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Systems and methods for drain pump operation in washing machine appliances

Abstract

A controller is configured to monitor the pressure measurement of the pressure sensor and record an ambient temperature measurement in response to the pressure measurement stabilizing. Activate the pump and a timer in response to a drain cycle starting. The controller also configured to record a turbidity measurement from the turbidity sensor, a conductivity measurement from the conductivity sensor, and a temperature measurement from the temperature sensor and compare the turbidity measurement to a reference turbidity value, the conductivity measurement to a reference conductivity value, and the temperature measurement to the ambient temperature measurement. Then determine either a presence or an absence of fluid in the wash tub based at least in part on the turbidity measurement, the conductivity measurement, and the temperature measurement, and deactivate the pump in response to either the timer expiring or the determination of the absence of fluid in the wash tub.

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Background/Summary

FIELD OF THE INVENTION
(1) The present subject matter relates generally to operation of a drain pump in washing machine appliances.
BACKGROUND OF THE INVENTION
(2) Washing machine appliances generally include a wash tub for containing water or wash fluid (e.g., water, detergent, bleach, or other wash additives). A basket is rotatably mounted within the wash tub and defines a wash chamber for receipt of articles for washing. During normal operation of such washing machine appliances, the wash fluid is directed into the wash tub and onto articles within the wash chamber of the basket. The basket or an agitation element can rotate at various speeds to agitate articles within the wash chamber, to wring wash fluid from articles within the wash chamber, etc.
(3) Washing machine appliances can operate in numerous cycles. For example, the typical washing machine appliance may be operable in various wash cycles, rinse cycles, drain cycles, and spin cycles. In the wash cycle, the wash fluid is directed into the wash tub and onto articles within the wash chamber of the basket. The rinse cycle includes rinsing the articles in the wash tub, e.g., with fresh water. The drain cycle is used in between different cycles to drain the wash fluid out of the wash tub. In each of the cycles, fluid may be present in the tub of the washing machine appliance, and proper operation of the washing machine may rely upon knowing how much fluid, if any, is in the tub.
BRIEF DESCRIPTION OF THE INVENTION
(4) Aspects and advantages of the invention will be set forth in part in the following description, or may be apparent from the description, or may be learned through practice of the invention.
(5) In one example embodiment, a washing machine appliance includes a cabinet, a wash tub positioned within the cabinet, and a wash basket rotatably mounted within the wash tub. The wash basket is accessible through an opening in the cabinet. A pump is configured to remove fluid from the wash tub, and a pressure sensor is disposed at the wash tub. A turbidity sensor, a conductivity sensor, and a temperature sensor are disposed in the cabinet, and a controller is in signal communication with the pressure sensor, the turbidity sensor, the conductivity sensor and the temperature sensor. The controller is configured to monitor the pressure measurement of the pressure sensor and record an ambient temperature measurement in response to the pressure measurement stabilizing. Activate the pump and a timer in response to a drain cycle starting. The controller is also configured to record a turbidity measurement from the turbidity sensor, a

conductivity measurement from the conductivity sensor, and a temperature measurement from the temperature sensor and compare the turbidity measurement to a reference turbidity value, the conductivity measurement to a reference conductivity value, and the temperature measurement to the ambient temperature measurement. Then determine either a presence or an absence of fluid in the wash tub based at least in part on the turbidity measurement, the conductivity measurement, and the temperature measurement, and deactivate the pump in response to either the timer expiring or the determination of the absence of fluid in the wash tub.
(6) In another example embodiment, a method of operating a washing machine appliance. The washing machine appliance includes a cabinet, a wash tub positioned within the cabinet, and a wash basket rotatably mounted within the wash tub. The wash basket is accessible through an opening in the cabinet. A pump is configured to remove fluid from the wash tub, and a pressure sensor is disposed at the wash tub. A turbidity sensor, a conductivity sensor, and a temperature sensor are disposed in the cabinet, and a controller is in signal communication with the pressure sensor, the turbidity sensor, the conductivity sensor and the temperature sensor. The method includes monitoring, by the controller, the pressure measurement of the pressure sensor and recording, at the controller, an ambient temperature measurement in response to the pressure measurement stabilizing. Then activating, by the controller, the pump and a timer in response to a drain cycle starting, and recording, at the controller, a turbidity measurement from the turbidity sensor, a conductivity measurement from the conductivity sensor, and a temperature measurement from the temperature sensor. Then comparing, by the controller, the turbidity measurement to a reference turbidity value, the conductivity measurement to a reference conductivity value, and the temperature measurement to the ambient temperature measurement, and determining, by the controller, either a presence or an absence of fluid in the wash tub based at least in part on the turbidity measurement, the conductivity measurement, and the temperature measurement. Then, deactivating, by the controller, the pump in response to either the timer expiring or the determination of the absence of fluid in the wash tub.
(7) These and other features, aspects and advantages of the present invention will become better understood with reference to the following description and appended claims. The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate embodiments of the invention and, together with the description, serve to explain the principles of the invention.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) A full and enabling disclosure of the present invention, including the best mode thereof, directed to one of ordinary skill in the art, is set forth in the specification, which makes reference to the appended figures.
(2) FIG. **1** provides a perspective view of a washing machine appliance according to example embodiments of the present disclosure.
(3) FIG. **2** provides a sectional elevation view of the example washing machine appliance of FIG. **1**.
(4) FIG. **3** provides an example table of values stored on a controller of the example washing machine appliance of FIG. **1**.
(5) FIG. **4** provides an example method of operating the example washing machine appliance of FIG. **1**.
(6) FIG. **5** provides an example method of operating the example washing machine appliance of FIG. **1**.
(7) Repeat use of reference characters in the present specification and drawings is intended to

represent the same or analogous features or elements of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

(8) Reference now will be made in detail to embodiments of the invention, one or more examples of which are illustrated in the drawings. Each example is provided by way of explanation of the invention, not limitation of the invention. In fact, it will be apparent to those skilled in the art that various modifications and variations can be made in the present invention without departing from the scope of the invention. For instance, features illustrated or described as part of one embodiment can be used with another embodiment to yield a still further embodiment. Thus, it is intended that the present invention covers such modifications and variations as come within the scope of the appended claims and their equivalents.

(9) As used herein, the term "or" is generally intended to be inclusive (i.e., "A or B" is intended to mean "A or B or both"). The phrase "in one embodiment," does not necessarily refer to the same embodiment, although it may. The terms "first," "second," and "third" may be used interchangeably to distinguish one component from another and are not intended to signify location or importance of the individual components. The terms "upstream" and "downstream" refer to the relative flow direction with respect to fluid flow in a fluid pathway. For example, "upstream" refers to the flow direction from which the fluid flows, and "downstream" refers to the flow direction to which the fluid flows.

(10) Turning now to the figures, FIGS. **1** and **2** provide separate views of a washing machine appliance **50** according to example embodiments of the present disclosure. As shown, washing machine appliance **50** generally defines a vertical direction V, a lateral direction L, and a transverse direction T. The vertical direction V, lateral direction L, and transverse direction T are each mutually perpendicular and form an orthogonal direction system. Washing machine appliance **50** may include a cabinet **52** and a cover **54**. A backsplash **56** extends from cover **54**, and a control panel **58**, including a plurality of input selectors **60**, is coupled to backsplash **56**.

(11) Control panel **58** and input selectors **60** collectively form a user interface input for operator selection of machine cycles and features, and in one example embodiment, a display **61** indicates selected features, a countdown timer, or other items of interest to machine users. It should be appreciated, however, that in other example embodiments, the control panel **58**, input selectors **60**, and display **61**, may have any other suitable configuration. For example, in other example embodiments, one or more of the input selectors **60** may be configured as manual "push-button" input selectors, or alternatively may be configured as a touchscreen (e.g., on display **61**).

(12) A **7** **62** may be mounted to cover **54** and rotatable between an open position (not shown) facilitating access to a tub, also referred to as a wash tub, **64** located within cabinet **52** and a closed position (FIG. **1**) forming an enclosure over tub **64**. Lid **62** in example embodiment includes a transparent panel **63**, which may be formed of, for example, glass, plastic, or any other suitable material. The transparency of the panel **63** allows users to see through the panel **63**, and into the tub **64** when the lid **62** is in the closed position. In some example embodiments, the panel **63** itself can generally form the lid **62**. In other example embodiments, the lid **62** includes the panel **63** and a frame **65** surrounding and encasing the panel **63**. Alternatively, panel **63** need not be transparent.

(13) As may be seen in FIG. **2**, tub **64** includes a bottom wall **66** and a sidewall **68**. A wash drum or basket **70** is rotatably mounted within tub **64**. In particular, basket **70** is rotatable about a central axis, which may when properly balanced and positioned in the example embodiment illustrated be a vertical axis. Thus, washing machine appliance is generally referred to as a vertical axis washing machine appliance or a top load washing machine appliance. Basket **70** defines a wash chamber **73** for receipt of articles for washing and extends, for example, vertically, between a bottom portion **80** and a top portion **82**. Basket **70** includes a plurality of openings or perforations **71** therein to facilitate fluid communication between an interior of basket **70** and tub **64**.

(14) A nozzle **72** is configured for flowing a liquid into tub **64**. In particular, nozzle **72** may be positioned at or adjacent to top portion **82** of basket **70**. Nozzle **72** may be in fluid communication

with one or more water sources **76**, **77** in order to direct liquid (e.g., water) into tub **64** or onto articles within chamber **73** of basket **70**. Nozzle **72** may further include apertures **88** through which water may be sprayed into the tub **64**. Apertures **88** may, for example, be tubes extending from the nozzles **72** as illustrated, or simply holes defined in the nozzles **72** or any other suitable openings through which water may be sprayed. Nozzle **72** may additionally include other openings, holes, etc. (not shown) through which water may be flowed (i.e., sprayed or poured) into the tub **64**.

(15) Various valves may regulate the flow of fluid through nozzle **72**. For example, a flow regulator may be provided to control a flow of hot or cold water into the wash chamber of washing machine appliance **50**. For the example embodiment depicted, the flow regulator includes a hot water valve **74** and a cold water valve **75**. The hot and cold water valves **74**, **75** are used to flow hot water and cold water, respectively, therethrough. Each valve **74**, **75** can selectively adjust to a closed position in order to terminate or obstruct the flow of fluid therethrough to nozzle **72**. The hot water valve **74** may be in fluid communication with a hot water source **76**, which may be external to the washing machine appliance **50**. The cold water valve **75** may be in fluid communication with a cold water source **77**, which may be external to the washing machine appliance **50**. The cold water source **77** may, for example, be a commercial water supply, while the hot water source **76** may be, for example, a water heater. Such water sources **76**, **77** may supply water to the appliance **50** through the respective valves **74**, **75**. A hot water conduit **78** and a cold water conduit **79** may supply hot and cold water, respectively, from the sources **76**, **77** through the respective valves **74**, **75** and to the nozzle **72**.

(16) An additive dispenser **84** may additionally be provided for directing a wash additive, such as detergent, bleach, liquid fabric softener, etc., into the tub **64**. For example, dispenser **84** may be in fluid communication with nozzle **72** such that water flowing through nozzle **72** flows through dispenser **84**, mixing with wash additive at a desired time during operation to form a liquid or wash fluid, before being flowed into tub **64**. For the example embodiment depicted, nozzle **72** is a separate downstream component from dispenser **84**. In other example embodiments, however, nozzle **72** and dispenser **84** may be integral, with a portion of dispenser **84** serving as the nozzle **72**, or alternatively dispenser **84** may be in fluid communication with only one of hot water valve **74** or cold water valve **75**. In still other example embodiments, the washing machine appliance **50** may not include a dispenser, in which case a user may add one or more wash additives directly to wash chamber **73**. A pump assembly **90** (shown schematically in FIG. **2**) is located beneath tub **64** and basket **70** for gravity assisted flow to drain tub **64**.

(17) An agitation element **92** may be oriented to rotate about the rotation axis A (e.g., parallel to the vertical direction V). Generally, agitation element **92** includes an impeller base **120** and extended post **130**. The agitation element **92** depicted is positioned within the basket **70** to impart motion to the articles and liquid in the chamber **73** of the basket **70**. More particularly, the agitation element **92** depicted is provided to impart downward motion of the articles along the rotation axis A. For example, with such a configuration, during operation of the agitation element **92** the articles may be moved downwardly along the rotation axis A at a center of the basket **70**, outwardly from the center of basket **70** at the bottom portion **80** of the basket **70**, then upwardly along the rotation axis A towards the top portion **82** of the basket **70**.

(18) In optional example embodiments, basket **70** and agitation element **92** are both driven by a motor **94**. Motor **94** may, for example, be a pancake motor, direct drive brushless motor, induction motor, or other motor suitable for driving basket **70** and agitation element **92**. As motor output shaft **98** is rotated, basket **70** and agitation element **92** are operated for rotatable movement within tub **64** (e.g., about rotation axis A). Washing machine appliance **50** may also include a brake assembly (not shown) selectively applied or released for respectively maintaining basket **70** in a stationary position within tub **64** or for allowing basket **70** to spin within tub **64**.

(19) Various sensors may additionally be included in the washing machine appliance **50**. For example, a pressure sensor **110** may be positioned in the tub **64** as illustrated or, alternatively, may

be remotely mounted in another location within the appliance **50** and be operationally connected to tub **64** by a hose (not shown). Any suitable pressure sensor **110**, such as an electronic sensor, a manometer, or another suitable gauge or sensor, may be used. The pressure sensor **110** may generally measure the pressure of water in the tub **64**. This pressure can then be used to estimate the height or amount of water in the tub **64**. Pump **90** may be configured to operate in response to pressure sensor **101** measuring a water level exceeding a limit value, e.g., a maximum fill value. In other words, controller **100** may be configured to operate pump **90** to remove fluid from tub **64**. Additionally, a suitable speed sensor can be connected to the motor **94**, such as to the output shaft **98** thereof, to measure speed and indicate operation of the motor **94**. Other suitable sensors, such as temperature sensors, water sensors, moisture sensors, etc., may additionally be provided in the washing machine appliance **50**.

(20) Operation of washing machine appliance **50** is controlled by a processing device or controller **100**, that is operatively coupled to the input selectors **60** located on washing machine backsplash **56** for user manipulation to select washing machine cycles and features. Controller **100** may further be operatively coupled to various other components of appliance **50**, such as the flow regulator (including valves **74**, **75**), motor **94**, pressure sensor **110**, other suitable sensors, etc. In response to user manipulation of the input selectors **60**, controller **100** may operate the various components of washing machine appliance **50** to execute selected machine cycles and features.

(21) While described in the context of specific example embodiments of washing machine appliance **50**, using the teachings disclosed herein it will be understood that washing machine appliance **50** is provided by way of example only. Other washing machine appliances having different configurations, different appearances, or different features may also be used with the present subject matter as well.

(22) In addition to pressure sensor **110**, washing machine appliance **50** may include various other sensors, e.g., a turbidity sensor **132**, a conductivity sensor **134**, and a temperature sensor **136**. Each of turbidity sensor **132**, conductivity sensor **134**, and temperature sensor **136** may be configured for signal communication with controller **100**, e.g., sending measurement data or signals to controller **100**. In some example embodiments, turbidity sensor **132**, conductivity sensor **134**, and temperature sensor **136** may be combined in any combination to reduce to the total number of sensors in washing machine appliance **50**. Further, turbidity sensor **132**, conductivity sensor **134**, and temperature sensor **136** may be positioned in tub **64**, e.g., on a bottom wall **66** of tub **64**.

(23) Controller **100** of washing machine appliance **50** may be configured to monitor, e.g., continuously, a pressure measurement of pressure sensor **110**. The pressure measurement may be indicative of the height of the fluid in tub **64**. Pressure sensor **110** may read values continuously, e.g., the values incrementally increase as the height of the fluid within tub **64** increases. Before filling tub **64** with fluid, controller **100** may record an ambient temperature measurement in response to the pressure measurement stabilizing, e.g., before washing machine appliance **50** begins operating, the ambient temperature measurement may be recorded. During a drain cycle of washing machine appliance **50**, controller **100** may be configured to record a turbidity measurement from turbidity sensor **132**, a conductivity measurement from conductivity sensor **134**, and a temperature measurement from temperature sensor **136**. These turbidity, conductivity, and temperature measurements may be recorded in response to the pressure measurement further incrementing, e.g., the pressure measurement may be incrementally increasing when the pressure measurement is not expected to incrementally increase.

(24) When the various measurements are recorded, controller **100** may be configured to compare the turbidity measurement to a reference turbidity value, the conductivity measurement to a reference conductivity value, and the temperature measurement to the ambient temperature measurement. As seen in table **300** of FIG. **3**, when fluid is present in tub **64**, turbidity sensor **132** may record a turbidity measurement between eight-hundred and one-thousand one-hundred Nephelometric Turbidity units (800 NTU-1100 NTU), conductivity sensor **134** may record a

conductivity measurement between four hundred and two hundred micro-Siemens per centimeter (400 μS/cm-200 μS/cm), and temperature sensor **136** may record a temperature measurement between thirty-five degrees Celsius and thirty-eight degrees Celsius (35° C.-38° C.). When fluid is not present in tub **64**, turbidity sensor **132** may record a turbidity measurement between zero and four hundred Nephelometric Turbidity units (0 NTU-400 NTU), conductivity sensor **134** may record a conductivity measurement of zero μS/cm (0 μS/cm), and temperature sensor **136** may record a temperature measurement between twenty degrees Celsius and twenty-three degrees Celsius (20° C.-23° C.).

(25) With table **300** of FIG. **3** stored in the memory of controller **100**, controller **100** may determine a presence of fluid in tub **64** via the values of the turbidity measurement, the conductivity measurement, and the temperature measurement. In the situation where the pressure measurement is incrementally increasing and it is determined that there is no fluid in tub **64**, controller **100** may terminate operation of washing machine appliance **50**, because pressure sensor may be broken. For example, following the drain cycle of washing machine appliance **50**, there may be no water in tub **64**, but pressure sensor **110** may still be incrementing the pressure measurement. The turbidity measurement, conductivity measurement, and temperature measurement may verify the presence, or absence, of water in tub **64**. In response to no water being in tub **64**, controller **100** may then terminate the operation of washing machine appliance **50**. The extraneous incrementation of the pressure measurement may be indicative of failure of pressure sensor **110**. Thus, controller **100** may be configured to notify a user that the pressure sensor **110** may have failed and may not be working properly.

(26) Shown in FIG. **4**, method **400** provides a method of operating washing machine appliance **50**. At **410**, controller **100** of washing machine appliance **50** may continuously monitor the pressure measurement of pressure sensor **110**. The pressure measurement may be indicative of the height of the fluid in tub **64**. Pressure sensor **110** may read values continuously, e.g., the values incrementally increase as the height of the fluid within tub **64** increases. Before filling tub **64** with fluid, at **420** controller **100** may record an ambient temperature measurement in response to the pressure measurement stabilizing, e.g., before washing machine appliance **50** begins operating, the ambient temperature measurement may be recorded. During the drain cycle of washing machine appliance **50**, e.g., at **430**, controller **100** may record a turbidity measurement from turbidity sensor **132**, a conductivity measurement from conductivity sensor **134**, and a temperature measurement from temperature sensor **136**. These measurements may be recorded in response to the pressure measurement further incrementing, e.g., the pressure measurement may be incrementally increasing when the pressure measurement is not expected to increase.

(27) When the various measurements are recorded, controller **100** may, at **440**, compare the turbidity measurement to a reference turbidity value, the conductivity measurement to a reference conductivity value, and the temperature measurement to the ambient temperature measurement. Thus at **460**, controller **100** may determine the presence of fluid in tub **64** via the values of the turbidity measurement, the conductivity measurement, and the temperature measurement. As stated above, table **300** of FIG. **3** may be stored in the memory of controller **100** and provides the reference values for the turbidity measurement, the conductivity measurement, and the temperature measurement with respect to the presence of fluid in tub **64**.

(28) Referring again to FIGS. **1-3**, washing machine appliance **50** may be configured to operate pump **90** to drain fluid from tub **64**, e.g., during the drain cycle. The drain cycle may include a timer during which pump **90** operates. The length of time of the timer may be determined by an algorithm that includes fill height (FHt), time (T), and constant values such as a buffer time constant (BC), a time to reach coefficient (TC), and a fill height coefficient (FC). Thus, the algorithm may be:

Length of Timer=$BC+(TC*T)+(FC*FHt)$

The algorithm described above is provided by way of example only and may include more or less variables in other example embodiments. In addition to the timer, pump **90** may also be deactivated in response to the determination that there is no fluid in tub **64** for a set length of time via turbidity sensor **132**, conductivity sensor **134**, and temperature sensor **136**. The set length of time of determining no fluid in tub **64** may be at least five seconds.

(29) Shown in FIG. **5**, method **500** provides a method of operating washing machine appliance **50**. At **510**, controller **100** may monitor the pressure measurement of the pressure sensor. Then at **520**, controller **100** may record an ambient temperature measurement in response to the pressure measurement stabilizing. At **530** controller **100** may activate pump **90** and the timer to start the drain cycle. At **540**, controller **100** may record a turbidity measurement from turbidity sensor **132**, a conductivity measurement from conductivity sensor **134**, and a temperature measurement from temperature sensor **136**. Then at **550**, controller **100** may compare the turbidity measurement to a reference turbidity value, the conductivity measurement to a reference conductivity value, and the temperature measurement to the ambient temperature measurement. Based on the comparison, at **560** controller **100** may determine one of a presence or an absence of fluid in tub **64**. Based on the determination, at **570** controller **100** may deactivate pump **90** in response to either the timer expiring or the determination of the absence of fluid in tub **64**.

(30) FIGS. **4** and **5** depict steps performed in a particular order for purposes of illustration and discussion. Those of ordinary skill in the art, using the disclosures provided herein, will understand that the steps of any of the methods discussed herein may be adapted, rearranged, expanded, omitted, or modified in various ways without deviating from the scope of the present disclosure. Moreover, although aspects of method **400** and method **500** are explained using washing machine appliance **50** as an example, it should be appreciated that these methods may be applied to the operation of any suitable appliance.

(31) This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they include structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

Claims

1. A washing machine appliance comprising: a cabinet; a wash tub positioned within the cabinet; a wash basket rotatably mounted within the wash tub and accessible through an opening in the cabinet; a pump configured to remove fluid from the wash tub; a pressure sensor disposed at the wash tub; a turbidity sensor, a conductivity sensor and a temperature sensor disposed in the cabinet; a controller in signal communication with the pump, the pressure sensor, the turbidity sensor, the conductivity sensor, and the temperature sensor, the controller configured to monitor a pressure measurement of the pressure sensor while the wash tub fills with water, record an ambient temperature measurement from the temperature sensor in response to the monitored pressure measurement stabilizing, wherein the wash tub is filled with water, activate the pump and a timer in response to a drain cycle starting, record a turbidity measurement from the turbidity sensor, a conductivity measurement from the conductivity sensor, and a temperature measurement from the temperature sensor, compare the turbidity measurement to a reference turbidity value, the conductivity measurement to a reference conductivity value, and the temperature measurement to the ambient temperature measurement, determine either a presence or an absence of fluid in the wash tub based at least in part on the turbidity measurement, the conductivity measurement, and the temperature measurement, and deactivate the pump in response to either the timer expiring or

the determination of the absence of fluid in the wash tub.
2. The washing machine appliance of claim 1, wherein the controller is configured to operate the pump in response to the pressure measurement exceeding a limit value.
3. The washing machine appliance of claim 1, wherein the reference turbidity value and the reference conductivity value are values stored in a memory of the controller.
4. The washing machine appliance of claim 1, wherein each of the turbidity sensor, the conductivity sensor, and the temperature sensor are disposed at a bottom portion of the wash tub.
5. The washing machine appliance of claim 1, wherein the washing machine is a top load washing machine appliance.
6. The washing machine appliance of claim 1, wherein the turbidity sensor, the conductivity sensor, and the temperature sensor are combined within a single sensor assembly.
7. The washing machine appliance of claim 1, wherein a length of the timer is calculated by an algorithm that comprises a plurality of constant values that are each a respective factor of a fill height measured by the pressure sensor and elapsed time.
8. The washing machine appliance of claim 1, wherein the controller is configured to determine the absence of fluid in the wash tub in response to the turbidity measurement being less than the reference turbidity value, the conductivity measurement being less than the reference conductivity value, and the temperature measurement being different than the ambient temperature measurement for a set length of time.
9. The washing machine appliance of claim 8, wherein the set length of time is no less than five seconds.
10. A method of operating a washing machine appliance, the washing machine appliance comprising a cabinet, a wash tub positioned within the cabinet, a wash basket rotatably mounted within the wash tub and accessible through an opening in the cabinet, a pump configured to remove fluid from the wash tub, a pressure sensor disposed at the wash tub, the pressure sensor configured to continuously record a pressure measurement, a turbidity sensor, a conductivity sensor, and a temperature sensor disposed in the cabinet, a controller in signal communication with the pressure sensor, the turbidity sensor, the conductivity sensor and the temperature sensor, the method comprising: monitoring, by the controller, the pressure measurement of the pressure sensor while the wash tub fills with water, recording, at the controller, an ambient temperature measurement from the temperature sensor in response to the pressure measurement stabilizing, wherein the wash tub is filled with water, activating, by the controller, the pump and a timer in response to a drain cycle starting, recording, at the controller, a turbidity measurement from the turbidity sensor, a conductivity measurement from the conductivity sensor, and a temperature measurement from the temperature sensor, comparing, by the controller, the turbidity measurement to a reference turbidity value, the conductivity measurement to a reference conductivity value, and the temperature measurement to the ambient temperature measurement, determining, by the controller, either a presence or an absence of fluid in the wash tub based at least in part on the turbidity measurement, the conductivity measurement, and the temperature measurement, and deactivating, by the controller, the pump in response to either the timer expiring or the determination of the absence of fluid in the wash tub.
11. The method of claim 10, further comprising operating, by the controller, the pump in response to the pressure sensor measurement exceeding a limit value.
12. The method of claim 10, wherein the reference turbidity value and the reference conductivity value are values stored in a memory of the controller.
13. The method of claim 10, wherein each of the turbidity sensor, the conductivity sensor and the temperature sensor are disposed at bottom portion of the wash tub.
14. The method of claim 10, wherein the washing machine is a top load washing machine appliance.
15. The method of claim 10, wherein the turbidity sensor, the conductivity sensor, and the

temperature sensor are combined within a single sensor assembly.
16. The method of claim 10, wherein a length of the timer is calculated by an algorithm that comprises a plurality of constant values that are each a respective factor of a fill height measured by the pressure sensor and elapsed time.
17. The method of claim 10, wherein the controller is configured to determine the absence of fluid in the wash tub in response to the turbidity measurement being less than the reference turbidity value, the conductivity measurement being less than the reference conductivity value, and the temperature measurement being different than the ambient temperature measurement for a set length of time.
18. The method of claim 17, wherein the set length of time is no less than five seconds.