DESCRIPTION

METHODS AND APPARATUS FOR CALORIMETRIC VERIFICATION

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of priority of U.S. provisional patent application no. 62/568,090, titled "Methods and Apparatus for Calorimetric Verification," filed on October 4, 2017, which is incorporated herein in its entirety by this reference.

TECHNICAL FIELD

[0002] Embodiments described herein relate generally to systems and methods for measuring quantities of heat, and more specifically, to measuring the amount of excess heat generated during an exothermic reaction.

BACKGROUND

[0003] An exothermic reaction is a reaction that generates heat as a result of chemical, nuclear, or other type of reactions. The amount of heat generated during an exothermic reaction can differ by one or two orders of magnitude depending on the type of reaction. For example, the amount of heat generated during a chemical reaction is normally on the same scale as the energy of a chemical bond, which is around 10-100 kJ/mol. By comparison, the amount of heat generated by a nuclear reaction normally is on the scale of 1000 MJ/mol. For example, in the following fusion reaction, 23.85 MeV energy is generated when two deuterium atoms combine to form helium, which amounts to 2300 MJ/mol: $^{2}D + {}^{2}D = {}^{4}He$.

[0004] In many cases, calorimetry techniques are used to determine what type of reactions have taken place or are taking place inside a reaction vessel or a sample. This is done using a calorimeter. Depending on the types of reaction or the quantities of heat generated during the reaction, calorimeters of different capacities and/or sensitivities may be needed. For example, a calorimeter designed for a chemical reaction should produce a reading when the amount of input heat is in the range of kilojoules. On the other hand, the requirements for a calorimeter designed for a naturally occurring nuclear-decay process would be quite different.

[0005] There are a number of well-known calorimeters, such as Calvet-type calorimeters, constant-pressure calorimeters, and heat-flow calorimeters. These types of calorimeters are widely used, for example, in research and/or industrial applications. In the realm of naturally occurring nuclear-decay processes, however, existing calorimeters are not sensitive to the typical thermal energy generation rate in a naturally occurring nuclear reaction. In addition, existing calorimeters may not provide reliable indications of the type of nuclear reactions taking place inside a reaction chamber or vessel.

[0006] Accordingly, a need exists for an improved calorimeter that accurately measures the quantity of heat generated during an exothermic nuclear reaction and that can be used to ascertain the type of exothermic nuclear reaction based on the measured quantity of heat.

SUMMARY

[0007] The present invention provides apparatuses and methods for an improved calorimeter that accurately measures the quantity of heat generated during an exothermic nuclear reaction and that can be used to ascertain the type of exothermic nuclear reactions based on the measured quantity of heat. A calorimeter in accordance with the present invention includes a reservoir and a tank with a reactor. The calorimeter includes a fluid that is pumped such that it circulates between the reservoir and the tank while passing through a volume flow rate gauge, a pressure sensor, and a temperature sensor at the inlet to the tank and the outlet to the tank.

[0008] According to one embodiment of the present invention, a calorimeter that measures the quantity of excess heat generated during an exothermic nuclear reaction is disclosed. The calorimeter includes a tank filled with a fluid that has an associated specific heat. The calorimeter further includes a pump, wherein the pump circulates the fluid at a flow rate. The calorimeter further includes a reactor within the tank for containing the exothermic nuclear reaction. The calorimeter further includes a reservoir filled with the fluid, wherein the reservoir includes a reservoir temperature sensor and a temperature regulator that maintains a constant temperature in the reservoir. The calorimeter is communicatively coupled to a data logger. The excess heat generated during the exothermic nuclear reaction is calculated as $((Tout\text{-}Tin) * F * C) - Qloss$.

[0009] In one embodiment, the calorimeter further includes an inlet volume flow rate gauge that measures the flow rate of the fluid as it enters the tank, an inlet pressure sensor that measure the pressure of the fluid as it enters the tank, and an inlet temperature sensor that measures the temperature of the fluid as it enters the tank.

[0010] In one embodiment, the calorimeter further includes an outlet volume flow rate gauge that measures the flow rate of the fluid as it exits the tank, an outlet pressure sensor that measure the pressure of the fluid as it exits the tank, and an outlet temperature sensor that measures the temperature of the fluid as it exits the tank.

[0011] In one embodiment of the calorimeter, the tank includes a plurality of tank top temperature sensors and a plurality of tank bottom temperature sensors.

[0012] In one embodiment of the calorimeter, the tank includes a tank pressure sensor.

[0013] In one embodiment, the calorimeter further includes an ambient temperature sensor.

[0014] In one embodiment, the calorimeter further includes a humidity sensor.

[0015] In one embodiment, the calorimeter further includes a plurality of outside tank temperature sensors.

[0016] In one embodiment, the calorimeter further includes a thermal imagery sensor.

[0017] According to one embodiment of the present invention, a method of calculating excess heat generated during an exothermic nuclear reaction in a calorimeter is disclosed. The method includes circulating a fluid through the calorimeter, wherein the fluid has a specific heat. The method further includes determining a flow rate F of the circulating fluid. The method further includes measuring temperature of the fluid at an inlet to a reactor in the calorimeter (*Tin*). The method further includes performing the exothermic nuclear reaction in the reactor. The method further includes measuring temperature of the fluid at an outlet of the reactor (*Tout*). The method further includes calibrating the calorimeter to determine *Qloss*. The method further includes calculating a rate of process energy output of the calorimeter using the formula ((*Tout* - *Tin*) * *F* * *C*) - *Qloss*.

[0018] In one embodiment of the method of calculating excess heat, the flow rate *F* of the circulating fluid is calculated as *density * velocity * flow area*.

[0019] In one embodiment of the method of calculating excess heat, *Qloss* is calculated as the power lost in the calorimeter.

[0020] In one embodiment, the method further includes holding the temperature of the fluid constant using a temperature regulator in a reservoir of the calorimeter.

[0021] In one embodiment, the method further includes collecting measurements from the calorimeter using a data logger that is communicatively coupled to the calorimeter.

[0022] In one embodiment of the method of calculating excess heat, the calculations are performed using a computer that is communicatively coupled to the calorimeter.

[0023] The features and advantages described in this summary and the following detailed description are not all-inclusive. Many additional features and advantages will be apparent to one of ordinary skill in the art in view of the drawings, specification, and claims presented herein.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] The present embodiments are illustrated by way of example and are not intended to be limited by the figures of the accompanying drawings. In the drawings:

[0025] FIG. 1 depicts an exemplary calorimeter in accordance with the present disclosure.

[0026] FIG. 2 depicts a flowchart for an exemplary process of measuring dissipated heat in a reactor within a calorimeter.

DETAILED DESCRIPTION

[0027] The following description and figures are illustrative and are not to be construed as limiting. Numerous specific details are described to provide a thorough understanding of the disclosure. In certain instances, however, well-known or conventional details are not described in order to avoid obscuring the description. References to “one embodiment” or “an embodiment” in the present disclosure may be (but are not necessarily) references to the same embodiment, and such references mean at least one of the embodiments.

[0028] Reference in 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 of the disclosure. The appearances of the phrase “in one embodiment” in various places in the specification are not necessarily all referring to the same embodiment, nor are separate or alternative embodiments mutually exclusive of other embodiments. Moreover, various features are described which may be exhibited by some embodiments and not by others. Similarly, various requirements are described which may be requirements for some embodiments but not for other embodiments.

[0029] The terms used in this specification generally have their ordinary meanings in the art, within the context of the disclosure, and in the specific context where each term is used. Certain terms that are used to describe the disclosure are discussed below, or elsewhere in the specification, to provide additional guidance to the practitioner regarding the description of the disclosure. It will be appreciated that same thing can be said in more than one way.

[0030] Alternative language and synonyms may be used for any one or more of the terms discussed herein, nor is any special significance to be placed upon whether or not a term is elaborated or discussed herein. Synonyms for certain terms are provided. A recital of one or more synonyms does not exclude the use of other synonyms. The use of examples anywhere in this specification, including examples of any terms discussed herein, is illustrative only, and is not intended to further limit the scope and meaning of the disclosure or of any exemplified term. Likewise, the disclosure is not limited to various embodiments given in this specification.

[0031] Without intent to limit the scope of the disclosure, examples of instruments, apparatus, methods and their related results according to the embodiments of the present disclosure are given below. Note that titles or subtitles may be used in the examples for convenience of a reader, which in no way should limit the scope of the disclosure. Unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this disclosure pertains. In the case of conflict, the present document, including definitions, will control.

[0032] As will be described in greater detail below with reference to the figures, the subject matter described herein provides new apparatuses and methods for an improved calorimeter that accurately measures the quantity of heat generated during an exothermic nuclear reaction and that can be used to ascertain the type of exothermic nuclear reactions based on the measured quantity of heat.

[0033] FIG. 1 depicts an exemplary calorimeter in accordance with the present disclosure.

[0034] Referring to FIG. 1, the calorimeter 100 is a reusable calorimeter that can be used to test, run, and/or maintain various reactor designs, materials, loading methods, and trigger methods.

[0035] The calorimeter 100 shown in FIG. 1 includes a reactor 113. The reactor 113 is within a tank 101. The tank 101 is insulated and at a constant pressure. The tank 101 contains a fluid 121.

[0036] In one embodiment, the fluid 121 is distilled water. In one embodiment, the reactor 113 is up to 12 inches in length and 2 inches in diameter. In one embodiment, the reactor 113 may support up to a 10,000 VDC triggering voltage differential. In one embodiment, the reactor 113 is electrically insulated from the calorimeter body. In one embodiment, the calorimeter body is floating (i.e., ungrounded). In one embodiment, the dielectric barrier between the calorimeter body and the reactor body supports a minimum of 20,000 VDC triggering voltage up to a maximum of 1 Watt. The reactor 113 may be in various types of designs, such as, for example, aqueous, semi-aqueous, and/or solid-state electrolytic Pd/D2 reactors, within the scope of this disclosure.

[0037] The fluid 121 has a specific heat of C. The fluid 121 with a specific heat of C surrounds the reactor 113 in the insulated, constant-pressure tank 101.

[0038] The tank 101 includes multiple temperature sensors that are used for performing calorimetry. For example, the tank 101 includes at least two temperature sensors inside the tank at the top of the tank (e.g., tank top temperature sensors 112) and at least two temperature sensors inside the tank at the bottom of the tank (e.g., tank bottom temperature sensors 114). In addition, the tank 101 includes a tank pressure sensor 119 that measures the tank pressure (i.e., the pressure inside the tank). The tank 101 may include an opening that allows for a stirrer 122 to be inserted into the fluid 121. The stirrer 121 is optional for the calorimeter. The tank 101 includes a pressure blow-off valve 123.

[0039] The calorimeter 100 includes a temperature sensor 111, pressure sensor 110, and volume flow rate gauge 109 at the inlet. These calorimeter inlet sensors measure the properties of the fluid as it flows into the calorimeter. These calorimeter inlet sensors are communicatively coupled to data logger 115. In one embodiment, the inlet temperature of the calorimeter, as measured at inlet temperature sensor 111, measures between 1 and 25 degrees Celsius.

[0040] The calorimeter 100 includes a temperature sensor 102, pressure sensor 103, and volume flow rate gauge 104 at the outlet. These calorimeter outlet sensors measure the properties of the fluid 121 as it flows out of the calorimeter 100. These calorimeter outlet sensors are communicatively coupled to data logger 115. In one embodiment, the maximum outlet temperature of the calorimeter 100, as measured at outlet temperature sensor 102, measures around 90 degrees Celsius. In one embodiment, the outlet flow gauge 104 may further include an inline turbine, in which case the calorimeter 101 may also work for a closed circuit inline power generator and control (e.g., if the reactor is an electrolytic reactor with a 20:1 output:input ratio).

[0041] The calorimeter 100 includes a reservoir 105. Reservoir 105 is a recirculating fluid reservoir. The temperature of the fluid 121 in the recirculating fluid reservoir 105 must be constant. Reservoir 105 includes a temperature sensor 107 and a temperature regulator 106. The temperature regulator 106 maintains a constant temperature of the fluid 121 in the reservoir 105. The temperature regulator 106 monitors the temperature of fluid 121 and either heats or cools the fluid, as necessary, to maintain the fluid at a constant temperature. The temperature at which the fluid is held constant is determined by the calorimeter. The temperature sensor 107 is communicatively coupled to data logger 115.

[0042] As shown by the flow arrow 124 in FIG. 1, the fluid 121 within the calorimeter 100 circulates in a clockwise direction. As the fluid flows out of the tank 101, it flows through the outlet temperature sensor 102, the outlet pressure sensor 103, and the outlet volume flow rate gauge 104 and into the reservoir 105. The outlet temperature sensor 102, the outlet pressure sensor 103, and the outlet volume flow rate gauge 104 are communicatively to data logger 115.

[0043] As shown by the flow arrow 124 in FIG. 1, the fluid 121 flows out of the reservoir 105 through pump 108. Pump 108 pumps the fluid from the reservoir 105 to the tank 101, keeping the fluid moving in the clockwise direction. Pump 108 has a mass flow rate of the fluid going in and the fluid going out that is calculated as *density* * *velocity* * *flow area*.

[0044] The fluid 121 from pump 108 flows through the inlet temperature sensor 111, the inlet pressure sensor 110, and the inlet volume flow rate gauge 109 before entering the tank 101, as shown in FIG. 1. The inlet temperature sensor 121, the inlet pressure sensor 110, and the inlet volume flow rate gauge 109 are connected to data logger 115.

[0045] For each of the inlet and outlet temperature sensors, pressure sensors, and volume flow rate gauges, the operating range, accuracy, and tolerance may be determined. In one embodiment, these values may be determined through analysis. In another embodiment, these values may be determined from the hardware specifications of the sensors. In another embodiment, these values may be determined from a combination of analysis and hardware specifications.

[0046] The calorimeter 100 includes at least four outside tank temperature sensors (e.g., temperature sensors 119) outside of the insulated surface of the calorimeter body. These temperature sensors measure the temperature outside of the tank 101.

[0047] The calorimeter 100 includes at least four temperature sensors that measure the ambient temperature of the calorimeter (e.g., temperature sensors 117).

[0048] The calorimeter 100 may include a thermal imagery sensor 120. The thermal imagery sensor 120 is optional, and may be used for qualitative measurement. It allows a user of the calorimeter to view thermal images of a reaction. In addition, it allows for computer analysis of the thermal images of the reaction to increase the accuracy of the calorimeter 100.

[0049] The calorimeter 100 may include a humidity sensor 118. The humidity sensor 118 is optional, and may be used to sense the humidity in the calorimeter 100. An analysis of the impact of humidity on the error in the heat transfer to ambient air may be performed using the humidity sensor 118.

[0050] The various sensors and gauges of the calorimeter 100 include a digital interface, an analog interface, or both. The interface, whether digital or analog, allows the sensors to communicate with data logger 115 and/or computer 116, or both.

[0051] The sensors and gauges in the calorimeter 100 are communicatively coupled to a data logger 115 and/or a computer 116. For example, the reservoir temperature sensor 107, inlet flow gauge 109, inlet pressure sensor 110, inlet temperature sensor 111, tank top sensors 112, tank pressure sensor 119, tank bottom temperature sensors 114, outlet temperature sensor 102, outlet pressure sensor 103, outlet flow gauge 104, ambient temperature sensor 117, humidity sensor 118, outside tank temperature sensors 119, and thermal imagery sensor 120 may be communicatively coupled to the data logger 115. In addition, the reservoir temperature sensor 107 and the pump 108 may be communicatively coupled to the computer 116.

[0052] The data logger records readings from the sensor and gauges to which it is communicatively coupled. The data logger may be a standalone unit, or it may be a piece of software running on computer 116. In one embodiment, the data logger 115 and the computer 116 are communicatively coupled to one another. The computer 116 may be a general-purpose computer, or a specifically designed computer for operating the calorimeter 100. The computer 116 may be used to perform the calculations necessary to determine the heat generated in the calorimeter. In addition, the computer 116 may be used to control the sensors and gauges to which it is communicatively coupled. For example, the computer 116 may be used to adjust the flow of the pump 108 by sending commands to the pump.

[0053] The calorimeter in accordance with the present disclosure should be tested to verify that it does not leak. The testing is performed to verify that the measurements of flow-in and flow-out are consistent with each other.

[0054] FIG. 2 depicts a flowchart for an exemplary process of measuring dissipated heat in a reactor within a calorimeter.

[0055] Referring to FIG. 2, the process begins at step 201, where fluid is circulated through the calorimeter. As explained in the context of FIG. 1, the fluid being circulated has a specific heat denoted by C. The circulation of the fluid is performed using a pump with a flow rate denoted by F, as explained above.

[0056] At step 202, the flow rate of the circulating fluid is calculated. In one embodiment, the flow rate of the circulating fluid is calculated as F from the pump that is doing the circulating. In another embodiment, the flow rate is calculated by taking into account the volume flow rate of the fluid as measured at the inlet to the tank and/or reactor as well as the volume flow rate of the fluid as measured at the outlet of the tank and/or reactor.

[0057] At step 203, the fluid temperature is measured at the inlet of the tank and/or reactor. This measurement may be measured using a temperature sensor at the inlet. In one embodiment, this measurement may further take into account the temperature of the fluid as measured by various temperature sensors located at the top of the tank and/or temperature sensors located at the bottom of the tank.

[0058] At step 204, an exothermic reaction is performed in the reactor.

[0059] At step 205, the fluid temperature is measured at the outlet of the tank and/or reactor. This measurement may be measured using a temperature sensor at the outlet. In one embodiment, this measurement may further take into account the temperature of the fluid as measured by various temperature sensors located at the top of the tank and/or temperature sensors located at the bottom of the tank.

[0060] At step 206, the calorimeter is calibrated to determine a *Qloss* value. The *Qloss* value represents the amount of power lost in the calorimeter, and the calibration of the system allows for calculation of power lost in the system, or *Qloss*. The calorimeter is calibrated to ensure accuracy and to provide baseline calibration information. To calibrate the calorimeter, a reactor heater element is used. The calibration is performed across various flow rates and various input powers. The calibration may measure the voltage isolation between the reactor and the calorimeter body.

[0061] In addition, the calorimeter in accordance with the present disclosure may use a robust error-analysis scheme to establish a valid estimate of measurement error. With a valid measurement error established, the calorimeter can adjust any readings to provide an accurate output.

[0062] The calorimeter allows for accurate and precise calibration of the system. In addition, the calorimeter includes a robust error tolerance analysis that can withstand independent review.

[0063] At step 207, the rate of process energy output is calculated. This is performed by measuring the dissipated power in the reactor to compare the dissipated power with the input power to the system. The rate of process energy output of the system is calculated as:

[0064] $\big((Tout - Tin) * F * C\big) - Qloss.$

[0065] In the above equation, *Tout* refers to the outlet temperature, *Tin* refers to the inlet temperature, *F* refers to the mass flow rate of fluid in and out (as explained above), and *C* refers to specific heat of the fluid in the calorimeter.

[0066] In various embodiments, the calculation of the rate of process energy may further take into account ambient temperature, temperature outside the tank, tank pressure, thermal imagery, humidity outside the tank, and any other data values that are measured by the sensors of the calorimeter.

[0067] As will be appreciated by one skilled in the art, aspects of the present invention may be embodied as a system, method or computer program product. Accordingly, aspects of the present invention may take the form of an entirely hardware embodiment, an entirely software embodiment (including firmware, resident software, micro-code, etc.) or an embodiment combining software and hardware aspects that may all generally be referred to herein as a "circuit," "module" or "system." Furthermore, aspects of the present invention may take the form of a computer program product embodied in one or more computer readable medium(s) having computer readable program code embodied thereon.

[0068] Any combination of one or more computer readable medium(s) may be utilized. The computer readable medium may be a computer readable signal medium or a computer readable storage medium (including, but not limited to, non-transitory computer readable storage media). A computer readable storage medium may be, for example, but not limited to, an electronic, magnetic, optical, electromagnetic, infrared, or semiconductor system, apparatus, or device, or any suitable combination of the foregoing. More specific examples (a non-exhaustive list) of the computer readable storage medium would include the following: an electrical connection having one or more wires, a portable computer diskette, a hard disk, a random access memory (RAM), a read-only memory (ROM), an erasable programmable read-only memory (EPROM or Flash memory), an optical fiber, a portable compact disc read-only memory (CD-ROM), an optical storage device, a USB storage device, a magnetic storage device, cloud-based storage (such as servers accessible through an internet connection like WiFi or cellular connectivity) or any suitable combination of the foregoing. In the context of this document, a computer readable storage medium may be any tangible medium that can contain, or store a program for use by or in connection with an instruction execution system, apparatus, or device.

[0069] A computer readable signal medium may include a propagated data signal with computer readable program code embodied therein, for example, in baseband or as part of a carrier wave. Such a propagated signal may take any of a variety of forms, including, but not limited to, electro-magnetic, optical, or any suitable combination thereof. A computer readable signal medium may be any computer readable medium that is not a computer readable storage medium and that can communicate, propagate, or transport a program for use by or in connection with an instruction execution system, apparatus, or device.

[0070] Program code embodied on a computer readable medium may be transmitted using any appropriate medium, including but not limited to wireless, wireline, optical fiber cable, RF, etc., or any suitable combination of the foregoing.

[0071] Computer program code for carrying out operations for aspects of the present invention may be written in any combination of one or more programming languages, including object oriented and/or procedural programming languages. Programming languages may include, but are not limited to: Ruby®, JavaScript®, Java®, Python®, PHP, C, C++, C#, Objective-C®, Go®, Scala®, Swift®, Kotlin®, OCaml®, assembly language and/or native computer code, or the like. The program code may execute entirely on the user's computer, partly on the user's computer, as a stand-alone software package, partly on the user's computer, and partly on a remote computer or entirely on the remote computer or server. In the latter situation scenario, the remote computer may be connected to the user's computer through any type of network, including a local area network (LAN) or a wide area network (WAN), or the connection may be made to an external computer (for example, through the Internet using an Internet Service Provider).

[0072] Aspects of the present invention are described below reference to flowchart illustrations and/or block diagrams of methods, apparatus (systems) and computer program products according to embodiments of the invention. It will be understood that each block of the flowchart illustrations and/or block diagrams, and combinations of blocks in the flowchart illustrations and/or block diagrams, can be implemented by computer program instructions.

[0073] These computer program instructions may be provided to a processor of a general purpose computer, special purpose computer, or other programmable data processing apparatus to produce a machine, such that the instructions, which execute via the processor of the computer or other programmable data processing apparatus, create means for implementing the functions/acts specified in the flowchart and/or block diagram block or blocks.

[0074] These computer program instructions may also be stored in a computer readable medium that can direct a computer, other programmable data processing apparatus, or other devices to function in a particular manner, such that the instructions stored in the computer readable medium produce an article of manufacture including instructions which implement the function/act specified in the flowchart and/or block diagram block or blocks.

[0075] The computer program instructions may also be loaded onto a computer, other programmable data processing apparatus, or other devices to cause a series of operational steps to be performed on the computer, other programmable apparatus or other devices to produce a computer implemented process such that the instructions which execute on the computer or other programmable apparatus provide processes for implementing the functions/acts specified in the flowchart and/or block diagram block or blocks.

[0076] The flowchart and block diagrams in the figures illustrate the architecture, functionality, and operation of possible implementations of systems, methods and computer program products according to various embodiments of the present invention. In this regard, each block in the flowchart or block diagrams may represent a module, segment, or portion of code, which comprises one or more executable instructions for implementing the specified logical function(s). It should also be noted, in some alternative implementations, the functions noted in the block may occur out of the order noted in the figures. For example, two blocks shown in succession may, in fact, be executed substantially concurrently, or the blocks may sometimes be executed in the reverse order, depending upon the functionality involved. It will also be noted that each block of the block diagrams and/or flowchart illustration, and combinations of blocks in the block diagrams and/or flowchart illustration, can be implemented by special purpose hardware-based systems that perform the specified functions or acts, or combinations of special purpose hardware and computer instructions.

[0077] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the invention. As used herein, the singular forms “a,” “an” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms “comprises” and/or “comprising,” when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

[0078] The corresponding structures, materials, acts, and equivalents of all means or step plus function elements in the claims below are intended to include any structure, material, or act for performing the function in combination with other claimed elements as specifically claimed. The description of the present invention has been presented for purposes of illustration and description, but is not intended to be exhaustive or limited to the invention in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art without departing from the scope and spirit of the invention. The embodiment was chosen and described in order to best explain the principles of the invention and the practical application, and to enable others of ordinary skill in the art to understand the invention for various embodiments with various modifications as are suited to the particular use contemplated.

[0079] The descriptions of the various embodiments of the present invention have been presented for purposes of illustration, but are not intended to be exhaustive or limited to the embodiments disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art without departing from the scope and spirit of the described embodiments. The terminology used herein was chosen to best explain the principles of the embodiments, the practical application or technical improvement over technologies found in the marketplace, or to enable others of ordinary skill in the art to understand the embodiments disclosed herein.

CLAIMS

What is claimed is:

1. A calorimeter that measures the quantity of excess heat generated during an exothermic nuclear reaction, comprising:

a tank filled with a fluid that has an associated specific heat;

a pump, wherein the pump circulates the fluid at a flow rate;

a reactor within the tank for containing the exothermic nuclear reaction; and

a reservoir filled with the fluid, wherein the reservoir includes a reservoir temperature sensor and a temperature regulator that maintains a constant temperature in the reservoir;

wherein the calorimeter is communicatively coupled to a data logger; and

wherein the excess heat generated during the exothermic nuclear reaction is calculated as $\left((Tout - Tin) * F * C\right) - Qloss$.

2. The calorimeter of claim 1, further comprising:

an inlet volume flow rate gauge that measures the flow rate of the fluid as it enters the tank;

an inlet pressure sensor that measure the pressure of the fluid as it enters the tank; and

an inlet temperature sensor that measures the temperature of the fluid as it enters the tank.

3. The calorimeter of claim 2, further comprising:

an outlet volume flow rate gauge that measures the flow rate of the fluid as it exits the tank;

an outlet pressure sensor that measure the pressure of the fluid as it exits the tank; and

an outlet temperature sensor that measures the temperature of the fluid as it exits the tank.

4. The calorimeter of claim 3, wherein the tank includes a plurality of tank top temperature sensors and a plurality of tank bottom temperature sensors.

5. The calorimeter of claim 4, wherein the tank includes a tank pressure sensor.

6. The calorimeter of claim 1, further comprising an ambient temperature sensor.

7. The calorimeter of claim 1, further comprising a humidity sensor.

8. The calorimeter of claim 1, further comprising a plurality of outside tank temperature sensors.

9. The calorimeter of claim 1, further comprising a thermal imagery sensor.

10. A method of calculating excess heat generated during an exothermic nuclear reaction in a calorimeter, comprising:

circulating a fluid through the calorimeter, wherein the fluid has a specific heat;

determining a flow rate F of the circulating fluid;

measuring temperature of the fluid at an inlet to a reactor in the calorimeter (Tin);

performing the exothermic nuclear reaction in the reactor;

measuring temperature of the fluid at an outlet of the reactor ($Tout$);

calibrating the calorimeter to determine $Qloss$; and calculating a rate of process energy output of the calorimeter using the formula

$$\left((Tout - Tin) * F * C\right) - Qloss.$$

11. The method of claim 10, wherein the flow rate *F* of the circulating fluid is calculated as *density* * *velocity* * *flow area*.

12. The method of claim 11, wherein *Qloss* is calculated as the power lost in the calorimeter.

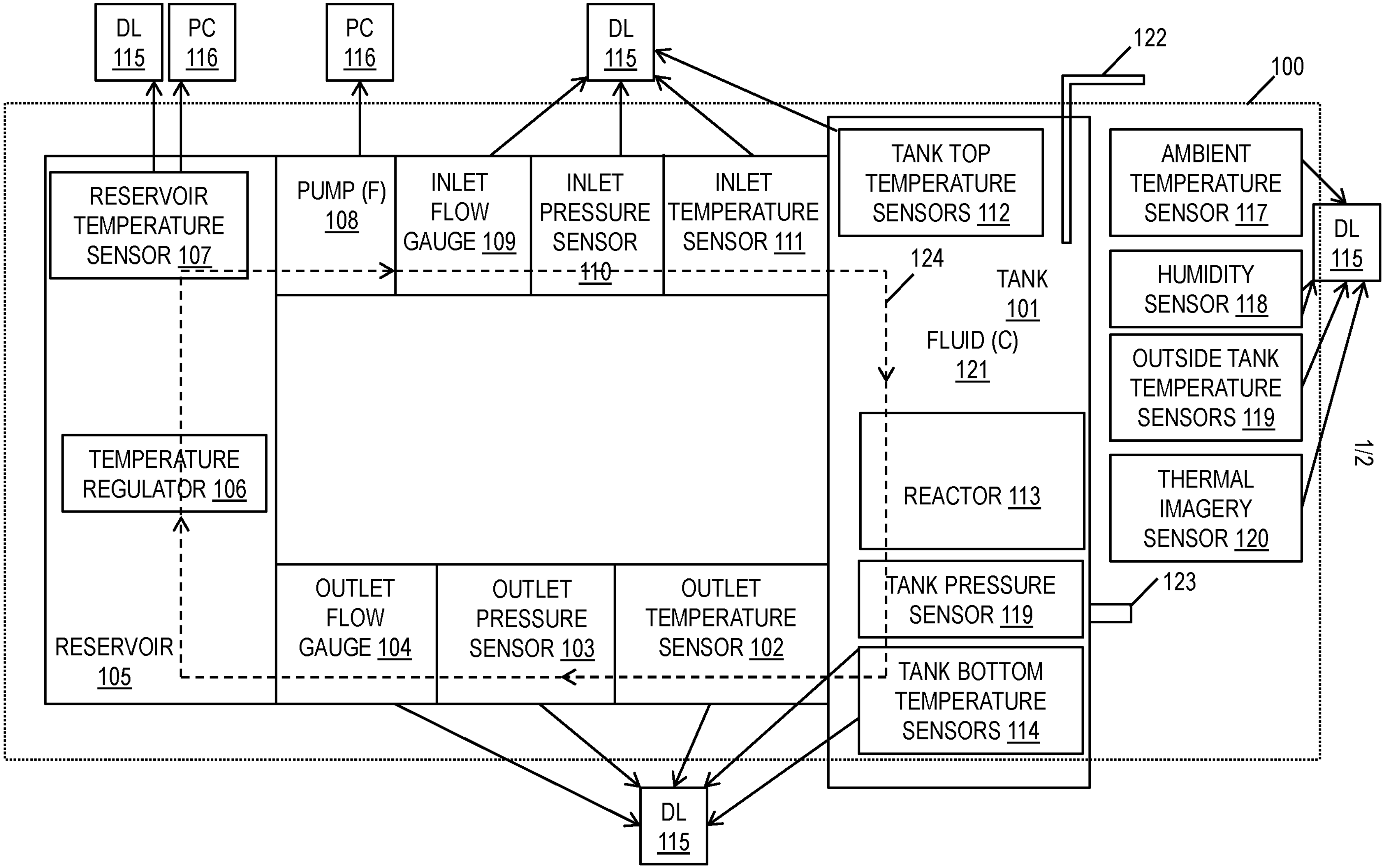
13. The method of claim 10, further comprising holding the temperature of the fluid constant using a temperature regulator in a reservoir of the calorimeter.

14. The method of claim 10, further comprising collecting measurements from the calorimeter using a data logger that is communicatively coupled to the calorimeter.

15. The method of claim 10, wherein the calculations are performed using a computer that is communicatively coupled to the calorimeter.

ABSTRACT

A calorimeter is disclosed that accurately measures the quantity of excess heat generated during an exothermic nuclear reaction and that can be used to ascertain the type of exothermic nuclear reactions based on the measured quantity of heat.


DL 115
PC 116
PC 116
DL 115
122
100
RESERVOIR TEMPERATURE SENSOR 107
PUMP (F) 108
INLET FLOW GAUGE 109
INLET PRESSURE SENSOR 110
INLET TEMPERATURE SENSOR 111
TANK TOP TEMPERATURE SENSORS 112
AMBIENT TEMPERATURE SENSOR 117
HUMIDITY SENSOR 118
OUTSIDE TANK TEMPERATURE SENSORS 119
THERMAL IMAGERY SENSOR 120
DL 115
124
TANK 101
FLUID (C) 121
REACTOR 113
TEMPERATURE REGULATOR 106
TANK PRESSURE SENSOR 119
123
TANK BOTTOM TEMPERATURE SENSORS 114
OUTLET FLOW GAUGE 104
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RESERVOIR 105
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FIG. 1

ATTORNEY DOCKET NO.: 438-9-2 PCT

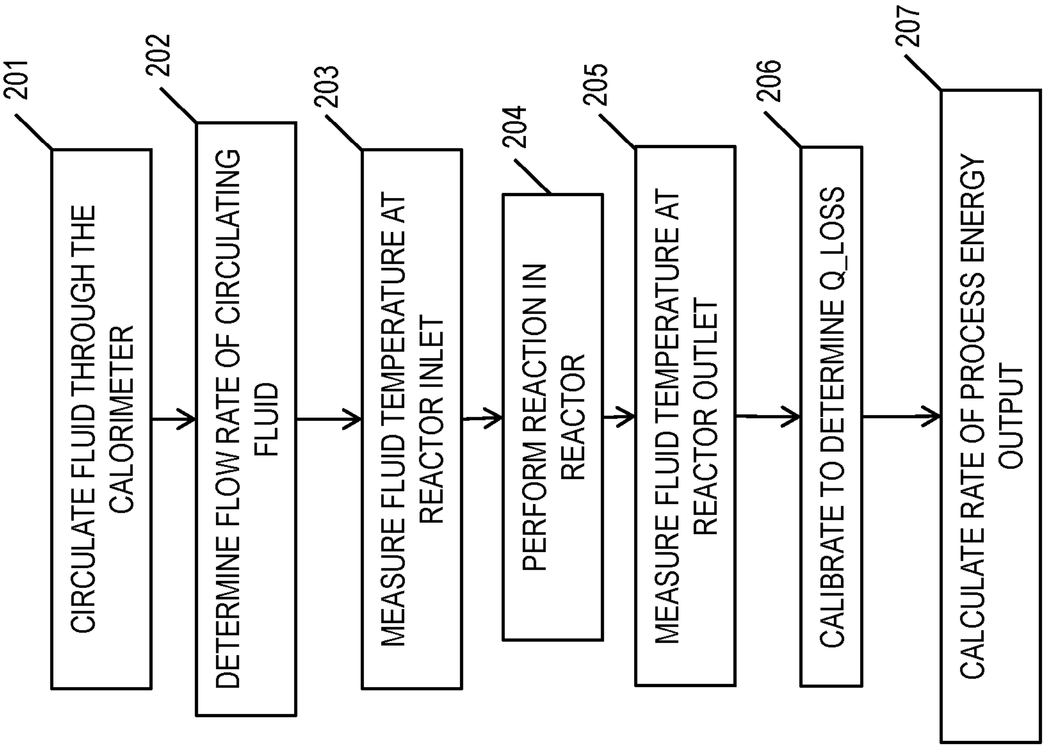

FIG. 2