**12**O illustrate another example of a fluid detection system consistent with the present disclosure. As shown, fluid detection system **1200** includes a sensor module **401** and an electronics module **413**. A liquid flow path **405** extends through the sensor module **401**. The function of sensor module **401** and electronics module **413** are largely the same as described above in connection with FIG. **4**, and so will not be reiterated in detail. This embodiment is also functionally like systems **1000** and **1100** described above. Like fluid detection systems **1000**, **1100**, fluid detection system **1200** may be particularly useful to detect leaks from smaller water systems, such as residential water systems, recreational vehicle water systems, hot water heaters, and the like.

(136) As best shown in FIGS. **12**A, **12**I, and **12**N electronics module **413** is separable from sensor module **401**. That is, electronics module **413** may be physically connected and disconnected from sensor module **401**, such that fluid detection system **1200** is in an assembled or disassembled state. In the assembled state a controller (e.g., a controller **419** as described previously) in electronics module **413** is communicatively coupled to a sensor element **1215** in sensor module **401**. The controller within electronics module **413** may be communicatively coupled to sensor element **1215** in any suitable manner. For example, and as will be described later, when fluid detection system **1200** is in an assembled state and sensor element **1215** includes a sensor printed circuit board (PCB) **1221**, sensor element **1215** may be communicatively coupled to a controller in electronics module **413** by one or more electronics terminals that couple to a sensor PCB **1221** coupled to a proximal portion of sensor element **1215**.

(137) As best shown in FIGS. **12**A and **12**H, sensor module **401** includes a sensor cover **1202**, a sensor base **1203**, and sensor element **1215**. The sensor cover **1202** and sensor base **1203** are separable from each other as shown in FIG. **12**I. When sensor cover **1202** and sensor base **1203** are coupled to one another they form a sensor housing, as shown in FIG. **12**H. As best shown in FIG. **12**I, sensor cover **1202** and sensor base **1203** are detachable from one another. The way sensor cover **1202** and sensor base **1203** can be coupled to one another is not limited. In embodiments, sensor cover **1202** and sensor base **1203** are coupled by one or more fasteners (e.g., screws), a weld, an interference fit between corresponding parts of sensor cover **1202** and sensor base **1203**, combinations thereof, and the like. For example, and as shown in FIGS. **12**B, **12**D, and **12**H, sensor cover **1202** and sensor base **1203** may include one or more fastener openings **1205** that are configured facilitate coupling of sensor cover **1202** to sensor base **1203** with one or more fasteners. The number of fastener openings **1205** is not limited, and any of such openings may be omitted.

(138) Sensor cover **1202** includes a cover body. The cover body includes a first cover cavity **1255** and a second cover cavity **1256**. The first cover cavity **1255** is generally configured (e.g., along with a first base cavity **1263**) to receive or otherwise couple to at least a portion of electronics module **413**, as illustrated in FIGS. **12**A and **12**N. The way sensor cover **1202** (and, more particularly, first cover cavity **1255**) couples to electronics module **413** is not limited, and such components may be coupled in any suitable manner. For example, sensor cover **1202** may couple to electronics module **413** via one more fasteners, an adhesive, a weld, an interference fit, or the like. In embodiments, sensor cover **1202** is configured to couple to electronics module **413** using one or

more fasteners that extend through one or more fastener openings **1205** within first cover cavity **1055** and electronics module **413**. In such instances, the fastener openings **1205** within first cover cavity **1255** may be positioned to align with corresponding fastener openings **1205** of electronics module **413**, such that a fastener may be placed therein to couple sensor cover **1202** with electronics module **413**.

(139) In embodiments and as shown in FIG. **12**B, at least a portion of second cover cavity **1256** is positioned substantially opposite at least a portion of first cover cavity **1255**, with a cover divider **1257** therebetween. In embodiments, cover divider **1257** is or includes a wall that preferably defines at least a portion of both first cover cavity **1255** and second cover cavity **1256**. For example, and as shown in FIGS. **12**B and **12**E, cover divider **1257** may form at least part of a wall of first cover cavity **1255** and may also form at least part of a wall of second cover cavity **1256**. In any case, an opening **1262** may be formed through cover divider **1257** to facilitate coupling of a controller in electronics module **413** with sensor element **1215**, as described in more detail later.

(140) Second cover cavity **1256** may receive at least a portion of sensor base **1203** therein when fluid detection system **1200** is in an assembled state. As shown in FIGS. **12**B, **12**D and **12**E, sensor cover **1202** includes a cover inner wall **1229** and a cover outer wall **1230**. The cover inner wall **1229** defines at least a portion of a cover passageway **1252** through which at least a portion of sensor base **1203** extends when fluid detection system **1200** is in an assembled state. The outward facing surface **1232** of cover inner wall **1229** and an inward facing surface **1233** of cover outer wall **1230** define at least a portion of the second cover cavity **1256**, as best shown in FIG. **12**B.

(141) A ridge **1234** projects inwardly from and extends at least partially (and in some embodiments continuously) around inward facing surface **1231** of cover inner wall **1230**. Regardless of its configuration, ridge **1234** is configured to support and maintain the position of sensor element **1215** within sensor module **401**. For example, and as shown in FIGS. **12**B and **12**C, a distal portion **1244** of sensor element **1215** may extend proximate to and around inward facing surface **1231** of cover inner wall **1229**, and proximal portion **1243** of sensor element **1215** may extend through a gap **1235** in cover inner wall **1229** and into second cover cavity **1256**. In such instances ridge **1234** may provide an abutment surface for abutting at least one edge of sensor element **1215**, which can help to maintain the position and alignment of distal portion **1244** of sensor element **1215**.

(142) In general, sensor base **1203** is configured to provide a liquid flow path through which a liquid may flow when fluid detection system **1200** is in use. Sensor base **1203** is also configured to support and/or position sensor element **1215** relative to the liquid flow path, such that sensor element **1215** can detect a capacitance within the liquid flow path. With that in mind and as best shown in FIGS. **12**I-**12**L, sensor base **1203** includes a tubular body **1207** and a flange **1208**. A liquid flow path **405** extends through the tubular body **1207** from an inlet **1236** to an outlet **1237**. The tubular body includes an outer wall **1258** with outward facing surface **1259** and an inward facing surface **1260**. The liquid flow path **405** is at least partially defined by the perimeter of inward facing surface **1260**. For the sake of illustration and ease of understanding liquid flow path **405**, perimeter **1212**, inward facing surface **1260** are depicted as having a circular cross section, but such components may have any suitable shape. In this embodiment, the inlet **1236** and outlet **1237** are positioned opposite to one another. Consequently, liquid flow path **405** is straight or substantially straight between the inlet **1236** and the outlet **1237**. Of course, inlet **1236** and outlet **1237** of liquid flow path **405** may be sized and positioned differently, with a corresponding difference in the shape of the passageway there between.

(143) As noted above and the tubular body **1207** of sensor base **1203** includes an outer wall **1258** with an outward facing surface **1259**. At least a portion of the outward facing surface **1259** defines a base step **1261** (which may also be referred to as sensor support) that extends at least partially (and preferably fully) around the outer wall **1031**. Base step **1261** may be a raised or recessed region of outer wall **1258** that is configured to support and/or receive at least a portion of sensor element **1215** when the sensor housing of fluid detection system **1200** is in an assembled state.

Without limitation, base step **1261** is preferably a raised portion of outer wall **1258**, as shown in FIGS. **12**J and **12**K. The height of base step **1261** is not limited, and may be selected to correspond to a shape of distal portion **1244** of sensor element **1215**. In embodiments base step **1261** is sized and positioned such that it is disposed opposite to the inward facing surface **1233** of outer wall **1230** in sensor cover **1202** when the sensor housing is in an assembled state. In such instances, at least the distal portion **1244** of sensor element **1215** may be disposed between outer wall **1230** (of sensor cover **1202**) and base step **1261** of sensor base **1203**.

(144) The portion of outer wall **1258** forming base step **1261** may have a thickness R**3** between the outward facing surface **1259** and the inward facing surface **1260**, as shown in FIG. **12**M. The thickness R**3** may be selected to space distal portion **1244** of sensor element **1215** a desired distance from liquid flow path **405** when distal portion **1244** is disposed about at least a portion of base step **1261**. The value of R**3** may vary depending on the size (e.g., internal diameter) of liquid flow path **405**, the size of sensing element **1215**, and other parameters. In embodiments, R**3** is in a range of about 0.05 to about 0.5 inches (about 1.3 to about 12.7 millimeters (mm)), such as about 0.07 to 0.3 inches (about 1.8 to about 7.6 mm), or even 0.1 to about 0.25 inches (about 2.5 to about 6.35 mm) Without limitation, R**3** is preferably about 0.22 inches (about 5.6 mm) when an internal diameter (ID**3**) of liquid flow path **405** is about 2 inches (about 50.8 mm) Of course, R**3** is not limited to such ranges and the liquid flow path **405** may have any suitable diameter.

(145) In an assembled state sensor cover **1202** and sensor base **1203** form a receptacle for receiving or otherwise coupling to electronics module **413**. For example, and as best shown in FIGS. **12**B, **12**H, and **12**I, sensor cover **1202** includes a first cover cavity **1255** and sensor base **1203** includes a first base cavity **1263**. The first cover cavity **1255** and first base cavity **1263** together form respective first and second portions of a receptacle for receiving or otherwise coupling to electronics module **413**. Of course, sensor module **401** need not be configured in that manner, and the receptacle for the electronics module **413** may be configured differently and/or defined by other portions of the sensor cover **1202** and/or sensor base **1203**. For example, the receptacle for the electronics module **413** may be positioned entirely on sensor cover **1202** or entirely on sensor base **1203**.

(146) The function of sensor element **1215** is the same as sensor elements **407**, **515**, and **1015** described above, and so is not reiterated in detail. Like those previously described elements, sensor element **1215** is generally configured to detect the capacitance within liquid flow path **405**. As shown in FIG. **12**C, sensor element **1215** may include a proximal portion **1243** and a distal portion **1244**, both of which may be formed from or include a band of conductive material such as copper, aluminum, gold, or the like. As discussed above, distal portion **1244** of sensor element **1215** is configured to be disposed between outward facing surface **1232** and base step **1261** when the sensor housing is in an assembled state. As shown in FIG. **12**C, proximal portion **1243** may be coupled to a sensor printed circuit board (PCB) **1221** that includes a sensor terminal **1223**. Although not shown in FIG. **12**B, sensor PCB **1221** may be configured to align sensor terminal **1223** with opening **1262** in cover divider **1257**, such that sensor terminal **1223** can contact corresponding electronics terminal **1225** of electronics module **413**.

(147) As shown in FIGS. **12**A, **12**N, and **12**O, electronics module **413** includes an electronics base **1297** and an electronics cover **1299**, which are detachably coupled to one another, e.g., via one or more fasteners. Electronics module **413** further includes electronics circuitry (e.g., a controller), which is configured to be disposed in an electronics cavity defined by electronics base **1297** and electronics cover **1299**. As best shown in FIG. **12**O, electronics base **1297** includes an opening **1298** through which electronics terminal **1225** extends. The electronics terminal(s) **1225** is/are configured to contact one or more sensor terminals **1223** when fluid detection system **1200** is in an assembled state, thereby communicatively coupling sensor element **1215** with the controller in electronics module **413**. Electronics terminal(s) **1225** may have any suitable configuration and may be formed of or include any suitable electrically conductive material (e.g., metals such as copper,

aluminum, gold, and the like). In embodiments, electronics terminal **1225** is in the form of one or more pins or pads that is/are configured to extend through opening **1262** within cover divider **1257** such that it/they contact sensor terminal **1223**. Without limitation, electronics terminal **1225** is preferably biased towards sensor terminal(s) **1223**, e.g., with a spring or other biasing mechanism. In such instances, electronics terminal **1225** may be referred to as a spring-loaded terminal or a spring load pin.

(148) In an assembled state (as shown in FIG. **12**A), sensor base **1203** and sensor cover **1202** are coupled to one another to forma sensor housing (FIG. **12**H), with distal portion **1244** of sensor element **1215** disposed between outward facing surface **1232** and base step **1261**. The proximal portion **1243** of sensor element **1215** is coupled to sensor PCB **1221**, and sensor PCB **1221** is positioned to align sensor terminal **1223** with opening **1262** in cover divider **1257**. Electronics module **413** is coupled to the sensor housing via one or more fasteners as described above. When electronics module **413** is so coupled, electronics terminal **1225** extends through opening **1262** to contact sensor terminal **1223** as described above. In that way, sensor element **1215** is communicatively coupled to the controller within electronics module **413** by electronics terminal **1225** and sensor terminal **1223**. The fluid detection system **1200** may then be used to detect the presence or absence of fluid in liquid flow path **405**, e.g., in the same manner as described above connection with fluid detection systems **400**, **600**, **800** and **1000**.

(149) Although not shown, fluid detection system **1200** may include a cable, e.g., for providing power to the components of electronics module **413**, and optionally to provide a wired connection to a communications system that may be sued to send notifications in response to a detected wet and/or flood event. The cable may also provide a connection to earth ground for sensor element **1215**. However, sensor element **1215** may be ground in another manner as discussed above in connection with sensor element **407**.

(150) FIG. **15** depicts one example of a valve leak detection system that includes a fluid detection system **1200** consistent with the present disclosure. As shown, valve leak detection system **1500** includes a valve system **1501**, fluid detection system **1200**, and an air gap **1503**. Valve system **1501** includes a liquid flow path that includes an outlet coupled to the inlet of air gap **1503**. The outlet of the air gap **1503** is coupled to an inlet of fluid detection system **1200**. In operation, valve system **1501** may regulate the flow of fluid in a liquid supply system, such as a water supply system. Under normal operating conditions liquid may flow through valve system **1501** from an inlet to an outlet thereof. Under certain conditions or if valve system **1501** fails, however, liquid may flow through the liquid flow path **405** in fluid detection system **1200**, which, which flow may be facilitated by a flow of air provided by air gap **1503**.

(151) Consistent with the foregoing disclosure, fluid detection system **1200** may monitor the capacitance of liquid flow path **405** to determine whether liquid is present within the liquid flow path—which may be indicative of a faulty condition of valve system **1501**. To accomplish that function, when fluid detection system **1200** is installed as shown in FIG. **15**, a calibration operation may be executed to establish a baseline capacitance within liquid flow path **405**. Alternatively, the baseline capacitance may be pre-set. In any case, the sensor element **1215** within fluid detection system **1200** may monitor the capacitance of liquid flow path **405** and provide a sensor signal indicative of that capacitance to a controller, e.g., within electronics module **413**. The controller may then determine the detected capacitance in the liquid flow path **405**, and determine whether a wet, dry, and/or flood event is occurring in liquid flow path **405** based at least in part on the detected capacitance as previously described. The controller may also perform recording and reporting operations as previous described.

EXAMPLES

(152) The following are additional example embodiments of the present disclosure.

(153) Example 1: According to this example there is provided a fluid detection system, including: a sensor module including: a sensor housing, the sensor housing including a liquid flow path that

extends through the sensor housing; and a sensor element outside the liquid flow path, at least portion of the sensor element extending at least partially around a perimeter of the liquid flow path; wherein: the sensor element is configured to detect a capacitance within the liquid flow path and to provide a detection signal indicative of a detected capacitance within the liquid flow path; and the sensor element is configured to communicatively couple to a controller within an electronics module.

(154) Example 2: This example includes any or all of the elements of example 1, wherein the sensor module further includes an air flow path extending through the sensor housing.

(155) Example 3: This example includes any or all of the elements of example 2, wherein at least a portion of the liquid flow path and at least a portion of the air flow path extend parallel or substantially parallel to each other.

(156) Example 4: This example includes any or all of the elements of example 1, wherein: the sensor module further includes a sensor channel; the sensor channel is at least partially disposed around the perimeter of the liquid flow path; and at least a portion of the sensor element is within the sensor channel.

(157) Example 5: This example includes any or all of the elements of example 1, wherein: the sensor element includes a first portion and a second portion; the first portion of the sensor element is disposed around at least a portion of the perimeter of the liquid flow path; and the second portion of the sensor element is configured to communicatively couple to the controller.

(158) Example 6: This example includes any or all of the elements of example 1, further including the electronics module, wherein: the controller is within the electronics module; and the electronics module is configured to physically couple to the sensor housing such that the sensor element is communicatively coupled to the controller.

(159) Example 7: This example includes any or all of the elements of example 5, wherein the controller is configured to receive the detection signal from the sensor module, and to determine whether a liquid is present within the liquid flow path based at least in part on the detection signal.

(160) Example 8: This example includes any or all of the elements of example 7, wherein the controller is configured to: determine the detected capacitance at least in part from the detection signal; compare the detected capacitance to a capacitance threshold; and determine whether liquid is present within the liquid flow path based at least in part on comparing the detected capacitance to the capacitance threshold, and to determine whether a wet event has occurred based on the determination.

(161) Example 9: This example includes any or all of the elements of example 8, wherein the controller wherein the controller is configured to determine that a wet event has occurred when the detected capacitance is less than or equal to the capacitance threshold.

(162) Example 10: This example includes any or all of the elements of example 7, wherein the controller is further configured to: compare a total number of wet events occurring within a measurement period to a threshold number of wet events for the measurement period; and determine that a flood event has occurred when the total number of wet events occurring within a measurement period meets or exceeds the threshold number of wet events for the measurement period.

(163) Example 11: This example includes any or all of the elements of example 10, further including communications circuitry (COMMS), wherein the controller is configured to cause the COMMS to issue a flood notification via a wired or wireless communication protocol in response to detection of a flood event.

(164) Example 12: This example includes any or all of the elements of example 8, further including a calibration module in communication with the controller, wherein: the calibration module is configured to cause the controller to establish a baseline capacitance within the liquid flow path; and the controller is configured to set the capacitance threshold relative to the baseline capacitance.

(165) Example 13: This example includes any or all of the elements of example 12, wherein the

electronics module includes the calibration module.
(166) Example 14: This example includes any or all of the elements of example 12, wherein the calibration module includes a calibration button, wherein actuation of the calibration button causes the calibration module to establish the baseline capacitance based at least in part on the detection signal provided by the sensor element.
(167) Example 15: According to this example there is provided a method of fluid detection, including, with a fluid detection system including a sensor module and an electronics module, the sensor module including a sensor housing, a liquid flow path extending through the sensor housing, and a sensor element disposed at least partially around a perimeter of the liquid flow path, the electronics module including a controller communicatively coupled to the sensor element: detecting, with the sensor element, a capacitance within the liquid flow path; conveying a sensor signal indicative of the capacitance to the controller; determining a detected capacitance within the liquid flow path with the controller; comparing, with the controller, the detected capacitance to a capacitance threshold; and determining, with the controller, whether a wet event has occurred in the liquid flow path based at least in part on the comparing the detected capacitance to the capacitance threshold.
(168) Example 16: This example includes any or all of the elements of example 15, wherein the fluid detection system further includes an air flow path extending through the sensor housing, and at least a portion of the liquid flow path and at least a portion of the air flow path extend parallel or substantially parallel to each other.
(169) Example 17: This example includes any or all of the elements of example 15, wherein the electronics module is physically coupled to the sensor housing such that the sensor element is communicatively coupled to the controller.
(170) Example 18: This example includes any or all of the elements of example 15, wherein the controller is to determine that a wet event has occurred with the detected capacitance is less than or equal to the capacitance threshold.
(171) Example 19: This example includes any or all of the elements of example 18, further including, with the controller: comparing a total number of wet events occurring within a measurement period to a threshold number of wet events for the measurement period; and determining that a flood event has occurred when the total number of wet events occurring within a measurement period meets or exceeds the threshold number of wet events for the measurement period.
(172) Example 20: This example includes any or all of the elements of example 19, wherein the fluid detection system if communicatively coupled to communications circuitry (COMMS), and the method further includes: causing, with the controller, the COMMS to issue a flood notification via wired or wireless communication when the controller determines that a flood event has occurred.
(173) Example 21: This example includes any or all of the elements of example 15, wherein the fluid detection system further includes a calibration module in communication with the controller, and the method further includes: causing, with the calibration module, the controller to establish a baseline capacitance within the liquid flow path based at least in part on the sensor signal provided by the sensor element; and setting, with the controller, the capacitance threshold relative to the baseline capacitance.
(174) Example 22: This example includes any or all of the elements of example 21, wherein the electronics module includes the calibration module.
(175) Example 23: This example includes any or all of the elements of example 21, wherein the calibration module includes a calibration button, wherein actuation of the calibration button causes the calibration module to establish the baseline capacitance.
(176) Example 24: This example includes any or all of the elements of example 21, wherein the capacitance threshold is offset above the baseline capacitance by a predetermined margin.
(177) Example 25: According to this example there is provided a fluid detection system, including:

a sensor module including: a sensor base; a sensor cover coupled to the sensor base; and a sensor element; wherein: the sensor element is configured to detect a capacitance within a liquid flow path from a position outside the liquid flow path and to communicatively couple to a controller of an electronics module including a pin; and the sensor base or the sensor housing includes: a first cavity configured to house at least a portion of the sensor element; a second cavity configured to couple with an electronics module; and at least one divider to separate the first cavity from the second cavity, the divider including an opening to facilitate coupling of the sensor element with the pin of the electronics module.

(178) Example 26: This example includes any or all of the features of example 25, further including the electronics module including the controller and the pin, wherein: the electronics module is coupled to the second cavity; and at least a portion of the pin extends through the opening in the at least one divider to electrically couple to the sensor element.

(179) Example 27: This example includes any or all of the features of example 26, wherein: the sensor module further includes a conduit part including an outward facing surface and an inward facing surface, the inward facing surface of the conduit part defining at least a portion of the liquid flow path; and the sensor element is disposed around the outward facing surface of the conduit part.

(180) Example 28: This example includes any or all of the features of example 27, wherein the sensor base and sensor cover at least partially define a passageway through which the conduit part extends.

(181) Example 29: This example includes any or all of the features of example 27, wherein the sensor element includes a metal band.

(182) Example 30: This example includes any or all of the features of example 26, wherein the pin is a spring loaded pin.

(183) Example 31: This example includes any or all of the features of example 25, further including the electronics module including the controller and the pin, wherein: a proximal portion of the sensor element extends from the first cavity through the opening and into the second cavity; and the electronics module is coupled to the second cavity such that at least a proximal portion of the pin contacts the proximal portion of the sensor element.

(184) Example 32: This example includes any or all of the features of example 31, wherein at least a portion of the liquid flow path is defined by an inner wall of the sensor cover.

(185) Example 33: This example includes any or all of the features of example 31, wherein: the sensor cover includes the first cavity and the second cavity; the sensor cover includes a sensor channel around the liquid flow path; and at least a distal portion of the sensor element is disposed in the sensor channel.

(186) Example 34: This example includes any or all of the features of example 33, wherein: the sensor base includes a base cavity; the electronics module includes an electronics base including a first receptacle; the base cavity and the second cavity at least partially define a second receptacle; and the electronics module is coupled to sensor module by coupling the first receptacle to the second receptacle.

(187) Example 35: This example includes any or all of the features of example 34, wherein the electronics module is coupled to the sensor module by receiving the second receptacle in the first receptacle.

(188) Example 36: This example includes any or all of the features of example 31, wherein the sensor element includes a first bend in the first cavity and a second bend in the second cavity.

(189) Example 37: This example includes any or all of the features of example 32, wherein the sensor cover further includes at least one standoff to position the distal portion of the sensor element in the sensor channel.

(190) Example 38: This example includes any or all of the features of example 32, wherein: the sensor cover includes a cover outer wall and a cover inner wall; the cover inner wall defines at least a portion of the liquid flow path; and the at least one divider includes first and second dividers that

each extend from the cover outer wall.

(191) Example 39: This example includes any or all of the features of example 32, wherein the pin is a spring loaded pin.

(192) Example 40: This example includes any or all of the features of example 26, wherein: the sensor cover includes a cover inner wall that defines at least a portion of a cover passageway extending through the sensor cover; at least a portion of the sensor base is disposed through the cover passageway; and at least a portion of the sensor element is disposed between the cover inner wall and an outer wall of the sensor base.

(193) Example 41: This example includes any or all of the features of example 40, wherein the outer wall of the sensor base includes a recessed region and at least a portion of the sensor element is disposed within the recessed region.

(194) Example 42: This example includes any or all of the features of example 41, wherein the outer wall of the sensor base further includes a step proximate the recessed region.

(195) Example 43: This example includes any or all of the features of example 40, wherein the cover inner wall includes a gap, and at least a proximal portion of the sensor element extends through the gap into the first cavity.

(196) Example 44: This example includes any or all of the features of example 43, wherein: the proximal portion of the sensor element is coupled to a sensor printed circuit board including a sensor terminal; and the sensor PCB is configured to align at least the sensor terminal with the opening; and the pin is electrically coupled to the sensor terminal.

(197) Example 45: This example includes any or all of the features of example 44, wherein the pin is a spring loaded pin.

(198) As used herein the term “about” when used in connection with a value or a range, means+/−5% of said value or said range.

(199) “Circuitry”, as used in any embodiment herein, may comprise, for example, singly or in any combination, hardwired circuitry, programmable circuitry such as computer processors comprising one or more individual instruction processing cores, data machine circuitry, software and/or firmware that stores instructions executed by programmable circuitry.

(200) Reference throughout this specification to “one embodiment” or “an embodiment” means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment. Thus, appearances of the phrases “in one embodiment” or “in an embodiment” in various places throughout this specification are not necessarily all referring to the same embodiment. Furthermore, the particular features, structures, or characteristics may be combined in any suitable manner in one or more embodiments.

(201) The terms and expressions which have been employed herein are used as terms of description and not of limitation, and there is no intention, in the use of such terms and expressions, of excluding any equivalents of the features shown and described (or portions thereof), and it is recognized that various modifications are possible within the scope of the claims. Accordingly, the claims are intended to cover all such equivalents. Various features, aspects, and embodiments have been described herein. The features, aspects, and embodiments are susceptible to combination with one another as well as to variation and modification, as will be understood by those having skill in the art. The present disclosure should, therefore, be considered to encompass such combinations, variations, and modifications.

Claims

1. A fluid detection system, comprising: a sensor module comprising: a sensor base; a sensor cover removably coupled to the sensor base; and a sensor element; and a conduit part comprising an outward facing surface and an inward facing surface, the inward facing surface of the conduit part defining at least a portion of said liquid flow path; wherein: the sensor element comprising at least

one continuous conductor configured to detect a capacitance within a liquid flow path from a position outside the liquid flow path and to communicatively couple to a controller of an electronics module comprising a pin, the at least one continuous conductor configured to extend around substantially all of the outward facing surface of the conduit part; and wherein the sensor base and sensor cover at least partially define a passageway through which the conduit part extends, the sensor base or the sensor cover comprising: a first cavity configured to house at least a portion of the sensor element; a second cavity configured to couple with an electronics module; and at least one divider to separate the first cavity from the second cavity, the divider comprising an opening to facilitate coupling of the sensor element with the pin of the electronics module.
2. The fluid detection system of claim 1, further comprising the electronics module comprising said controller and said pin, wherein: the electronics module is coupled to the second cavity; and at least a portion of the pin extends through the opening in the at least one divider to electrically couple to said sensor element.
3. The fluid detection system of claim 2, wherein said pin is a spring loaded pin.
4. The fluid detection system of claim 2, wherein: said sensor cover comprises a cover inner wall that defines at least a portion of a cover passageway extending through the sensor cover; at least a portion of the sensor base is disposed through the cover passageway; and at least a portion of the at least one conductor is disposed between the cover inner wall and an outer wall of the sensor base.
5. The fluid detection system of claim 4, wherein the outer wall of the sensor base comprises a recessed region and at least a portion of the at least one conductor is disposed within the recessed region.
6. The fluid detection system of claim 5, wherein the outer wall of the sensor base further comprises a step proximate the recessed region.
7. The fluid detection system of claim 4, wherein the cover inner wall comprises a gap, and at least a proximal portion of the sensor element extends through the gap into the first cavity.
8. The fluid detection system of claim 7, wherein: the proximal portion of the at least one conductor is coupled to a sensor printed circuit board comprising a sensor terminal; and the sensor PCB is configured to align at least the sensor terminal with the opening; and the pin is electrically coupled to the sensor terminal.
9. The fluid detection system of claim 8, wherein the pin is a spring loaded pin.
10. The fluid detection system of claim 1, wherein the at least one conductor comprises a metal band.
11. The fluid detection system of claim 1, further comprising the electronics module comprising said controller and said pin, wherein: a proximal portion of the sensor element extends from the first cavity through the opening and into the second cavity; and the electronics module is coupled to the second cavity such that at least a proximal portion of the pin contacts the proximal portion of the sensor element.
12. The fluid detection system of claim 11, wherein at least a portion of the liquid flow path is defined by an inner wall of said sensor cover.
13. The fluid detection system of claim 12, wherein the sensor cover further comprises at least one standoff to position the distal portion of the sensor element in the sensor channel.
14. The fluid detection system of claim 12, wherein: the sensor cover comprises a cover outer wall and a cover inner wall; the cover inner wall defines at least a portion of the liquid flow path; and the at least one divider comprises first and second dividers that each extend from the cover outer wall.
15. The fluid detection system of claim 12, wherein said pin is a spring loaded pin.
16. The fluid detection system of claim 11, wherein: said sensor cover comprises the first cavity and the second cavity; the sensor cover comprises a sensor channel around the liquid flow path; and at least a distal portion of the at least one conductor is disposed in the sensor channel.
17. The fluid detection system of claim 16, wherein: the sensor base comprises a base cavity; the

electronics module comprises an electronics base comprising a first receptacle; the base cavity and the second cavity at least partially define a second receptacle; and the electronics module is coupled to sensor module by coupling the first receptacle to the second receptacle.
18. The fluid detection system of claim 17, wherein the electronics module is coupled to the sensor module by receiving the second receptacle in the first receptacle.
19. The fluid detection system of claim 11, wherein the at least one conductor comprises a first bend in the first cavity and a second bend in the second cavity.