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*[Continued on next page]*

# (54) Title: THERMAL BUFFERING OF DOWNHOLE EQUIPMENT WITH PHASE CHANGE MATERIAL

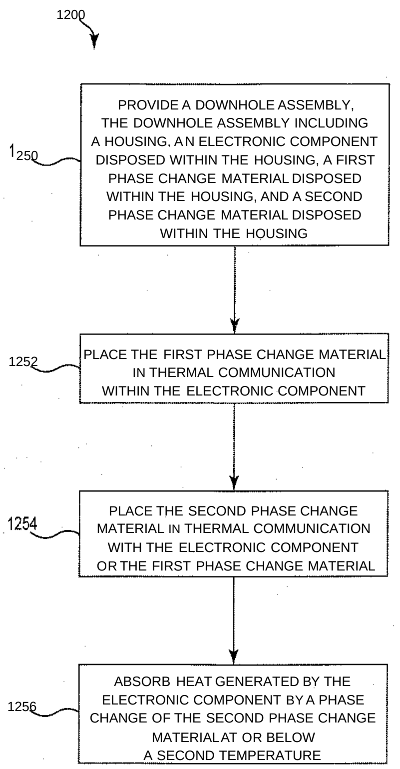


**Fig. 5**

**(57) Abstract: A** downhole assembly may include a housing containing a heat-producing component in thermal communication with a thermal buffering component. The thermal buffering component includes a container (232) having a phase change material disposed therein that is selected to have a phase change at or below a selected temperature.

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**Published:**

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# THERMAL BUFFERING OF DOWNHOLE EQUIPMENT WITH PHASE CHANGE MATERIAL

## Technical Field

**[0001]** The disclosure pertains generally to thermal buffering of electronic components and more particularly to thermal buffering of downhole electronic components using phase change materials.

## Background

**[0002]** Components of petroleum well downhole assemblies can be subjected to pressures, temperatures, and fluid compositions that are hostile to temperature-sensitive components. Temperature-sensitive components, such as various electronic components in downhole assembly tools can initially be protected from well temperatures by a housing, but the temperature within the housing eventually rises above a desired operating temperature as heat-producing components operate in an enclosed environment.

**[0003]** Therefore, a need remains for thermal buffering of temperature-sensitive components particularly in the high temperature environment of a petroleum well.

## Summary

**[0004]** This document provides methods, systems, and techniques relating to thermal buffering of heat-sensitive components.

**[0005]** In some embodiments, a downhole assembly of a wellsite system includes a housing containing an electronic component that can generate heat and a first phase change material. The first phase change material is packaged in a first container comprising a first microporous material and placed in thermal communication with the electronic component such that the heat generated by the electronic component can transfer to the first phase change material. The first phase change material has a phase change at a temperature at or below a first temperature.

**[0006]** In some embodiments, the downhole assembly further includes a second phase change material packaged in a second container comprising a second microporous material. The second phase change material is also in thermal communication with the electronic component such that the heat generated by the electronic component can also transfer to the second phase change material. The second phase change material has a phase change at a

temperature at or below a second temperature. The phase change temperature of the second phase change material is different than the phase change temperature of the first phase change material.

**[0007]** In some embodiments, the first temperature is a predetermined maximum operating temperature of the electronic component.

**[0008]** In some embodiments, the first phase change material changes from solid to liquid, liquid to gas, or solid to gas at a temperature at or below the first temperature.

**[0009]** In some embodiments, the second phase change material changes from solid to liquid, liquid to gas, or solid to gas at a temperature at or below the second temperature.

**[0010]** In some embodiments, each of the first and second temperatures is at or below a predetermined maximum operating temperature of the electronic component.

**[0011]** In some embodiments, the first or second container comprises a microporous polytetrafluoroethylene material, a microporous film, a laminate, or a coated fabric.

**[0012]** In some embodiments, the first phase change material is included at a mass sufficient to increase operating time of the electronic component at or below the first temperature by at least about 10%.

**[0013]** In some embodiments, the downhole assembly includes two phase change materials at a combined mass sufficient to increase operating time of the electronic component at or below a predetermined maximum operating temperature by at least about 10%.

**[0014]** In some embodiments, a method includes the steps of: a) providing downhole assembly comprising a housing, an electronic component disposed inside the housing, and a first phase change material disposed inside the housing; b) placing the first phase change material in thermal communication with the electronic component; and c) absorbing heat generated by the electronic component by a phase change of the first phase change material at or below a first temperature.

**[0015]** In some embodiments, the method provides a downhole assembly further comprising a second phase change material disposed inside the housing. The method further includes the steps of a) placing the second phase change material in thermal communication with the electronic component such that heat generated by the electronic component can transfer to the second phase change material; and b) absorbing the heat generated by the electronic component by a phase change of the second phase change material at or below a second temperature.

**[0016]** In some embodiments, the method further includes automatically stopping operation of the electronic component when a temperature inside the housing reaches the first or second temperature.

**[0017]** In some embodiments, the method further includes stopping operation of the electronic component at a time point calculated to be at or before a temperature in the housing reaches the first or second temperature.

**[0018]** In some embodiments, the first phase change material is provided at a mass sufficient to increase operating time of the electronic component at or below the first temperature by at least about 10%.

**[0019]** In some embodiments, the first phase change material and the second phase change material are provided at a combined mass sufficient to increase operating time of the electronic component at or below a predetermined maximum operating temperature of the electronic component by at least about 10%.

**[0020]** In some embodiments, the first and second temperatures are at or below a predetermined maximum operating temperature of the electronic component.

**[0021]** While multiple embodiments with multiple elements are disclosed, still other embodiments and elements of the present invention will become apparent to those skilled in the art from the following detailed description, which shows and describes illustrative embodiments of the invention. Accordingly, the drawings and detailed description are to be regarded as illustrative in nature and not restrictive.

## Brief Description of the Figures

**[0022]** Figure 1 is a schematic diagram of a wellsite system in accordance with an embodiment of the disclosure.

**[0023]** Figure 2 is a schematic cross-sectional diagram of an assembly in accordance with an embodiment of the disclosure.

**[0024]** Figure 3 is an example of a phase change material in a flexible container in accordance with an embodiment of the disclosure.

**[0025]** Figure 4 is a flow chart illustrating a method in accordance with an embodiment of the disclosure.

**[0026]** Figure 5 is a flow chart illustrating a method in accordance with an embodiment of the disclosure.

## Detailed Description

**[0027]** One or more specific embodiments of the present disclosure will be described below including method, apparatus and system embodiments. These described embodiments and their various elements are only examples of the presently disclosed techniques. It should be appreciated that in the development of any such actual implementation, as in any engineering or design project, numerous implementation-specific decisions can be made to achieve the developers' specific goals, such as compliance with system-related and business-related constraints, which can vary from one implementation to another. Moreover, it should be appreciated that such a development effort might be time consuming, but would nevertheless be a routine undertaking of design, fabrication, and manufacture for those of ordinary skill having the benefit(s) of this disclosure.

**[0028]** When introducing elements of various embodiments of the present disclosure, the articles "a," "an," and "the" are intended to mean that there are one or more of the elements. The terms "comprising," "including," and "having" are intended to be inclusive and mean that there can be additional elements other than the listed elements. Additionally, it should be understood that references to "one embodiment" or "an embodiment" of the present disclosure are not intended to be interpreted as excluding the existence of additional embodiments that also incorporate the listed elements.

**[0029]** Figure 1 illustrates an embodiment of a wellsite apparatus, system, and methodology. The wellsite system of Figure 1 can be onshore or offshore for, for example, exploring and producing oil, natural gas, and other resources that can be used, refined, and otherwise processed for fuel, raw materials and other purposes. In the wellsite system of Figure 1, a borehole 11 can be formed in subsurface formations, such as rock formations, by rotary drilling using any suitable technique. A drillstring 12 can be suspended within the borehole 11 and can have a bottom hole assembly 100 that includes a drill bit 105 at its lower end. A surface system of the wellsite system of Figure 1 can include a platform and derrick assembly 10 positioned over the borehole 11, the platform and derrick assembly 10 including a rotary table 16, kelly 17, hook 18, and rotary swivel 19. The drillstring 12 can be rotated by the rotary table 16, energized by any suitable means, which engages the kelly 17 at the upper end of the drillstring 12. The drillstring 12 can be suspended from the hook 18, attached to a traveling block (not shown), through the kelly 17 and the rotary swivel 19, which permits rotation of the drillstring 12 relative to the hook 18. A topdrive system could alternatively be used, which can be a topdrive system well known to those of ordinary skill in the art.

**[0030]** In the wellsite system of Figure 1, the surface system can also include drilling fluid or mud 26 stored in a pit 27 formed at the wellsite. A pump 29 can deliver the drilling fluid 26 to the interior of the drillstring 12 via a port in the swivel 19, causing the drilling fluid to flow downwardly through the drillstring 12 as indicated by the directional arrow 8. The drilling fluid 26 can exit the drillstring 12 via ports in the drill bit 105, and circulate upwardly through the annulus region between the outside of the drillstring 12 and the wall of the borehole 11, as indicated by the directional arrows 9. In this manner, the drilling fluid 26 lubricates the drill bit 105 and carries formation cuttings up to the surface, as the fluid 26 is returned to the pit 27 for recirculation.

**[0031]** The bottom hole assembly 100 of the wellsite system of Figure 1 can, as one example, include one or more of a logging-while-drilling (LWD) module 120, a measuring-while-drilling (MWD) module 130, a roto-steerable system and motor 150, and the drill bit 105. As will be appreciated, bottom hole assembly equipment can include heat-producing components *(e.g.,* electronic components) as well as heat-sensitive components *(e.g.,* electronic components), where thermal buffering may be beneficial.

**[0032]** As shown in Figure 1, the wellsite system is used for a logging-while-drilling (LWD) or measurement-while-drilling (MWD) operation performed on a land based rig, but could be any type of oil/gas operations (e.g., wireline, coiled tubing, testing, completions, production, etc.) performed on a land based rig or offshore platform.

**[0033]** Figure 2 is a schematic cross-sectional illustration of a downhole assembly 200 that can, for example, be included in an MWD module, an LWD module, or other downhole equipment such as well formation pressure testing equipment. The assembly 200 includes a housing 210 containing a heat-producing component 220 in thermal communication with a thermal buffering (e.g. phase change material) component 230. As used herein, a first component (e.g., a heat-producing component) is considered to be in thermal communication with a second component (e.g., a phase change material component) if thermal energy from the first component can be transferred to the second component within housing 210. In some embodiments, the heat-producing component 220 and the phase change material component 230 can be in thermal communication by direct physical contact. In some embodiments, the heat-producing component 220 and the phase change material component 230 can be in thermal communication indirectly such as, for example, through contact with another component or part of the housing or open space in the container 210.

**[0034]** A heat-producing component 220 can be an electronic component such as a multi-chip module. In some embodiments, a heat-producing component 220 can include individual electronic parts such as integrated circuit (IC) chips that are soldered or otherwise secured to a substrate such as a silicone-on-insulator (SOI) or printed circuit board. In some embodiments, copper wiring traces within the printed circuit board may assist in carrying thermal energy away from IC chips and other elements within the heat-producing component 220.

**[0035]** A phase change material component 230 includes a phase change material packaged in a container 232 (Figure 3) having any suitable shape. In some embodiments, a phase change material is packaged in a flexible container. In some embodiments, a phase change material can be packaged in a container comprising a material that prevents the phase change material from flowing out of the container 232 when the phase change material is in a fluid or semi-fluid phase. Materials suitable for use in a phase change material container include, without limitation, microporous films or membranes *(e.g.,* open pore and/or filled pore microporous polytetrafluoroethylene (PTFE), polypropylene, polyethylene, polyester, nylon, etc.), woven or nonwoven fabrics *(e.g.,* polyester, polypropylene, and polyethylene spunbonded, spunlaced, meltblown microfiber fabrics, etc.), laminates, coated fabrics, and the like. Various microporous films are available from a number of sources including W. L. Gore & Associates. Various microporous fabrics are available from various sources including Mogul Tekstil, BP Amoco, and DuPont.

**[0036]** In some embodiments, a material used to package a phase change material can be chosen based on the ability to maintain integrity at high temperature and/or the ability to conduct thermal energy to the packaged phase change material. In some embodiments, a material used to package a phase change material can be chosen based on a property *(e.g.,* hydrophobicity, hydrophilicity, fluidity of one or more phases, etc.) of the chosen phase change material. In some embodiments, different materials can be used to package different phase change materials.

**[0037]** In some embodiments, for example as illustrated in Figure 3, container 232 is flexible, allowing the phase change material component 230 to be inserted various spaces within the housing 210. In such embodiments, the phase change material contained within container 232 may be in a form that can be deformed, such as a pliable solid, a fluid, a powder, a slurry, or a plurality of encapsulated or unencapsulated portions. In some embodiments, the phase change material can be preformed to fit within a particular space within container 232.

**[0038]** A phase change material can be any suitable material that absorbs thermal energy during a phase change *(e.g.,* solid to solid, solid to liquid, liquid to gas, or solid to gas) that occurs as temperature increases. Examples of suitable phase change materials include, without limitation, paraffins, fatty acids, salt hydrates, and eutectic materials. Various phase change materials are available from a number of sources including PCM Products Ltd., PCM Thermal Solutions, Microtek Laboratories, Inc., and Amec Thermasol.

**[0039]** A phase change material may be chosen for the ability to absorb thermal energy during a phase change at or below a selected temperature. In some embodiments, a selected temperature can be at or below a predetermined maximum operating temperature, at or below which a heat-sensitive component typically does not fail due to thermal stress. In some embodiments, a selected temperature can be at or below a temperature at which a heat-sensitive component begins to fail due to thermal stress.

**[0040]** In some embodiments, assembly 200 includes a plurality of phase change material components 230 separately comprising different phase change materials each with different temperatures at which a phase change occurs. For example, different phase change materials may be chosen in order to increase total thermal energy absorption potential over the use of a single phase change material within the volume available in housing 210. In some embodiments, additional phase change materials may be chosen for a phase change that is at or below that of another phase change material. As such, a temperature can be selected that is at or below a temperature at which a phase change material changes phases.

**[0041]** A phase change material can be included in assembly 200 at a mass sufficient to increase the time at which a heat-producing component 220 can operate at or below a selected temperature. In some embodiments, a plurality of different phase change materials can be included in assembly 200 at a combined mass sufficient to increase the time at which a heat-producing component 220 can operate at or below a predetermined maximum operating temperature of a heat-sensitive component. In some embodiments, a phase change material can be included in assembly 200 at a mass sufficient to increase the time for which a heat-producing component 220 can operate at or below a selected temperature by at least about 5%. For example, the time for which a heat-producing component 220 can operate at or below a selected temperature can be increased by at least about 7%, 10%, 12%, 15%, 18%, 20%, 25%, 30%, 50%, or more.

**[0042]** In some embodiments, assembly 200 can further include additional components, such as a temperature sensor to gauge the temperature within housing 210. In some embodiments, a thermal switch can be included in assembly 200 that automatically shuts down the operation of a heat-producing component 220 when the temperature in container 210 reaches a selected temperature. In some embodiments, temperature within housing 210 can be monitored and the operation of a heat-producing component 220 can be switched off when the temperature in container 210 is observed to reach a selected temperature.

**[0043]** In some embodiments, the amount of time a heat-producing component 220 can operate at or below a selected temperature can be calculated based on a latent heat storage potential and mass of a selected phase change material included in assembly 200. In some embodiments, operation of a heat-producing component 220 can be stopped at a time point that is calculated to be at or before reaching a selected temperature.

**[0044]** As shown in Figure 4, one embodiment of method 1000 includes the steps of providing a downhole assembly comprising a housing, an electronic component disposed inside the housing, and a first phase change material also disposed inside the housing 1050; placing the first phase change material in thermal communication with the electronic component 1052; and absorbing heat generated by electronic component by a phase change of the first phase change material at or below a first temperature 1054. In some embodiments, as shown in Figure 5, a method 1200 can include the steps of providing a downhole assembly comprising a housing, an electronic component disposed inside the housing, and a first phase change material and a second phase change material also disposed inside the housing 1250; placing the first phase change material in thermal communication with the electronic component 1252; placing the second phase change material in thermal communication with the electronic component or the first phase change material 1254; and absorbing heat generated by electronic component by a phase change of the second phase change material at or below a second temperature 1256.

**[0045]** In some embodiments, a method 1000 or 1200 can include automatically stopping operation of the electronic component when a temperature inside the housing reaches the first or second temperature, or stopping operation of the electronic component at a time point calculated to be at or before a temperature in the housing reaches the first or second temperature.

**[0046]** Various modifications, additions and combinations can be made to the exemplary embodiments and their various features discussed without departing from the scope of the present invention. For example, while the embodiments described above refer to particular features, the scope of this invention also includes embodiments having different combinations of features and embodiments that do not include all of the above described features.

**WE CLAIM:**

1. A downhole assembly comprising:

   a housing;

   an electronic component disposed within the housing, wherein the electronic component can generate heat; and

   a first phase change material packaged in a first container comprising a first microporous material and disposed within the housing in thermal communication with the electronic component such that the heat generated by the electronic component can transfer to the first phase change material, the first phase change material having a phase change at a temperature at or below a first temperature.

2. The downhole assembly of claim 1, further comprising a second phase change material packaged in a second container comprising a second microporous material and disposed within the housing in thermal communication with the electronic component such that the heat generated by the electronic component can transfer to the second phase change material, the second phase change material having an phase change at a temperature that is at or below a second temperature and different than the phase change temperature of the first phase change material.

3. The downhole assembly of claim 1 or 2, wherein the first phase change material changes from solid to liquid, liquid to gas, or solid to gas at a temperature at or below the first temperature.

4. The downhole assembly of claim 2 or 3, wherein the second phase change material changes from solid to liquid, liquid to gas, or solid to gas at a temperature at or below the second temperature.

5. The downhole assembly of any of claims 1-4, wherein each of the first and second temperatures is at or below a predetermined maximum operating temperature of the electronic component.

6. The downhole assembly of any of claims 1-5, wherein the first or second microporous material comprises a microporous polytetrafluoroethylene material, a microporous film or membrane, a laminate, or a coated fabric.

7. The downhole assembly of any of claims 1-6, wherein the first phase change material is included at a mass sufficient to increase operating time of the electronic component at or below the first temperature by at least about 10%.

8. The downhole assembly of any of claims 2-7, wherein the first phase change material and the second phase change material are included at a combined mass sufficient to increase operating time of the electronic component at or below a predetermined maximum operating temperature of the electronic component by at least about 10%.

9. A method comprising:

providing a downhole assembly comprising a housing; an electronic component disposed inside the housing; and a first phase change material disposed inside the housing;

placing the first phase change material in thermal communication with the electronic component; and

absorbing heat generated by the electronic component by a phase change of the first phase change material at or below a first temperature.

10. The method of claim 9, wherein the downhole assembly further comprises a second phase change material disposed inside the housing; the method further comprising:

placing the second phase change material in thermal communication with the electronic component or the first phase change material; and

absorbing the heat generated by the electronic component by a phase change of the second phase change material at or below a second temperature.

11. The method of claim 9 or 10, further comprising automatically stopping operation of the electronic component when a temperature inside the housing reaches the first or second temperature.

12. The method of claim 9 or 10, further comprising stopping operation of the electronic component at a time point calculated to be at or before a temperature in the housing reaches the first or second temperature.

13. The method of any of claims 9-12, wherein the first phase change material is provided at a mass sufficient to increase operating time of the electronic component at or below the first temperature by at least about 10%.

14. The method of any of claims 10-13, wherein the first phase change material and the second phase change material are provided at a combined mass sufficient to increase operating time of the electronic component at or below a predetermined maximum operating temperature of the electronic component by at least about 10%.

15. The method of any of claims 9-14, wherein each of the first and second temperatures is at or below a predetermined maximum operating temperature of the electronic component.

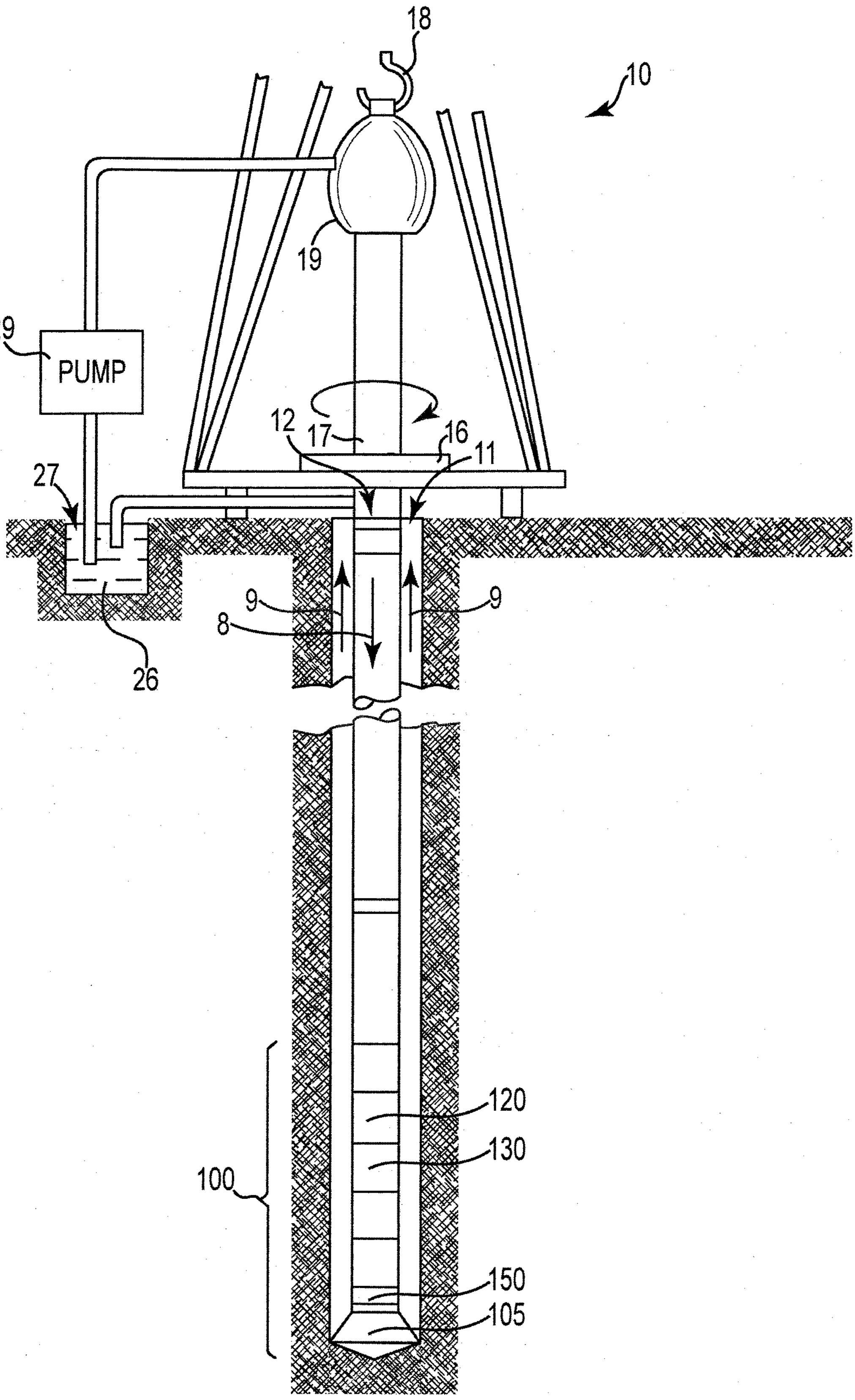


Fig. 1

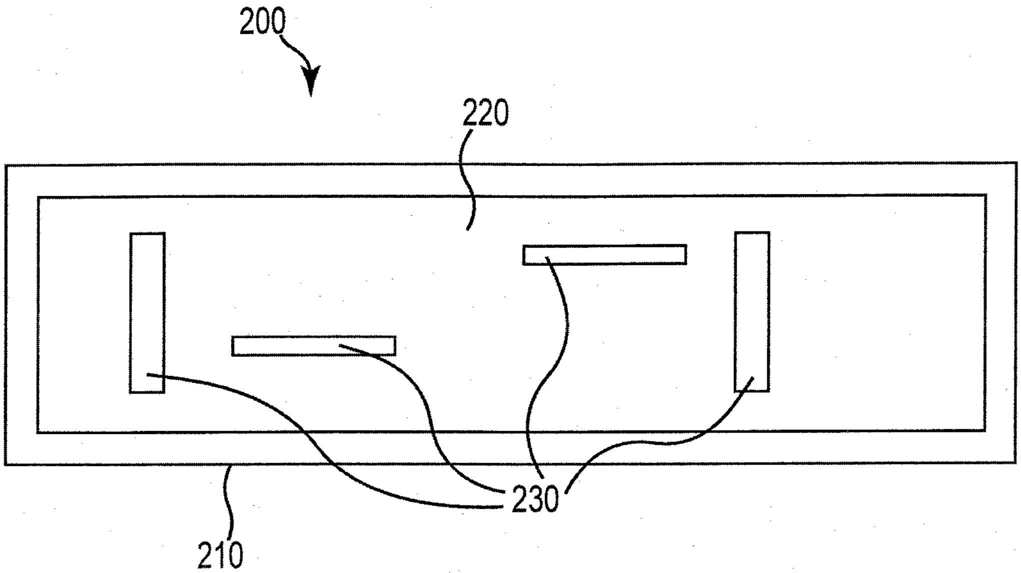


Fig. 2

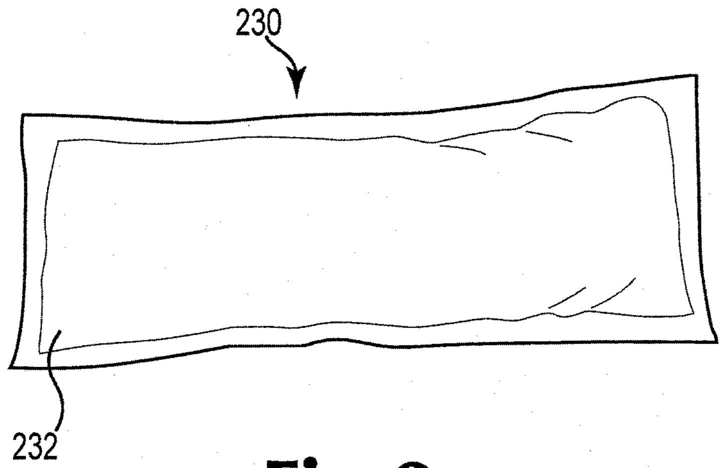


**Fig. 3**

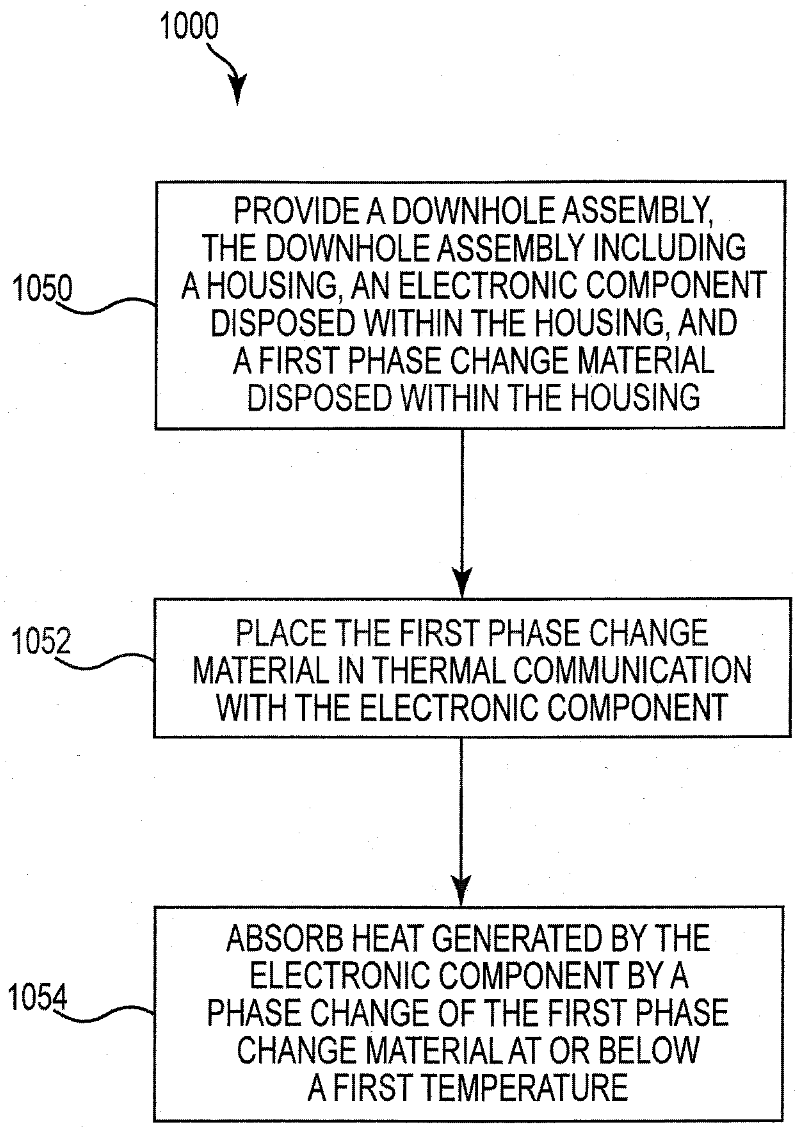
1000
1050
PROVIDE A DOWNHOLE ASSEMBLY, THE DOWNHOLE ASSEMBLY INCLUDING A HOUSING, AN ELECTRONIC COMPONENT DISPOSED WITHIN THE HOUSING, AND A FIRST PHASE CHANGE MATERIAL DISPOSED WITHIN THE HOUSING
1052
PLACE THE FIRST PHASE CHANGE MATERIAL IN THERMAL COMMUNICATION WITH THE ELECTRONIC COMPONENT
1054
ABSORB HEAT GENERATED BY THE ELECTRONIC COMPONENT BY A PHASE CHANGE OF THE FIRST PHASE CHANGE MATERIAL AT OR BELOW A FIRST TEMPERATURE

**Fig. 4**

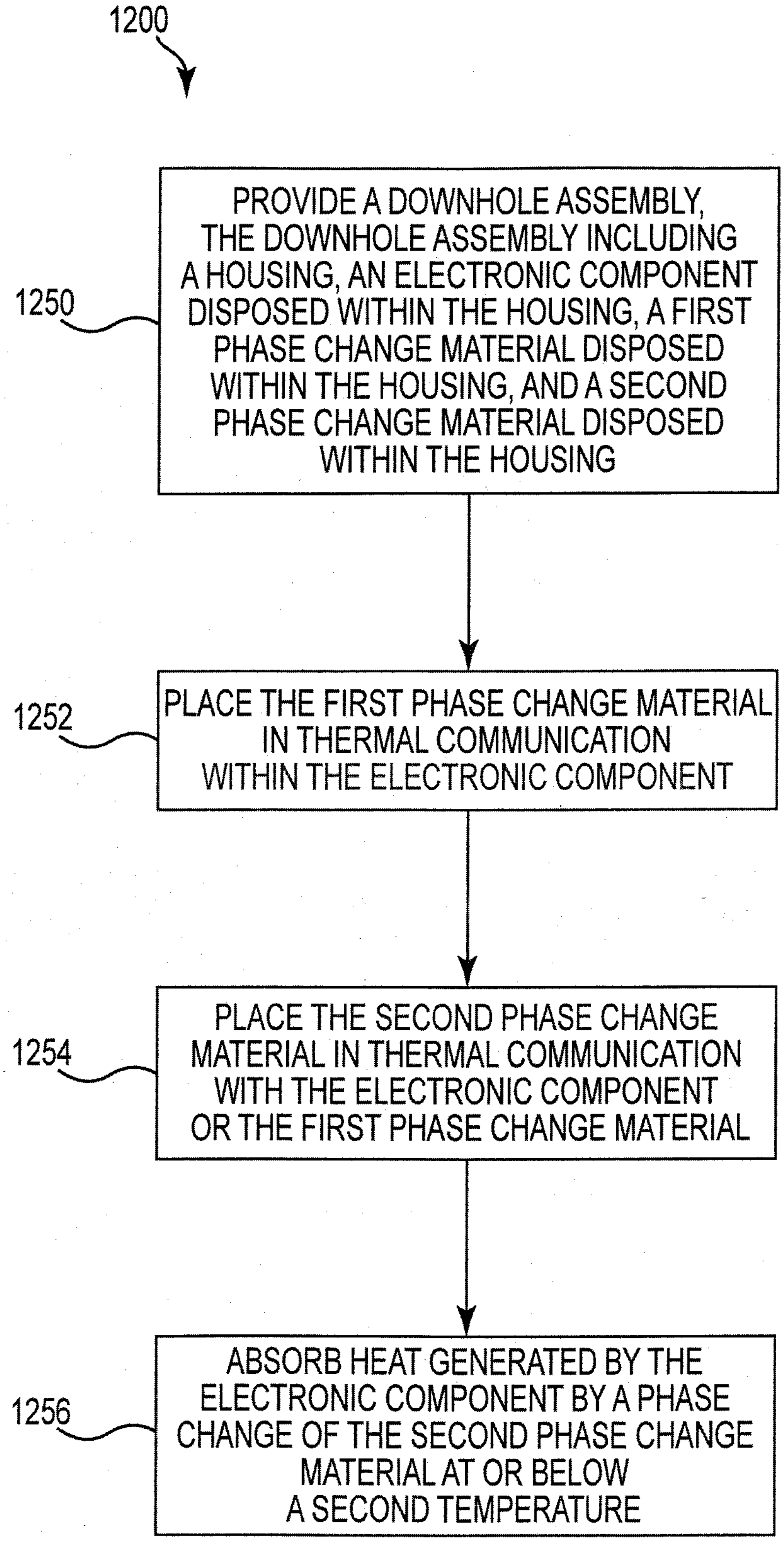
1200
1250
PROVIDE A DOWNHOLE ASSEMBLY, THE DOWNHOLE ASSEMBLY INCLUDING A HOUSING, AN ELECTRONIC COMPONENT DISPOSED WITHIN THE HOUSING, A FIRST PHASE CHANGE MATERIAL DISPOSED WITHIN THE HOUSING, AND A SECOND PHASE CHANGE MATERIAL DISPOSED WITHIN THE HOUSING
1252
PLACE THE FIRST PHASE CHANGE MATERIAL IN THERMAL COMMUNICATION WITHIN THE ELECTRONIC COMPONENT
1254
PLACE THE SECOND PHASE CHANGE MATERIAL IN THERMAL COMMUNICATION WITH THE ELECTRONIC COMPONENT OR THE FIRST PHASE CHANGE MATERIAL
1256
ABSORB HEAT GENERATED BY THE ELECTRONIC COMPONENT BY A PHASE CHANGE OF THE SECOND PHASE CHANGE MATERIAL AT OR BELOW A SECOND TEMPERATURE

**Fig. 5**

# INTERNATIONAL SEARCH REPORT

International application No
PCT/US2012/070806

**A. CLASSIFICATION OF SUBJECT MATTER**
INV. E21B47/01 E21B36/O0
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)
E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | US 2003/085039 AI (DIFOGGIO ROCCO [US]) 8 May 2003 (2003-05-08) paragraphs [0056] - [0058]; figures 5,6,8 the whole document ----- | 1-15 |
| X | US 6 341 498 BI (DIFOGGIO ROCCO [US]) 29 January 2002 (2002-01-29) column 4, lines 3-22 column 7, line 15 - column 10, line 2; figures 5,6 the whole document ----- | 1-15 |
| X | US 7 440 283 BI (RAFIE SAEED [US]) 21 October 2008 (2008-10-21) column 3, line 47 - column 5, line 9; figure 3 the whole document nanoporous material ----- | 1-15 |

-/--

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

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| Date of the actual completion of the international search | Date of mailing of the international search report |
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| 13 February 2013 | 22/02/2013 |

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