# CALIBRATION PROCEDURE FOR EXOTHERMIC REACTION CALORIMETER

## FIELD OF INVENTION

**[0001]** The present invention relates generally to calorimetry, and in particular to a calibration procedure for a calorimeter used to measure excess heat generated in an exothermic reaction.

## BACKGROUND

**[0002]** The phenomenon of excess heat generation has been observed when hydrogen/deuterium reaches high loading in a variety of metals or alloys. This excess heat has been attributed to exothermic reactions between occluded nuclei. In one theory, two deuterium nuclei, when trapped in the small confinement inside the metal lattice, have a wide spread of momentum based on the Heisenberg uncertainty principle. The combined probability of two deuterium nuclei having requisite momenta to overcome the Coulomb barrier may become statistically significant, triggering fusion reactions in the trapped deuterium gas. According to a second theory, the two trapped deuterium nuclei overcome the Coulomb barrier by going through a quantum tunnel to reach the lower energy state, i.e., to form a $^{4}He$ nucleus.

**[0003]** One type of exothermic reaction is the so-called Low Energy Nuclear Reaction. Many LENR experiments have been replicated around the world, and numerous different conditions, in which the generation of excess heat can be triggered at will and with control, have been documented. However, the LENRs are not well understood, and are a topic of significant ongoing theoretical and experimental research. A significant impediment to the systematic exploration of such triggering mechanisms is the lack of a consistent, reliable, calibrated means for both detecting and quantifying exothermic reactions.

**[0004]** The background section of this document is provided to place embodiments of the present invention in technological and operational context, to assist those of skill in the art in understanding their scope and utility. Approaches described in the background section could be pursued, but are not necessarily approaches that have been previously conceived or pursued. Unless explicitly identified as such, no statement herein is admitted to be prior art merely by its inclusion in the Background section.

## SUMMARY

**[0005]** The following presents a simplified summary of the disclosure in order to provide a basic understanding to those of skill in the art. This summary is not an extensive overview of the disclosure and is not intended to identify key/critical elements of embodiments of the invention or to delineate the scope of the invention. The sole purpose of this summary is to present some concepts disclosed herein in a simplified form as a prelude to the more detailed description that is presented later.

**[0006]** According to one or more embodiments described and claimed herein, a calorimeter designed to measure the excess heat of an exothermic reaction is carefully calibrated across a range of temperatures bracketing a desired operating temperature. The calorimeter block comprises a metal block holding an exothermic reaction chamber, heating elements, and thermocouples. The block is covered with thermoelectric generators (TEG) operative to output a voltage in response to a temperature difference between a hot side facing the block and a cold side facing away from the block. In some embodiments, heat sinks may cover the TEGs and/or the calorimeter may be disposed in a refrigerated container, both to maintain the TEG cold sides at a constant temperature. The block is heated to a temperature below the operating temperature by adjusting the power applied to heating elements. Once the calorimeter stabilizes at that temperature, as measured by the thermocouple outputs, the power applied to the heating elements is adjusted to bring the block to a higher temperature. This process is repeated throughout the range of temperatures bracketing the desired operating temperature. At regular intervals throughout the calibration procedure, such as every 60 seconds, at least the power

applied to the heating elements and the output voltage of the TEG's are recorded. In some embodiments, the temperature of heat sinks and the temperature in the refrigerated container are also recorded. The data are plotted, and provide a baseline against which changes in the TEG output voltage, caused by a temperature change in the calorimeter block other than a change in the power applied to the heating elements, may be measured and attributed to an exothermic reaction in the reaction chamber.

**[0007]** In another form of calibration procedure, the sensitivity of the calorimeter is ascertained. The intrinsic tolerance of the output voltage of the series-connected TEGs is ascertained. A power level, within the characterized range of the calorimeter, is selected and applied. After stabilization, the TEG output voltage is recorded. This voltage is increased by five times the tolerance to generate a target output voltage. An initial power is applied that generates approximately the target output voltage; the actual initial TEG output voltage is recorded. This initial power is reduced, and after stabilization the resulting TEG output voltage is recorded. The power reduction step is iteratively repeated until the difference between the current TEG output voltage and the initial TEG output voltage (with the initial power applied) is not greater than the TEG output voltage tolerance. The sensitivity of the calorimeter is then the difference between the initial power and the last power resulting in a TEG output voltage delta from the initial voltage that was greater than the output voltage tolerance.

**[0008]** One embodiment relates to a method of calibrating an exothermic reaction chamber calorimeter. The calorimeter comprises a metal block holding an exothermic reaction chamber in a first bore; a plurality of heating elements in a plurality of second bores; and a plurality of thermocouples in a plurality of third bores. Substantially all of the surface of the metal block is covered with thermoelectric generators (TEG) operative to output a voltage in response to a temperature difference between a hot side facing the metal block and a cold side facing away from the metal block. The TEGs are wired in series. With no power applied to the heating elements, a temperature output by each thermocouple and voltage output by the TEGs are recorded as zero-power data points. Power is applied to the heating elements in a sufficient amount to bring the input power to a first predetermined power level, which produces a reactor temperature below a maximum desired operating temperature. The power applied to the heating elements is maintained until the temperatures output by the thermocouples and the voltage output by the TEG's are stable for a first stabilization duration. The power applied to the heating elements is increased by a first delta amount, and that power is maintained until the temperatures output by the thermocouples and the voltage output by the TEG's are stable for the first stabilization duration. These steps are iteratively repeated until the heating elements reach a predetermined maximum applied power, and the outputs of the thermocouples reach thermal equilibrium. Throughout the calibration procedure, beginning with recording the zero-power data points, at each expiration of a predetermined measurement duration, the power applied to the heating elements and the voltage output by the TEG's are recorded.

**[0009]** Another method relates to testing the sensitivity of an exothermic reaction chamber calorimeter. The calorimeter comprises a metal block holding an exothermic reaction chamber in a first bore, a plurality of heating elements in a plurality of second bores, and a plurality of thermocouples in a plurality of third bores. Substantially all of the surface of the metal block IS covered with thermoelectric generators (TEG) operative to output a voltage in response to a temperature difference between a hot side facing the metal block and a cold side facing away from the metal block. The TEG's are wired in series. The sensitivity testing method comprises determining an intrinsic tolerance of the voltage output by the series-connected TEGs; selecting and applying an initial power to the heating elements; maintaining the initial power until the temperatures output by the thermocouples are stable for a stabilization duration, and recording an initial voltage output by the TEGs; applying a first power level greater than the initial power to the heating elements until the temperatures output by the thermocouples are stable for the stabilization duration, and recording the initial power and the current voltage output by the TEGs; reducing the power applied to the heating elements, maintaining the reduced power until the temperatures output by the thermocouples are stable for the stabilization duration, and recording the current voltage output by the TEGs; iteratively repeating the reducing step until the difference between the current voltage output by the TEGs and the voltage output by the TEGs when the initial power was applied, is not greater than the TEG output voltage tolerance; and determining that the difference between the initial power and the last applied power level resulting in a TEG having an output voltage difference from the initial value that is greater than the TEG output voltage tolerance, is the smallest power difference that can be detected by the calorimeter.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0010]** The present invention will now be described more fully hereinafter with reference to the accompanying drawings, in which embodiments of the invention are shown. However, this invention should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Like numbers refer to like elements throughout.

**[0011]** Figure 1 is a functional sectional view of a calorimeter.

**[0012]** Figure 2 is flow chart of a method of calibrating a calorimeter.

**[0013]** Figure 3 is a flow chart of a method of sensitivity testing a calorimeter.

**[0014]** Figure 4 is a flow chart of another method of sensitivity testing a calorimeter.

## DETAILED DESCRIPTION

**[0015]** For simplicity and illustrative purposes, the present invention is described by referring mainly to an exemplary embodiment thereof. In the following description, numerous specific details are set forth in order to provide a thorough understanding of the present invention. However, it will be readily apparent to one of ordinary skill in the art that the present invention may be practiced without limitation to these specific details. In this description, well-known methods and structures have not been described in detail so as not to unnecessarily obscure the present invention.

**[0016]** Figure 1 is a functional section diagram of some parts of a calorimeter 10 operative to measure the excess power of an exothermic reaction, according to one or more embodiments of the present invention. The basis of the calorimeter 10 is a metal block 12, which may for example comprise a copper block 12. A reaction chamber 68, in some experiments surrounded by magnets 70, is disposed in a first bore 14 formed in the block 12. The block 12 is heated to a relatively high temperature, such as 150º - 300º C, by a plurality of heating elements 74, each disposed in a second bore 16. The temperature of the block 12 is monitored by a plurality of thermocouples 76, each disposed in a third bore 18. The thermocouples 76 are referred to herein, for convenience, as outputting a temperature. As used herein, a thermocouple 76 outputting a voltage level, in combination with a conversion to a temperature indication, such as by applying one or more sets of calibration data, falls within the scope of the thermocouple 76 outputting a temperature. A controller 90 receives input from the thermocouples 76, and the heating elements 74 apply electrical power to the block 12 at a variety of power levels resulting in a variety of block temperatures and voltage outputs from the TEG's 20.

**[0017]** In some embodiments, a gas flow manifold 48 controls the pressure and flow of gasses into and out of the reaction chamber 68, facilitating experimentation with various conditions and reaction triggering events. The controller 90 provides high voltage (e.g., 5 kVDC) to an anode in the reaction chamber 68, and in some embodiments may superimpose an RF signal on the voltage.

**[0018]** When an exothermic reaction is triggered in the reaction chamber 68, the excess heat is conducted away by the block 12, raising the temperature of the block 12. This rise in temperature is detected by a plurality of thermoelectric generators (TEG's) 20, which surround the block 12. The TEG's generate a voltage proportional to the temperature difference between a “hot side,” which faces the block 12, and a “cold side,” which faces away from the block 12. Due to the high temperature of the block 12, in one embodiment heat sinks 30 are affixed to the cold side of the TEGs 20 to help cool the cold side, to maintain a thermal differential. In some embodiments, fans (not shown) direct convective cooling air over the fins of the heat sinks 30. In some embodiments, the entire calorimeter 10 may be placed in a refrigerated container (not shown).

**[0019]** The calorimeter 10 must be carefully calibrated to ascertain the relationship between power applied to the heating elements 74 and the output voltage of the series-connected TEG’s 20. Only with this baseline-calibrated relationship, can the excess power of a reaction in the reaction chamber 68 be ascertained, and positively attributed to an exothermic reaction. In general, the calibration procedure comprises two procedures. In a first calibration procedure, the input power to output voltage relationship is measured throughout a range of temperatures that bracket a desired, or targeted, operating temperature. In a second calibration procedure, the sensitivity of the calorimeter is ascertained by, once stabilized at a target temperature, changing the power applied to the heating elements by an incremental amount, such as 1 W, and measuring the change in output voltage of the TEG’s 20. The second calibration procedure may be repeated at a plurality of temperatures throughout the calibrated range.

**[0020]** Figure 2 depicts the first calibration procedure 100. A calorimeter 10 substantially similar to that in Figure 1, and described above, is assumed. An exothermic reaction chamber 68 is placed in the calorimeter 10, and TEG’s 20 and heat sinks 30 cover substantially the entire metal block 12, including the optional lid. The calorimeter 10 is placed in a refrigerated container and its temperature is allowed to stabilize at zero power input. The TEG 20 output voltage should be at or near 0 V. The first calibration procedure begins by recording zero-power data points – that is, the thermocouple 76 temperature outputs and TEG 20 output voltage are recorded with no power being applied to the heating elements 74 (block 102).

**[0021]** Throughout the first calibration procedure, relevant parameters are recorded at regular intervals – that is, each expiration of a predetermined measurement duration (block 104). In one embodiment, the predetermined measurement duration is one minute. The primary parameters to be recorded are the power applied to the heating elements 74, and the output voltage of the TEG's 20, which are related to the temperature difference of the metal block 12 and the heat sinks 30. However, in one embodiment, all parameters are preferably recorded for later analysis. These include, in the relevant experimental configurations, the outputs of each thermocouple 76, the output of a temperature measuring device affixed to heat sinks 30 placed over the cold sides of the TEGs 20, and the ambient temperature inside the refrigerated container.

**[0022]** Sufficient power is then applied to the heating elements 74 to achieve a predetermined input power and temperature level of the metal block 12, as measured by the thermocouples 76.

**[0023]** The power applied to the heating elements 78 is maintained at a constant level until the outputs of the thermocouples 76 are stable for a first stabilization duration (block 108). In one embodiment, the first stabilization duration is the time required for the thermocouple 76 outputs to produce a flat plot with a maximum variation within the intrinsic error of the thermocouples, which is typically +/- 0.1C. In another embodiment, the first stabilization duration may be a predetermined duration, such as 6-8 hours.

**[0024]** The power applied to the heating elements 74 is then increased by a first delta amount (block 110). In one embodiment, the first delta amount is 30 W. The first delta amount increase in power is split evenly among the heating elements 74 – *i.e.*, if four heating elements 74 are utilized, each would receive an increase of 7.5 W. This new power level is maintained for the first stabilization duration (block 110).

**[0025]** This process – increasing the applied power by the first delta amount and maintaining the new power for the first stabilization duration – is repeated iteratively.

Accordingly, electrical power applied to the block 12 will increase in a step-wise fashion. As stated above, all relevant data are recorded at each expiration of a predetermined measurement duration, such as one minute.

**[0026]** This process is continued until the power applied to the heating elements 74 reaches a predetermined maximum applied power level. In one embodiment, the predetermined maximum applied power level is 320 W. The range of temperatures recorded during the calibration should include the minimum and maximum desired operating temperatures.

**[0027]** The first calibration procedure 100 thus produces a quantified relationship between power input to the heating elements 74, and the voltage output of the TEG's 20, as the input power is increased in step-wise fashion by a known amount. Against this calibration data, a small increase in power input is added to the system, producing a large increase in the temperature of the calorimeter block 12 and in the voltage output of the TEG's 20. This triggering mechanism is typically less than 1 watt, representing less than 1% of total input power. This triggering input power is also added to the total electrical input power but is of such a low power level that any significant increase in reactor power output can confidently be attributed to an exothermic reaction in the LENR reaction chamber.

**[0028]** In one embodiment, the first calibration procedure 100 continues, recording data as applied power is decreased. In one embodiment, the power is decreased at each step by a second delta amount, which may be different from the first delta amount of power. In one embodiment, the second delta amount is 15 W. After each decrease in applied power, the new power input level is maintained for a second stabilization duration, which may be different than the first stabilization duration. The second stabilization duration may be the time required for the thermocouple 76 to produce a flat plot with a maximum variation within the intrinsic error of the thermocouples, which is typically +/- 0.1C, or it may be a predetermined duration, such as 6-8 hours. The step-wise decrease in applied power is iteratively repeated until the temperature output by least one of the thermocouples is at or below the first predetermined temperature.

**[0029]** All relevant parameters continue to be recorded at each expiration of a predetermined measurement duration, such as one minute. The relevant parameters include at least the power applied to the heating elements 74 and the output voltage of the TEGs 20. In some embodiments, relevant parameters to be recorded may additionally include the temperature output by each thermocouple 76, the temperature of the heat sinks 30, and the ambient temperature inside the refrigerated container. In one embodiment, throughout the first calibration procedure 100, if the ambient temperature inside the refrigerated container deviates by more than a predetermined ambient temperature deviation limit, the entire first calibration procedure 100 is invalidated. In one embodiment, the predetermined ambient temperature deviation limit is +/-0.2C.

**[0030]** The first calibration procedure 100 yields a rough picture of the relationship between power output by the reaction chamber 68 and the TEG 20 voltage. A best-fit line can be used to ascertain the expected power output of the reaction chamber 68 for a TEG 20 voltage at all power levels within the temperature range over which the first calibration procedure 100 was performed. However, the delta between the measurement is generally high. Accordingly, a user does not know the minimum power difference that can be detected by the calorimeter 10.

**[0031]** The second calibration procedure 200 measures the sensitivity of the calorimeter 10. Figure 3 depicts a flow chart of an exemplary second calibration procedure 200, also referred to herein as a method of calorimeter sensitivity testing. The second calibration procedure 200 quantifies the sensitivity of the calorimeter 10 to small changes in power applied to the heating elements 74 (corresponding to small changes in power output by the reaction chamber 68 in operation).

**[0032]** Initially, the intrinsic tolerance of the TEGs 20 must be ascertained. This can, for example, be found in the device data sheet, in conjunction with a voltmeter. This value should be small, such as on the order of 0.01V. The tolerance on the voltage output of all TEGs 20 connected in series, $V_{TOL}$, is then calculated from this value (block 202). Any voltage change detected in operation must exceed this value $V_{TOL}$ to be reliably ascribed to a change in power input.

**[0033]** The power difference that correlates to the smallest change in voltage that can be detected is then ascertained. An initial power input $P_{START}$ may be arbitrarily chosen, within certain constraints. Based on the data obtained in the first calibration procedure 100, selection of an initial power input level $P_{START}$ will yield an expected temperature and TEG 20 voltage output $V_{OUT\_EXPECTED}$. A 4% increase in the selected input power $P_{START}$ should be within the characterized range (i.e., $P_{START} + 0.04*P_{START} <$ upper limit of characterized range) (block 204).

**[0034]** From the data obtained from the first calibration procedure 100, determine the expected TEGs 20 voltage output $V_{OUT\_EXPECTED}$ at the selected initial power input. Calculate $V_{OUT\_MAX} = V_{OUT\_EXPECTED} + 5*V_{TOL}$. Determine the power input required to achieve $V_{OUT\_MAX}$ on the TEGs 20 (block 206).

**[0035]** The determined input power is then applied to the heating elements 74 as the starting power input (block 208).

**[0036]** The selected starting power input level $P_{START}$ should be applied to the heating elements 74 until the temperature values output by the thermocouples 76 and the voltage output of the TEGs 20 are stable for a third stabilization duration, which may be different than the first or second stabilization durations. The third stabilization duration may be the time required for the thermocouple 76 to produce a flat plot with a maximum variation within the intrinsic error of the thermocouples, which is typically +/- 0.1C, or it may be a predetermined duration, such as 6-8 hours (block 210).

**[0037]** Start values are recorded. The start values include at least the initial power input $P_{START}$, the thermocouple 76 temperature value, and the TEG 20 output voltage $V_{START}$ (block 212).

**[0038]** The power input to the heating elements 74 is then increased slightly (denoted $P_{START+}$), to bring the TEG 20 output voltage to approximately $V_{OUT\_MAX}$ (block 214). High precision in achieving this value is not necessary; it is an upper bound.

**[0039]** This higher input power level $P_{START+}$ is maintained until the temperature values output by the thermocouples 76 and the voltage output of the TEGs 20 are stable for the third stabilization duration (block 216).

**[0040]** The increased power input $P_{START+}$, the thermocouple 76 temperature value, and the TEG 20 output voltage are recorded (block 218).

**[0041]** The second calibration procedure 200 then enters an iterative loop in which changes in applied input power are reduced until the corresponding change in output voltage reaches the discernable limit $V_{TOL}$. At each iteration, the power currently applied to the heating elements 74 is $P_{CURRENT}$ and a new power level to be applied is $P_{NEW}$. At the first iteration, $P_{CURRENT} = P_{START+}$.

**[0042]** At each ensuing iteration, a new input power $P_{NEW}$ is calculated as

$$P_{NEW} = \frac{P_{CURRENT} + P_{START}}{2}$$ (block 220).

**[0043]** The calculated power level $P_{NEW}$ is applied to the heating elements 74 (block 222).

**[0044]** The power $P_{NEW}$ is maintained until the temperature values output by the thermocouples 76, and the voltage output of the TEGs 20, are stable for the third stabilization duration (block 224).

**[0045]** The power $P_{NEW}$, the thermocouple 76 temperature value, and the TEG 20 output voltage are recorded (block 226).

**[0046]** The TEG 20 voltage output difference $V_{DELTA}$ between the current TEG 20 output voltage $V_{OUT}$ and the starting TEG 20 output voltage $V_{START}$ is calculated as $V_{DELTA} = V_{OUT} - V_{START}$ (block 228).

**[0047]** This difference $V_{DELTA}$ is compared to the TEG 20 tolerance $V_{TOL}$ (block 230). If $V_{DELTA} > V_{TOL}$, the second calibration procedure 200 returns to step 220 and calculates a new (smaller) input power $P_{NEW}$. The system stabilizes with this new input power. The difference between TEG 20 output voltage and the start value is again compared to the TEG 20 tolerance, $V_{TOL}$ (blocks 222-230).

**[0048]** If $V_{DELTA} < V_{TOL}$ (block 230), the last power input value resulting in $V_{DELTA} > V_{TOL}$ is retrieved, and denoted $P_{SENSE}$ (block 232).

**[0049]** The smallest power change that the calorimeter 10 can detect, $P_{MIN\_DETECT}$, is then calculated as $P_{MIN\_DETECT} = P_{SENSE} - P_{START}$. (block 234).

**[0050]** $P_{MIN\_DETECT}$ is a measure of the sensitivity of the calorimeter 10. That is, $P_{MIN\_DETECT}$ is the minimum power change that can be reliably detected by a change in output voltage of the TEGs 20.

**[0051]** The second calibration procedure 200 may be performed at a plurality of different sensitivity testing temperatures – for example, below, near or at, and above the desired operating temperature. The calibration curve of the first calibration procedure 100 may be used to select the initial input power $P_{START}$ to yield the desired sensitivity testing temperature.

**[0052]** Embodiments of the present invention provide a means to calibrate an exothermic reaction chamber calorimeter 10, as well as quantify its sensitivity to incremental changes in power input. Both the calibration procedure 100 and the sensitivity testing 200 provide data against which data acquired during LENR experiments may be compared, to verify the presence of exothermic reactions in the LENR reaction chamber.

**[0053]** Figure 4 is a flow chart illustrating an exemplary method 400 for calibrating a calorimeter sensitivity. First, an intrinsic tolerance of the voltage output by the series-connected TEGs 20 is determined (step 402). Then, an initial power is selected and applied to the heating elements (step 404). The initial power is maintained until the temperature output by the thermocouples is stable for a stabilization duration. The initial voltage output is recorded by the TEGs 20 (step 406). Subsequently, a first power level greater than the initial power is applied to the heating elements until the temperature output by the thermocouples are stable for the stabilization duration and the current voltage output by the TEGs 20 is recorded (step 408).

**[0054]** The present invention may, of course, be carried out in other ways than those specifically set forth herein without departing from essential characteristics of the invention. The present embodiments are to be considered in all respects as illustrative and not restrictive, and all changes coming within the meaning and equivalency range of the appended claims are intended to be embraced therein.

**CLAIMS**

What is claimed is:

1. A method of calibrating an exothermic reaction chamber calorimeter, the calorimeter comprising a metal block holding a reaction chamber in a first bore, a plurality of heating elements in a plurality of second bores, and a plurality of thermocouples in a plurality of third bores, thermoelectric generators (TEG's) covering the surface of the metal block operative to output a voltage in response to a temperature difference between a hot side facing the metal block and a cold side facing away from the metal block, the TEGs wired in series, the calibration method comprising:

with no power applied to the heating elements, recording a voltage output by the TEG's as zero-power data points;

iteratively increasing power applied to the heating elements by a first delta amount and maintaining that power until the temperatures output by the thermocouples are stable for a first stabilization duration, and the power applied to the heating elements reaches a predetermined maximum applied power; and

throughout the calibration procedure, beginning with recording the zero-power data points, at each expiration of a predetermined measurement duration, recording the power applied to the heating elements and the voltage output by the TEGs.

2. The method of claim 1 further comprising, following the first stabilization duration for which the temperature output by at least one thermocouple is at or above the second predetermined temperature:

repeatedly decreasing the power applied to the heating elements by a second delta amount and maintaining that power until the temperatures output by the thermocouples are stable for a second stabilization duration, until the temperature output by least one of the thermocouples is at or below the first predetermined temperature.

3. The method of claim 1 wherein increasing the power applied to the heating elements by a first incremental amount and decreasing the power applied to the heating elements by a second incremental amount comprise increasing and decreasing the power applied to each heating element by a proportional amount of the first and incremental amounts, respectively.

4. The method of claim 1 further comprising plotting the TEG output voltage against power applied to the heating elements for each of a plurality of measurement durations.

5. The method of claim 4 wherein plotting the TEG output voltage against power applied to the heating elements comprises plotting the average of TEG output voltage against the average of power applied to the heating elements, the averages calculated over some or all of the first or second stabilization duration.

6. The method of claim 1 wherein the first delta amount of power is 30 W.

7. The method of claim 1 wherein the second delta amount of power is 15 W.

8. The method of claim 1 wherein the predetermined measurement duration is 1 minute.

9. The method of claim 1 wherein the predetermined maximum applied power is 320 W.

10. The method of claim 1 wherein the first stabilization duration is a duration sufficient to observe a maximum variation of +/- 0.1C in temperature output by each thermocouple or +/- 1% the total voltage output by the TEGs.

11. The method of claim 1 wherein the first stabilization duration is 6-8 hours.

12. The method of claim 1 wherein the second stabilization duration is 6-8 hours.

13. The method of claim 1 wherein the calorimeter further comprises heat sinks covering substantially all of the cold sides of the TEGs, at least one heat sink having a temperature measuring device attached thereto, and further comprising, at each expiration of the predetermined measurement duration, recording the temperature of the heat sinks.

14. The method of claim 1 wherein the calorimeter is disposed within a refrigerated container having a temperature measuring device therein, and further comprising, at each expiration of the predetermined measurement duration, recording the temperature of the refrigerated container.

15. The method of claim 13 wherein, if over the course of the calibration method, the temperature of the refrigerated container deviates by a predetermined ambient temperature deviation limit, the calibration is invalidated.

16. The method of claim 14 wherein the predetermined ambient temperature deviation limit is +/- 0.2C.

17. A method of testing the sensitivity of an exothermic reaction chamber calorimeter, the calorimeter comprising a metal block holding an exothermic reaction chamber in a first bore, a plurality of heating elements in a plurality of second bores, and a plurality of thermocouples in a plurality of third bores, substantially all of the surface of the metal block being covered with thermoelectric generators (TEG) operative to output a voltage in response to a temperature difference between a hot side facing the metal block and a cold side facing away from the metal block, the TEG's wired in series, the sensitivity testing method comprising:

determining an intrinsic tolerance of the voltage output by the series-connected TEGs;

selecting and applying an initial power to the heating elements;

maintaining the initial power until the temperatures output by the thermocouples are stable for a stabilization duration, and recording an initial voltage output by the TEGs;

applying a first power level greater than the initial power to the heating elements until the temperatures output by the thermocouples are stable for the stabilization duration, and recording the initial power and the current voltage output by the TEGs;

reducing the power applied to the heating elements, maintaining the reduced power until the temperatures output by the thermocouples are stable for the stabilization duration, and recording the current voltage output by the TEGs;

iteratively repeating the reducing step until the difference between the current voltage output by the TEGs and the voltage output by the TEGs when the initial power was applied, is not greater than the TEG output voltage tolerance; and

determining that the difference between the initial power and the last applied power level resulting in a TEG having an output voltage difference from the initial value that is greater than the TEG output voltage tolerance, is the smallest power difference that can be detected by the calorimeter.

18. The method of claim 17 further comprising repeating the method steps at one or more other initial power levels.

19. The method of claim 18 wherein the initial power levels are selected to generate a thermocouple output below and above a desired operating temperature.

20. The method of claim 17 wherein selecting an initial power comprises selecting a power level such that an increase of four percent of the power is within a calibrated range of power levels.

21. The method of claim 17 wherein the first power level greater than the initial power is the power level corresponding to an increase of five times the intrinsic tolerance of the voltage output by the series-connected TEGs over the TEG voltage output at the initial power level.

22. The method of claim 17, wherein, when the power applied to the heating elements is iteratively reduced, the reduced power for a subsequent iteration is set to the average of the applied power in the current iteration and the initial power.

23. The method of claim 17, wherein the smallest power difference that can be detected by the calorimeter is determined at various power levels.

24. A method of testing the sensitivity of an exothermic reaction chamber calorimeter, the calorimeter comprising a metal block holding an exothermic reaction chamber in a first bore, a plurality of heating elements in a plurality of second bores, and a plurality of thermocouples in a plurality of third bores, substantially all of the surface of the metal block being covered with thermoelectric generators (TEG) operative to output a voltage in response to a temperature difference between a hot side facing the metal block and a cold side facing away from the metal block, the TEG's wired in series, the sensitivity testing method comprising:

determining an intrinsic tolerance of the voltage output by the series-connected TEGs;

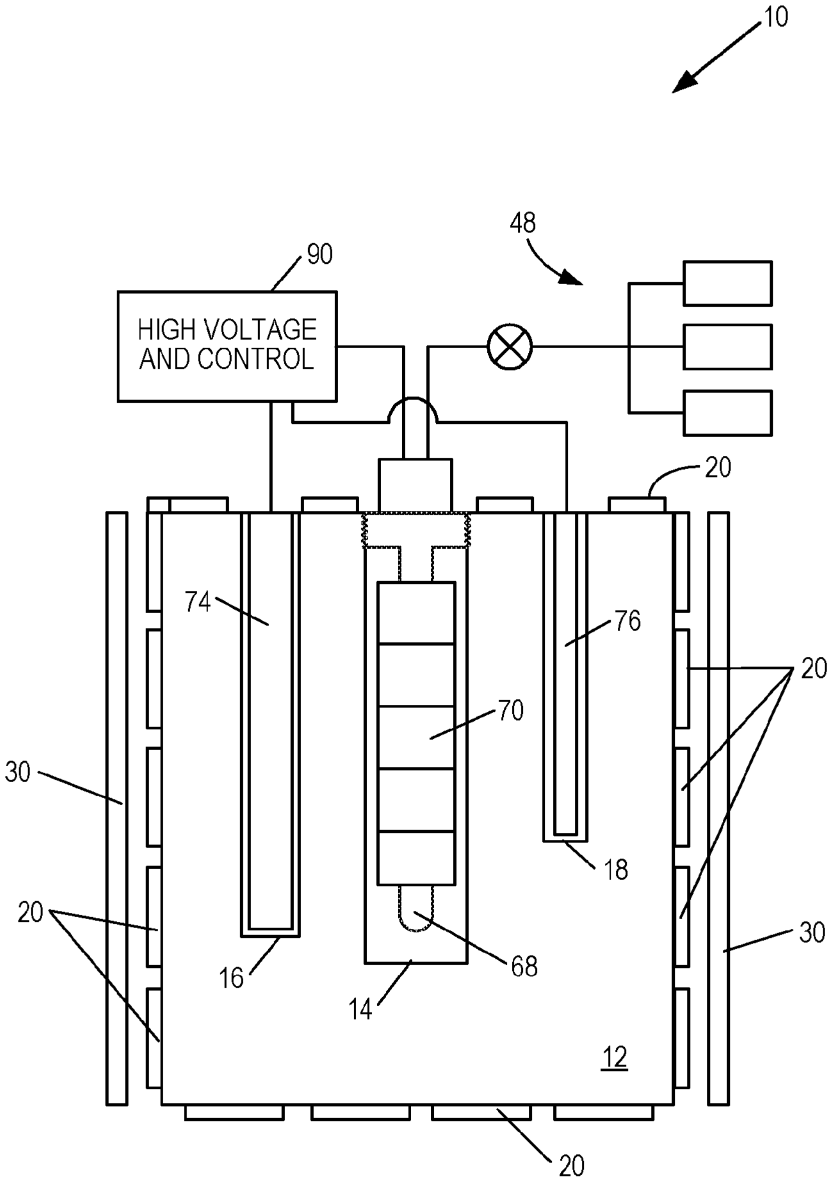
selecting and applying an initial power to the heating elements;

maintaining the initial power until the temperatures output by the thermocouples are stable for a stabilization duration, and recording an initial voltage output by the TEGs;

applying a first power level greater than the initial power to the heating elements until the temperatures output by the thermocouples are stable for the stabilization duration, and recording the initial power and the current voltage output by the TEGs.

## ABSTRACT

A calorimeter designed to measure the excess heat of an exothermic reaction is calibrated across a range of temperatures. The calorimeter comprises a metal block holding a reaction chamber, heating elements, and thermocouples. The block is covered with thermoelectric generators (TEG's) outputting a voltage in response to the block temperature. The block is heated by applying power to the heating elements. Once the calorimeter stabilizes at one temperature, as measured by the thermocouple outputs, the input power is increased to raise the block to a higher temperature. This process is repeated throughout a range of temperatures bracketing a desired operating temperature. At least the applied power and TEG output voltage are recorded at regular intervals (e.g., 1 minute.). The data provide a baseline against which deviations in the TEG output voltage, caused by an exothermic reaction in the LENR reaction chamber, may be measured. Another procedure tests the sensitivity of the calorimeter by determining the smallest increment of input power change that can be detected by the calorimeter and distinguished from device tolerance.


10
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HIGH VOLTAGE
AND CONTROL
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20

FIG. 1

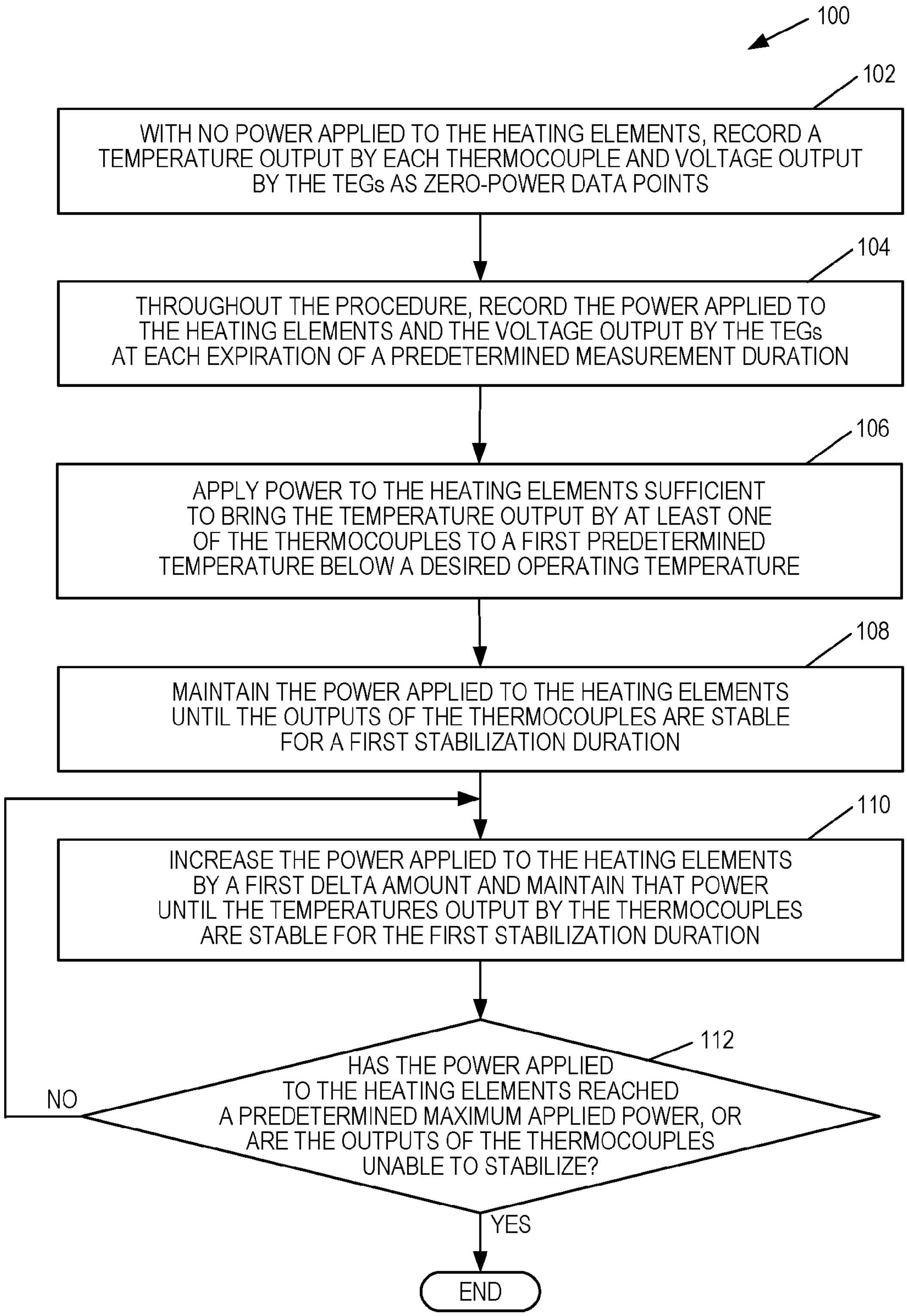
100
102
WITH NO POWER APPLIED TO THE HEATING ELEMENTS, RECORD A TEMPERATURE OUTPUT BY EACH THERMOCOUPLE AND VOLTAGE OUTPUT BY THE TEGs AS ZERO-POWER DATA POINTS
104
THROUGHOUT THE PROCEDURE, RECORD THE POWER APPLIED TO THE HEATING ELEMENTS AND THE VOLTAGE OUTPUT BY THE TEGs AT EACH EXPIRATION OF A PREDETERMINED MEASUREMENT DURATION
106
APPLY POWER TO THE HEATING ELEMENTS SUFFICIENT TO BRING THE TEMPERATURE OUTPUT BY AT LEAST ONE OF THE THERMOCOUPLES TO A FIRST PREDETERMINED TEMPERATURE BELOW A DESIRED OPERATING TEMPERATURE
108
MAINTAIN THE POWER APPLIED TO THE HEATING ELEMENTS UNTIL THE OUTPUTS OF THE THERMOCOUPLES ARE STABLE FOR A FIRST STABILIZATION DURATION
110
INCREASE THE POWER APPLIED TO THE HEATING ELEMENTS BY A FIRST DELTA AMOUNT AND MAINTAIN THAT POWER UNTIL THE TEMPERATURES OUTPUT BY THE THERMOCOUPLES ARE STABLE FOR THE FIRST STABILIZATION DURATION
112
HAS THE POWER APPLIED TO THE HEATING ELEMENTS REACHED A PREDETERMINED MAXIMUM APPLIED POWER, OR ARE THE OUTPUTS OF THE THERMOCOUPLES UNABLE TO STABILIZE?
NO
YES
END

*FIG. 2*

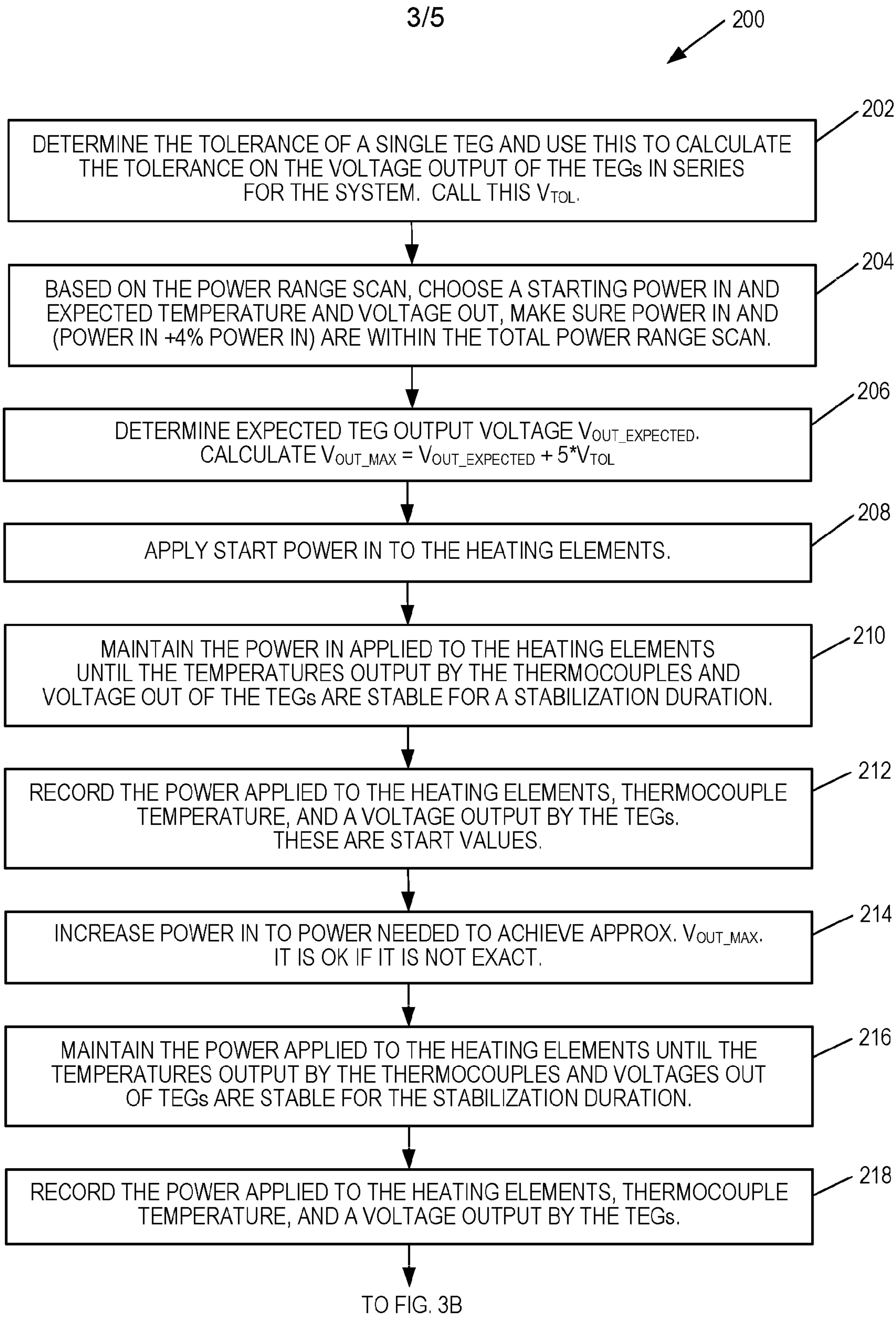
200
202
DETERMINE THE TOLERANCE OF A SINGLE TEG AND USE THIS TO CALCULATE THE TOLERANCE ON THE VOLTAGE OUTPUT OF THE TEGs IN SERIES FOR THE SYSTEM. CALL THIS $V_{TOL}$.
204
BASED ON THE POWER RANGE SCAN, CHOOSE A STARTING POWER IN AND EXPECTED TEMPERATURE AND VOLTAGE OUT, MAKE SURE POWER IN AND (POWER IN +4% POWER IN) ARE WITHIN THE TOTAL POWER RANGE SCAN.
206
DETERMINE EXPECTED TEG OUTPUT VOLTAGE $V_{OUT\_EXPECTED}$. CALCULATE $V_{OUT\_MAX} = V_{OUT\_EXPECTED} + 5*V_{TOL}$
208
APPLY START POWER IN TO THE HEATING ELEMENTS.
210
MAINTAIN THE POWER IN APPLIED TO THE HEATING ELEMENTS UNTIL THE TEMPERATURES OUTPUT BY THE THERMOCOUPLES AND VOLTAGE OUT OF THE TEGs ARE STABLE FOR A STABILIZATION DURATION.
212
RECORD THE POWER APPLIED TO THE HEATING ELEMENTS, THERMOCOUPLE TEMPERATURE, AND A VOLTAGE OUTPUT BY THE TEGs. THESE ARE START VALUES.
214
INCREASE POWER IN TO POWER NEEDED TO ACHIEVE APPROX. $V_{OUT\_MAX}$. IT IS OK IF IT IS NOT EXACT.
216
MAINTAIN THE POWER APPLIED TO THE HEATING ELEMENTS UNTIL THE TEMPERATURES OUTPUT BY THE THERMOCOUPLES AND VOLTAGES OUT OF TEGs ARE STABLE FOR THE STABILIZATION DURATION.
218
RECORD THE POWER APPLIED TO THE HEATING ELEMENTS, THERMOCOUPLE TEMPERATURE, AND A VOLTAGE OUTPUT BY THE TEGs.
TO FIG. 3B

***FIG. 3A***

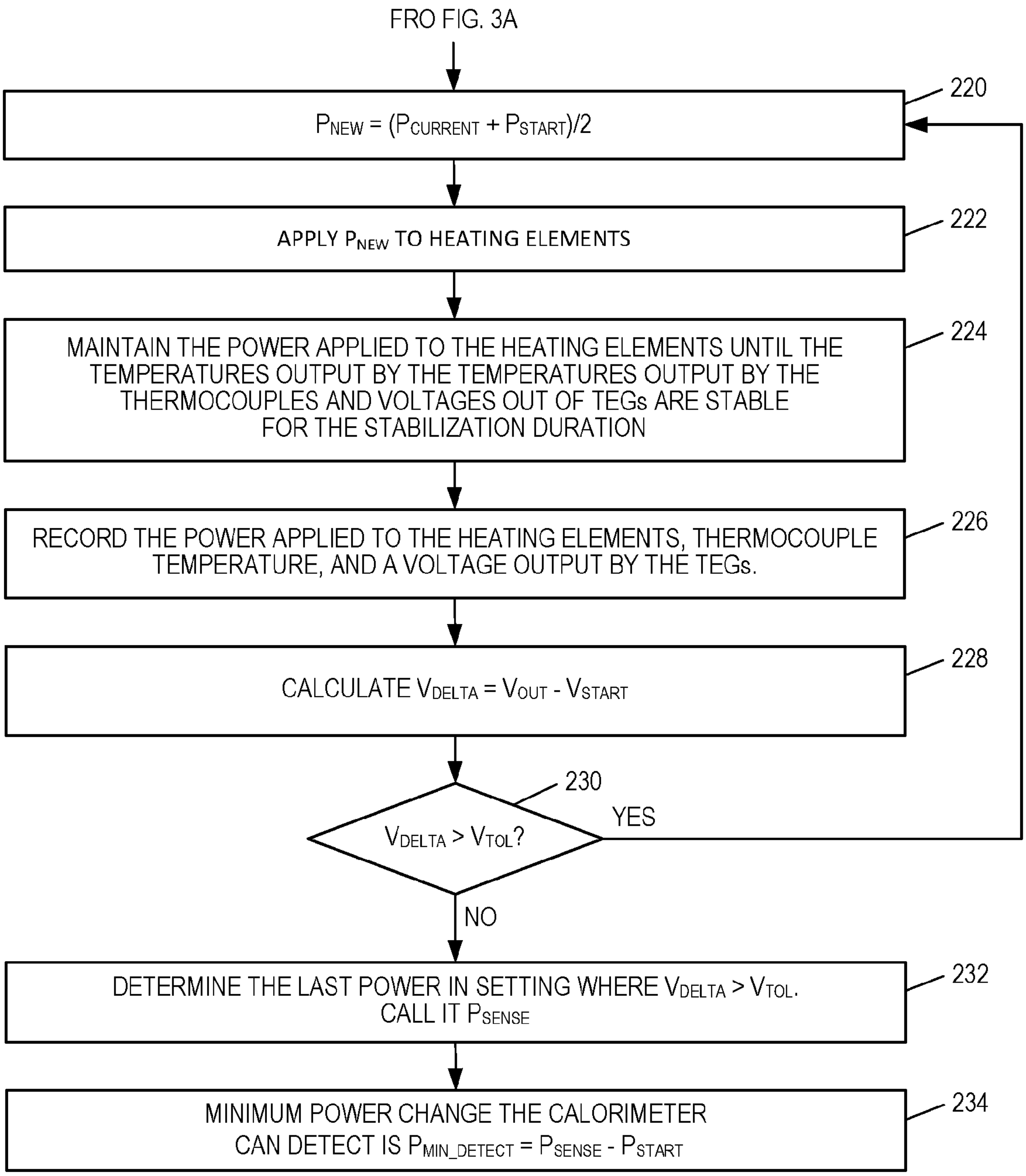
FRO FIG. 3A
220
$P_{NEW} = (P_{CURRENT} + P_{START})/2$
222
APPLY $P_{NEW}$ TO HEATING ELEMENTS
224
MAINTAIN THE POWER APPLIED TO THE HEATING ELEMENTS UNTIL THE TEMPERATURES OUTPUT BY THE TEMPERATURES OUTPUT BY THE THERMOCOUPLES AND VOLTAGES OUT OF TEGs ARE STABLE FOR THE STABILIZATION DURATION
226
RECORD THE POWER APPLIED TO THE HEATING ELEMENTS, THERMOCOUPLE TEMPERATURE, AND A VOLTAGE OUTPUT BY THE TEGs.
228
CALCULATE $V_{DELTA} = V_{OUT} - V_{START}$
230
$V_{DELTA} > V_{TOL}$?
YES
NO
232
DETERMINE THE LAST POWER IN SETTING WHERE $V_{DELTA} > V_{TOL}$. CALL IT $P_{SENSE}$
234
MINIMUM POWER CHANGE THE CALORIMETER CAN DETECT IS $P_{MIN\_DETECT} = P_{SENSE} - P_{START}$

***FIG. 3B***

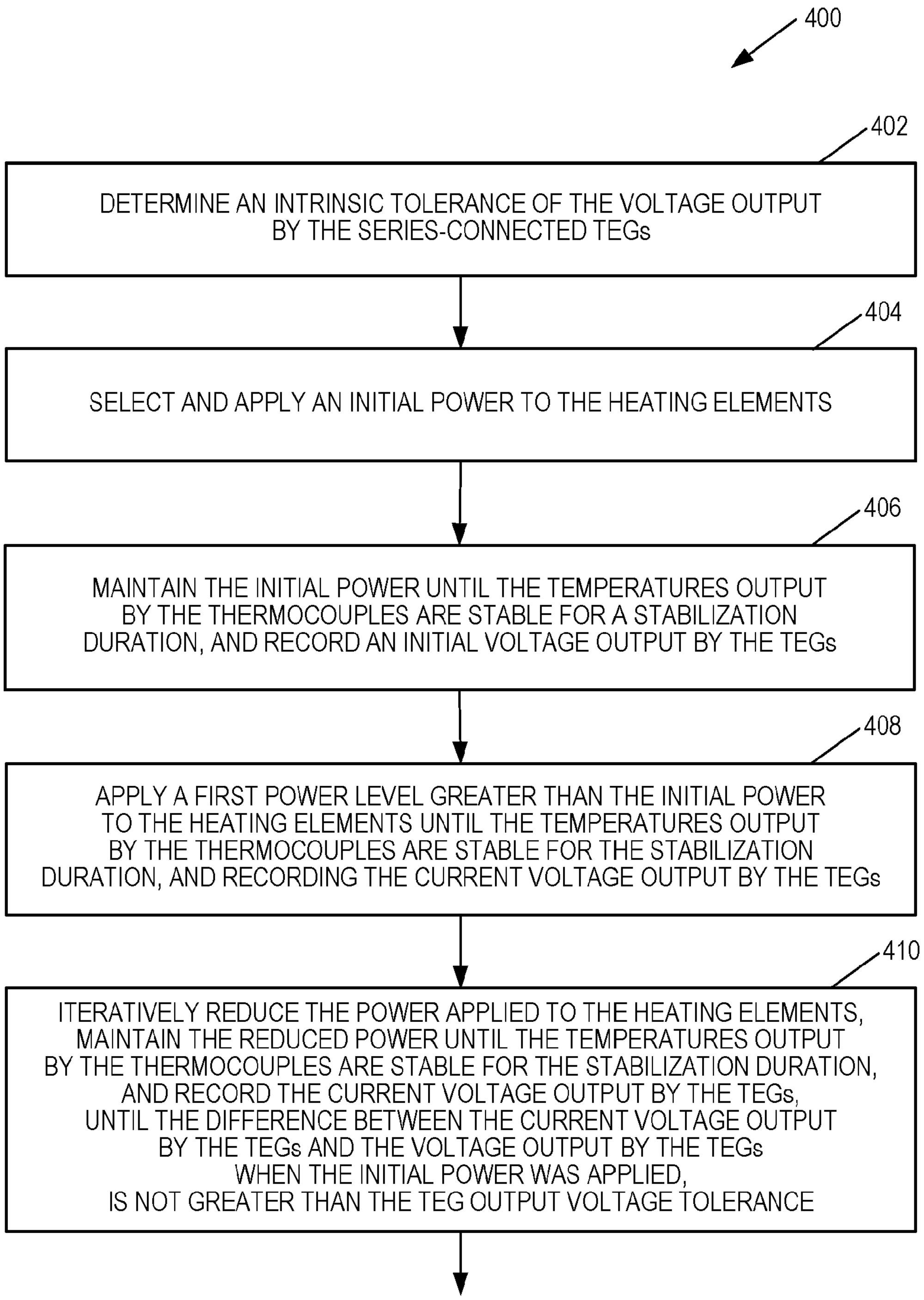
400
402
DETERMINE AN INTRINSIC TOLERANCE OF THE VOLTAGE OUTPUT BY THE SERIES-CONNECTED TEGs
404
SELECT AND APPLY AN INITIAL POWER TO THE HEATING ELEMENTS
406
MAINTAIN THE INITIAL POWER UNTIL THE TEMPERATURES OUTPUT BY THE THERMOCOUPLES ARE STABLE FOR A STABILIZATION DURATION, AND RECORD AN INITIAL VOLTAGE OUTPUT BY THE TEGs
408
APPLY A FIRST POWER LEVEL GREATER THAN THE INITIAL POWER TO THE HEATING ELEMENTS UNTIL THE TEMPERATURES OUTPUT BY THE THERMOCOUPLES ARE STABLE FOR THE STABILIZATION DURATION, AND RECORDING THE CURRENT VOLTAGE OUTPUT BY THE TEGs
410
ITERATIVELY REDUCE THE POWER APPLIED TO THE HEATING ELEMENTS, MAINTAIN THE REDUCED POWER UNTIL THE TEMPERATURES OUTPUT BY THE THERMOCOUPLES ARE STABLE FOR THE STABILIZATION DURATION, AND RECORD THE CURRENT VOLTAGE OUTPUT BY THE TEGs, UNTIL THE DIFFERENCE BETWEEN THE CURRENT VOLTAGE OUTPUT BY THE TEGs AND THE VOLTAGE OUTPUT BY THE TEGs WHEN THE INITIAL POWER WAS APPLIED, IS NOT GREATER THAN THE TEG OUTPUT VOLTAGE TOLERANCE

*FIG. 4*