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Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

[Continued on next page]

(54) Title: SHAPED MEMORY DEVICES AND METHOD FOR USING SAME IN WELLBORES

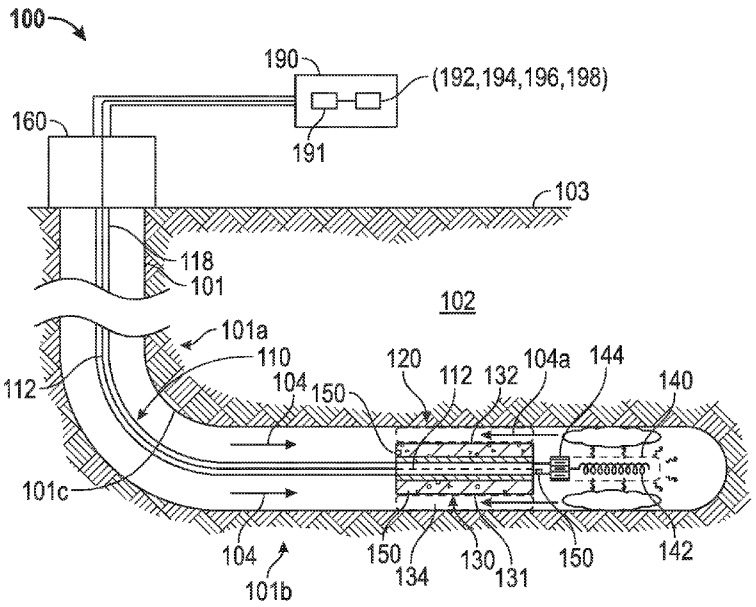

FIG. 1

(57) Abstract: In one aspect an apparatus for use in a wellbore is disclosed that in one embodiment includes a device or tool conveyable in the wellbore, wherein the device or tool further includes a shape memory member formed into a compressed state, the shape memory device having a glass transition temperature and a heating device associated with the shape memory member configured to heat in the wellbore the shape memory member to or above the glass transition temperature to expand the shape memory member to a second expanded state.

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SHAPED MEMORY DEVICES AND METHOD FOR USING SAME IN WELLBORES

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. Application No. 13/919568, filed on June 17, 2013, which is incorporated herein by reference in its entirety.

BACKGROUND

1. Field of the Disclosure

[0001] The disclosure relates generally to apparatus and methods for installing shape memory devices in wellbores.

2. Description of the Related Art

[0002] Hydrocarbons, such as oil and gas, are recovered from subterranean formations using a well or wellbore drilled into such formations. In some cases the wellbore is completed by placing a casing along the wellbore length and perforating the casing adjacent each production zone (hydrocarbon bearing zone) to extract fluids (such as oil and gas) from such a production zone. In other cases, the wellbore may be an open hole, which may be used to produce hydrocarbons or inject steam or other substances into a geological formation. One or more flow control devices are placed in the wellbore to control the flow of fluids from the formation into the wellbore. These flow control devices and production zones are generally fluidly isolated or separated from each other by installing a packer between them. Other devices also are utilized to temporarily plug sections of a wellbore or to control flow of fluids through the wellbore or a production string deployed to convey formation fluid to the surface. Certain devices having shape memory materials (shape memory devices) have been disclosed and utilized in wellbores for such purposes. A shape memory material can be heated to or above its glass transition temperature to attain a selected or desired expanded shape or state and then compressed to desired compressed shape to retain it in such compressed shape at temperatures below the glass transition temperature. When the shape material is again heated to or above its glass transition temperature, it expands to the expanded shape. For wellbore applications, a shape memory material or member, which may be a part of a device or tool, is typically formed in a compressed state and then deployed in the wellbore. The wellbores typically contain a fluid, such as a drilling or another fluid and are often at a temperature above the glass transition temperature of the shape memory material. The shape memory device deployed in the wellbore heats over time and attains the expanded shape. However, in certain wells, the temperature is not sufficiently high to heat the

shape memory device above its glass transition temperature or the heating process may take a relatively long time to cause the shape memory device to expand. It is thus desirable to have devices in the wellbore to controllably heat the shape memory devices in the wellbore to cause the shape memory materials to attain their expanded shapes.

[0003] The present disclosure provides shape memory devices and systems for controllably heating and setting such shape memory device in wellbores.

SUMMARY

[0004] In one aspect an apparatus for use in a wellbore is disclosed that in one embodiment includes a downhole tool or device conveyable in the wellbore, wherein the downhole tool or device further includes a shape memory member in a compressed shape or state, the shape memory member having a glass transition temperature and a heating device configured to heat in the wellbore the shape memory member to or above the glass transition temperature to expand the shape memory member to an expanded shape or state.

[0005] In another aspect, a method of providing an apparatus for use in a wellbore is disclosed that in one embodiment may include: providing a device having a shape memory member in a compressed state; placing a heating element proximate or in the shape memory member; and providing a source that supplies electrical energy to the heating element to heat the shape memory to an expanded state.

[0006] Examples of some features of the disclosure have been summarized rather broadly in order that detailed description thereof that follows may be better understood, and in order that some of the contributions to the art may be appreciated. There are, of course, additional features of the disclosure that will be described hereinafter and which will form the subject of the claims appended hereto.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] The advantages and further aspects of the disclosure will be readily appreciated by those of ordinary skill in the art as the same becomes better understood by reference to the following detailed description when considered in conjunction with the accompanying drawings, in which like reference characters generally designate like or similar elements throughout the several figures, and wherein:

FIG. 1 is a schematic elevation view of an exemplary wellbore system wherein a work string containing a shape memory device made according to one embodiment of the disclosure is deployed in a wellbore;

FIG. 2 shows a sectional side view of a shape memory device made according to one embodiment the disclosure and placed on a base pipe in a wellbore;

FIG. 3 shows shape memory device made according to another embodiment of the disclosure that includes a heating element installed on a base pipe, such as the base pipe shown in FIG. 3;

FIG. 4 shows a shape memory device that includes a coil embedded in the shape memory material to heat such material, according to yet other embodiment of the disclosure; and

FIG. 5 shows a shape memory device that includes one or more heat strips or rods embedded in the shape memory material to heat such material, according to yet another embodiment of the disclosure.

DETAILED DESCRIPTION OF THE DISCLOSURE

[0008] The present disclosure relates to devices and methods for controlling production of hydrocarbons in wellbores. The present disclosure is susceptible to embodiments of different forms. There are shown in the drawings, and herein described, specific embodiments of the present disclosure with the understanding that the present disclosure is to be considered an exemplification of the principles of the devices and methods described herein and is not intended to limit the disclosure to the specific embodiments. Also, the feature or a combination of features should not be construed as essential unless expressly stated as essential.

[0009] FIG. 1 shows an exemplary wellbore system 100 that includes a wellbore 101 drilled through an earth formation 102 from a surface location 103 for producing hydrocarbons from the formation 102. The wellbore 101 is shown as an open hole, i.e., without any casing therein. The wellbore 101 is shown to include a vertical section 101a and a deviated or substantially horizontal section 101b. The wellbore system 100 includes a work string 110 that includes a downhole assembly 120 conveyed in the wellbore 101 by a conveying member 118, such as a wireline or a coiled tubing. The wellbore system 100 further includes a wellhead unit 160 through which the conveying member 118 and the downhole assembly 120 are deployed into the wellbore 101. The wellbore 101 is further shown to contain a fluid 104, such as a drilling fluid.

[0010] Still referring to FIG. 1, the downhole assembly 120, in one aspect, includes a shape memory device 130, which device is desired to be placed or installed in the wellbore. In aspects, the shape memory device 130 may include a suitable shape memory material or

member known in the art. A shape memory member or material, for the purpose of this disclosure, is a material device that may be heated to or above its glass transition temperature to an expanded shape and then compressed to a compressed shape and cooled to retain the compressed shape until reheated to or above its glass transition temperature to case it to attain its expanded shape. Shape memory materials are known in the art and are thus not described in detail herein. Any suitable shape memory, however, included, but not limited to polymers, may be utilized. The shape memory device 130 is shown conveyed and placed in the wellbore 101 at a location where it is desired to be expanded and set. The particular shape memory device 130 has outer dimensions 131 when it is in the compressed state. The device 130 when heated to or above the glass transition temperature of its shape memory material will expand to contact and press against the wellbore wall 101c and attain the expanded shape as shown by dimensions 134.

[0011] The downhole assembly 120 further includes a heating device 140 that includes a heating element 142 and a source 144 for supplying electric energy or power to the heating element 142. The heating element may be made in the form of a coil, metallic strips or may have any other form known in the art. In one aspect, the electric energy source may be a battery 144 electrically coupled to the heating element 142 placed in the downhole assembly 130. In one aspect, the heating element may be placed downhole or below the shape memory device 130, whereas the battery 144 may be placed either uphole (above) or downhole of the shape memory device 130. In another aspect, the heating device 140 may be removably mounted in the downhole assembly 120, such that after setting or expanding the shape memory device 130 in the wellbore, the heating element 142 and the battery 144 may be retrieved to the surface 103. In another aspect, the electrical energy to the heating element 142 may be supplied from a surface source 191 via an electrical line 112 running through the conveying member 118. One or more temperature sensors, such as sensors 150, may be placed at suitable locations in the downhole assembly 120 to provide temperature measurements proximate the shape memory device 130.

[0012] Still referring to FIG. 1, the system 100 further includes a surface unit 190, which may be a computer-based system that may further include electrical circuits 192 to pre-process sensor signals, a processor 194, such as a microprocessor, one or more storage devices 196, such as memory devices, and programs 198 that include instructions accessible to the processor 192 for executing such instructions.

[0013] After setting or placing the downhole assembly 120 at the desired location in the wellbore 101, the control unit 190 may cause the electric energy source 144 or 191 at the

surface to supply electrical energy to the heating element 142. When the heating element is heated, the fluid 104 proximate the heating element is heated, which fluid causes the shape memory member to heat. The controller 190 determines the temperature of the fluid from the signals provided by the temperature sensor 150 and may control the supply of the electrical energy to the heating element 142 and thus the temperature of the heating element to cause the temperature of the shape memory member to rise to or above the glass transition temperature of the shape memory member. After the shape memory member has attained the desired expanded state or after a selected time period, the controller 190 may stop supplying the electrical energy to the heating element 142 (i.e., deactivate the heating element). The conveying member 118 may then be dislodged from the shape memory at a connection point 136 and retrieved to the surface 103 with the heating element 142 and the battery 144. In other aspects, the heating element and the battery may not be detachable element and thus may be left in the wellbore 101.

[0014] FIG. 2 shows a sectional side view of a shape memory device 200 made according to one embodiment of the disclosure and placed around a base pipe or tubing 210 having an axis 203. The base pipe 210, which may extend from a surface location into the wellbore, may be formed by axially joining base pipe sections, such as sections 210a, 210b, etc. Adjoining base pipe sections, such as 210a and 210b, may be joined by any suitable mechanical connection, such as a connector 212ab known in the art. The base pipe 210 includes a number of fluid passages 214 over a selected base pipe length to allow flow of fluid from the formation into the base pipe. In the particular embodiment of FIG. 2, the exemplary shape memory device 200 is shown as a packer, but it may be made into any other suitable shape or form according to the principles described herein. The shape memory device 200 includes a shape memory member (also sometimes referred to as an element or a material) 250 surrounding a tubular 240, which tubular may be made from any suitable material, such as steel or another suitable alloy. The tubular 240 includes a number of fluid passages 242 that allow a fluid passing through the shape memory element 250 to pass into the base pipe 210. The shape memory member 250 is shown in the compressed state having outer dimensions 260. The tubular 240 may include any number of fluid passages 242 to enable a fluid to pass from outside of the shape memory member 250 to inside 243 of the tubular 240. In one aspect, ends, such as end 254 of the shape memory device 200 may be securely inserted into a side pocket 234 of a centralizer 230 to form a unified assembly. The unified assembly may then be inserted over the base pipe 210 and secured thereon by suitable attachments, such as screws 232. The shape memory member or element 250, when heated in

the wellbore by a device made according to an embodiment or principles described herein, will expand to attain an expanded shape 270 and press against inside 205 of the wellbore 201. The shape memory device 200 further includes a heating element as described in reference to FIG. 1 or FIGS. 3-5 described below.

[0015] FIG. 3 shows a shape memory device 300 made according to another embodiment of the disclosure. FIG. 3 shows a base pipe 310 having a number of perforations of fluid passages 314. A heating element 320, such as a coil, may be wrapped around the base pipe 310 about the fluid passages 314. Alternatively, the heating element may be formed in the form of metallic strips and placed on the base pipe 310. Electric energy to the heating element 320 may be supplied from an energy source, such as a battery or a source at the surface 191, via terminals 322a and 222b, as described in reference to FIG. 1. The shape memory device 300 further includes a shape memory member or material 350 placed around a tubular member 340 having perforations or fluid passages 342. The combination of the tubular 340 and the shape memory member 350 may be formed as unitary member or device 355 that can be placed or slipped over the heating element 320. In such a configuration, the shape memory device 300 includes a heating element 320 placed on the base pipe 310 and a unitary device 355 that includes the shape memory material 350 on a tubular 340. The unitary member 355 is placed on the heating element 320 in a compressed state or shape 360 and conveyed into the wellbore to a selected depth. When electrical energy is supplied to the heating element 320, i.e., when the heating element 350 is activated, such as by the surface control unit 190, FIG. 1, or a timing device downhole, heat conducts from the heating element 320 to the tubular 340, which heats the shape memory material 350 to or above its glass transition temperature. The shape memory material 350 then expands from its compressed state or shape 360 to an expanded state or shape 370 and presses against the wellbore wall. Temperature sensors 380 placed at one or more suitable locations on or proximate the shape memory device may be utilized to control the electrical energy and timing thereof to controllably activate the shape memory device in the wellbore. Additionally, one or more pressure sensors 385 may be provided to determine pressure applied by the shape memory device on another element, such as wellbore wall to determine the adequacy of the contact between the shape memory device 300 and the wellbore wall. In aspects, the control unit 190 may determine the temperature from temperature sensors 180 and/or pressure from the pressure sensors and control heating of the shape memory member 350.

[0016] FIG. 4 shows a shape memory device 400 made according to yet another embodiment of the disclosure. The shape memory device 400 is shown placed around fluid passages 414 in a base pipe 410. In one aspect, the shape memory device 400 includes a shape memory member or material 450 placed or attached around a tubular 440 having fluid flow passages 442. A heating element 420 is embedded or partially embedded in the shape memory material 450 during manufacturing of the shape memory device 400. The electrical energy to the heating element 420 may be supplied via terminals 422a and 422b, as described in reference to FIGS. 1 and 3. Additionally temperature sensors 480 and pressure sensors 485 may be placed in or proximate to the shape memory device 400 and utilized by the controller 190 to control the heating of the heating element 420, as described in reference to FIG. 1.

[0017] FIG. 5 shows a shape memory device 500 made according to yet another embodiment of the disclosure. The shape memory device 500 is shown placed around fluid passages 514 in a base pipe 510. In one aspect, the shape memory device 500 includes a shape memory member or material 550 placed around or attached around to a tubular 540 having fluid flow passages 542. A heating element 520 containing one or more conductive strips 525 may be embedded or partially embedded in the shape memory material 550 during manufacturing of the shape memory device 500. The electrical energy to the heating element 520 may be supplied via terminals 522a and 522b, as described in reference to FIG. 1. Additionally, temperature sensors 580 and pressure sensors 585 may be placed in or proximate to the shape memory device 500 and utilized by the controller 190 to control the heating of the heating element 520, as described in reference to FIG. 1.

[0018] It should be understood that FIGS. 1-5 are intended to be merely illustrative of the teachings of the principles and methods described herein and which principles and methods may applied to design, construct and/or utilizes inflow control devices. Furthermore, foregoing description is directed to particular embodiments of the present disclosure for the purpose of illustration and explanation. It will be apparent, however, to one skilled in the art that many modifications and changes to the embodiment set forth above are possible without departing from the scope of the disclosure.

CLAIMS

1. An apparatus for use in a wellbore, comprising:

a downhole tool conveyable in the wellbore, the downhole tool comprising:

a shape memory member formed into a first compressed state, the shape memory device having a glass transition temperature;

a heating device associated with the shape memory member configured to heat in the wellbore the shape memory member to or above the glass transition temperature to expand the shape memory member to a second expanded state.

2. The apparatus of claim 1 further comprising a conveying member attached to the downhole tool for conveying the downhole tool into the wellbore.

3. The apparatus of claim 1 or 2, wherein the heating device includes a heating element and a power source for activating the heating element.

4. The apparatus of claim 1 or 3, wherein the power source is selected from a group consisting of: a battery in the downhole tool; and a power line in the conveying member that supplies electrical energy from a surface location to the heating element.

5. The apparatus of any of claims 1-4 further comprising a sensor for providing signals relating to a parameter of interest relating to expansion of the shape memory member in the wellbore.

6. The apparatus of claim 5, wherein the parameter of interest member selected from a group consisting of: temperature; pressure; expansion of the shape memory .

7. The apparatus of claim 5 further comprising a controller that receives signals from the sensor and in response thereto controls heating of the shape memory member.

8. The apparatus of any of the claims 1-7, wherein the heating device includes a heating element that is selected from a group consisting of: a heating element downhole and uphole of the shape memory member configured to heat a fluid in the wellbore proximate to the shape memory member to a selected temperature; a heating element at least partially embedded in the shape memory member; and a heating element placed on a tubing inside the shape memory member.

9. The apparatus of any of claims 1-7, wherein the heating device includes a heating element selected from group consisting of: a coil placed around a tubular associated with the shape memory member; a coil at least partially embedded inside a shape memory member; a heat conducting strip placed on a tubular associated with the shape memory member; and a heat conducting strip at least partially embedded inside the shape memory member.

10. A device for use in a wellbore, comprising:

a shape memory member that expands from a compressed shape to an expanded shape when the shape memory member is heated to a selected temperature;

a heating element placed proximate or in the shape memory member that heats the shape memory member to the selected temperature; and

a source proximate or embedded in the shape memory member that supplies electrical energy to the heating element to heat the shape memory member to or above a glass transition temperature of the shape memory member.

11. A method of providing an apparatus for use in a wellbore, comprising:

providing a shape memory member in a compressed state;

placing a heating element proximate or in the shape memory member; and

providing a source that supplies electrical energy to the heating element to heat the shape memory member to a selected temperature.

12. The method of claim 11, wherein providing the heating element comprises placing the heating element at a location selected from a group consisting of: downhole of the shape memory member; uphole of the shape memory member; at least partially inside the shape memory member; and on a metallic member placed within an opening in the shape memory member.

13. The method of claim 11 or 12, wherein providing the heating element comprises providing a heating element selected from a group consisting of: a coil placed around a metallic member proximate the shape memory member; a strip placed on a metallic member proximate to the shape memory member; a coil at least partially embedded in the shape memory member; a strip at least partially embedded inside the shape memory member; and heat element downhole of the shape memory member.

14. The method of any of claims 11-13 further comprising placing the shape memory member around a metallic tubular and placing the metallic tubular around a base pipe having a plurality of fluid flow passages to form a downhole assembly; and conveying the downhole assembly in the wellbore.

15. A method of producing fluid from a wellbore formed in a formation, comprising:

providing a work string containing a tool conveying member and a tool attached thereto, the tool including a shape memory member in a compressed state and heating element configured to heat the shape memory member while the tool is in the wellbore and a heating element configured to heat the shape memory member when the shape memory member is in the wellbore;

conveying the work string into the wellbore and locating the tool at a selected location in the wellbore;

supplying electrical energy to the heating element to heat the shape memory member for a selected time period to expand the shape memory member from the compressed state; and

producing the fluid from the wellbore through the expanded shape memory member.

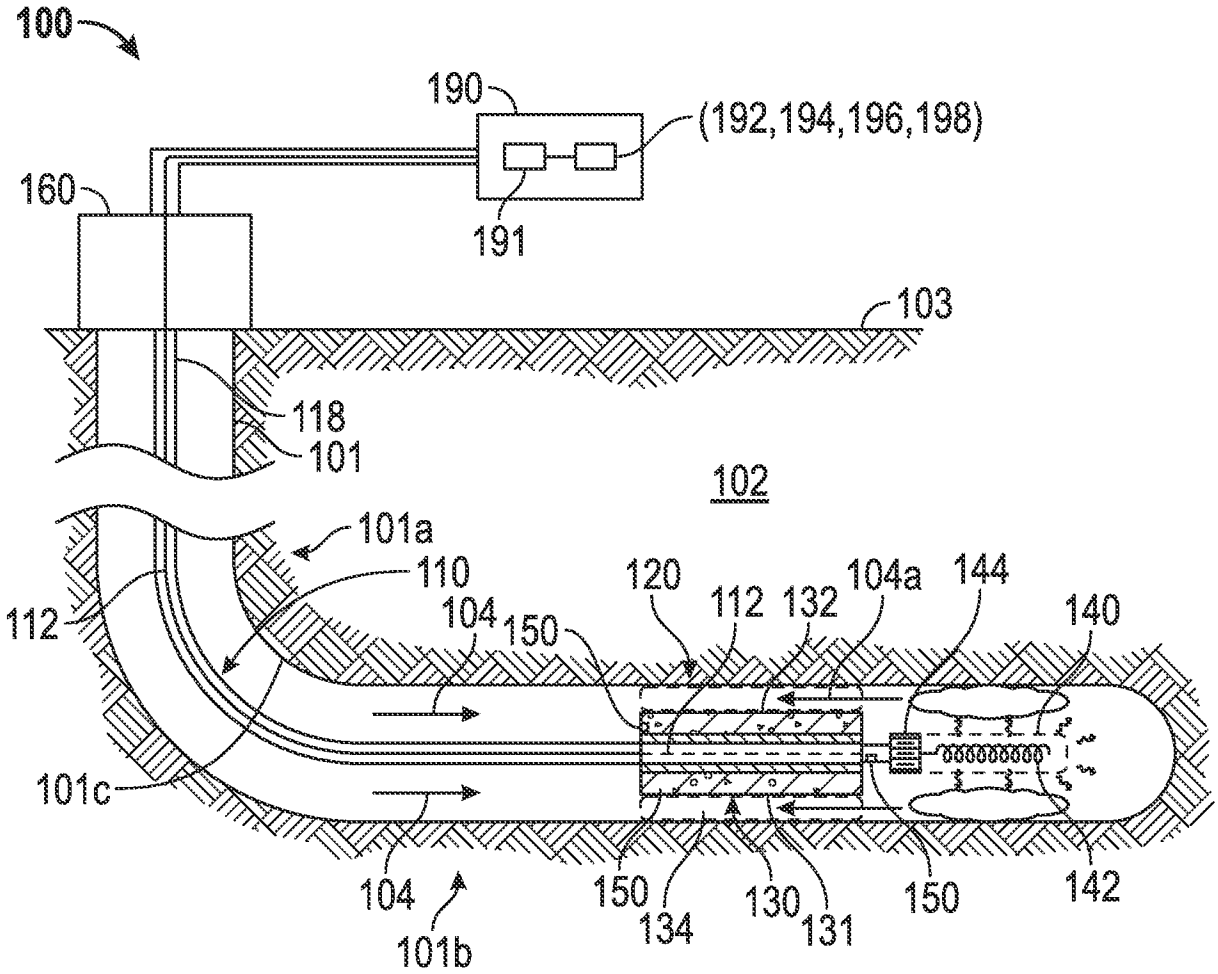
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FIG. 1

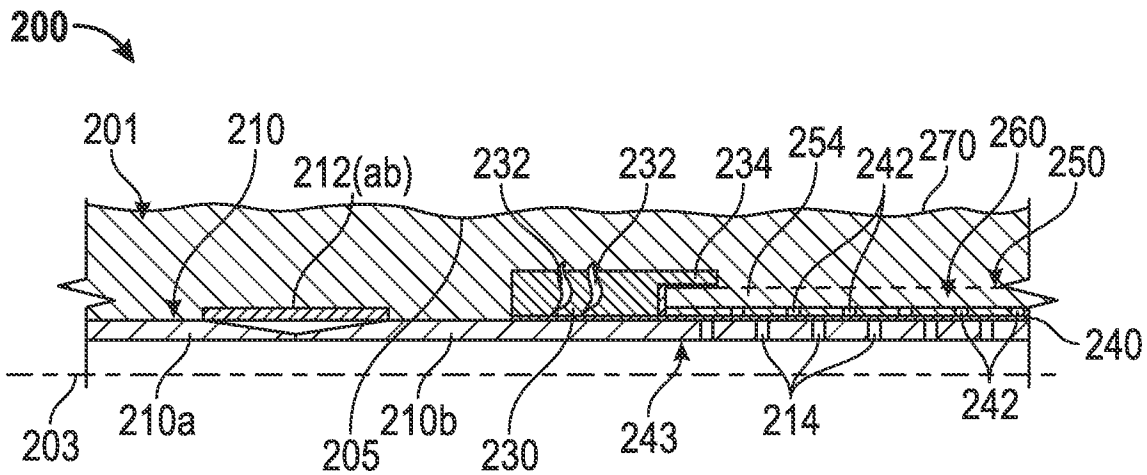
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FIG. 2

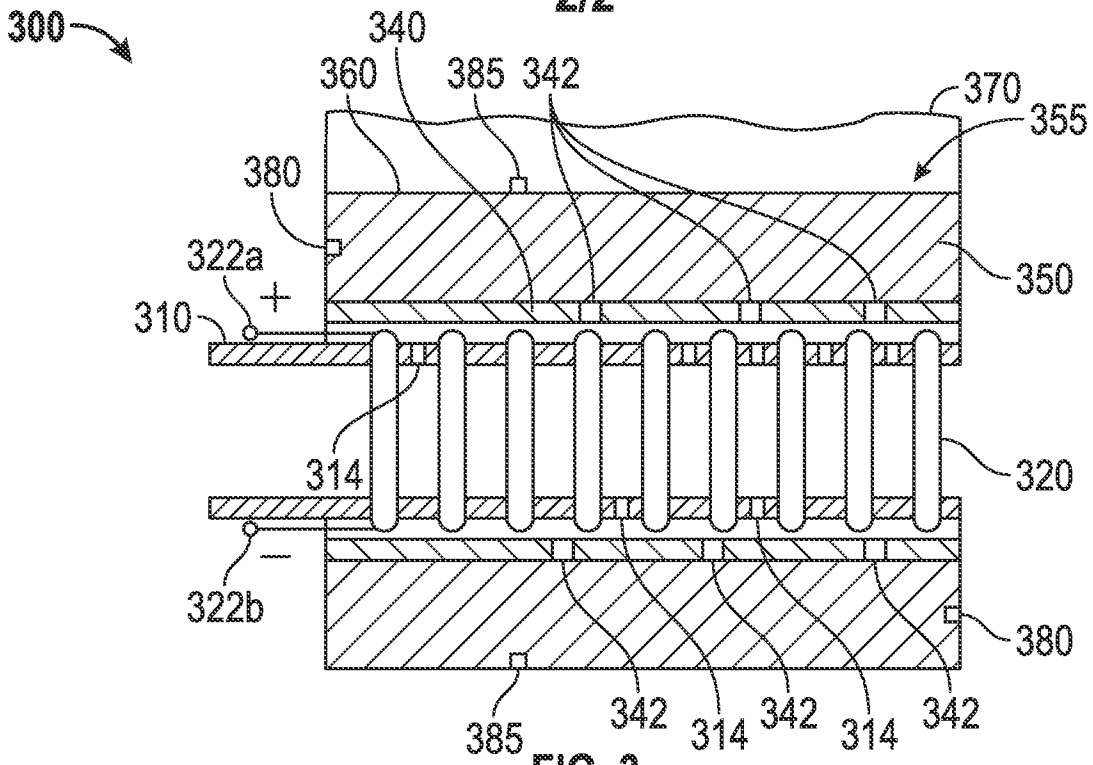

FIG. 3

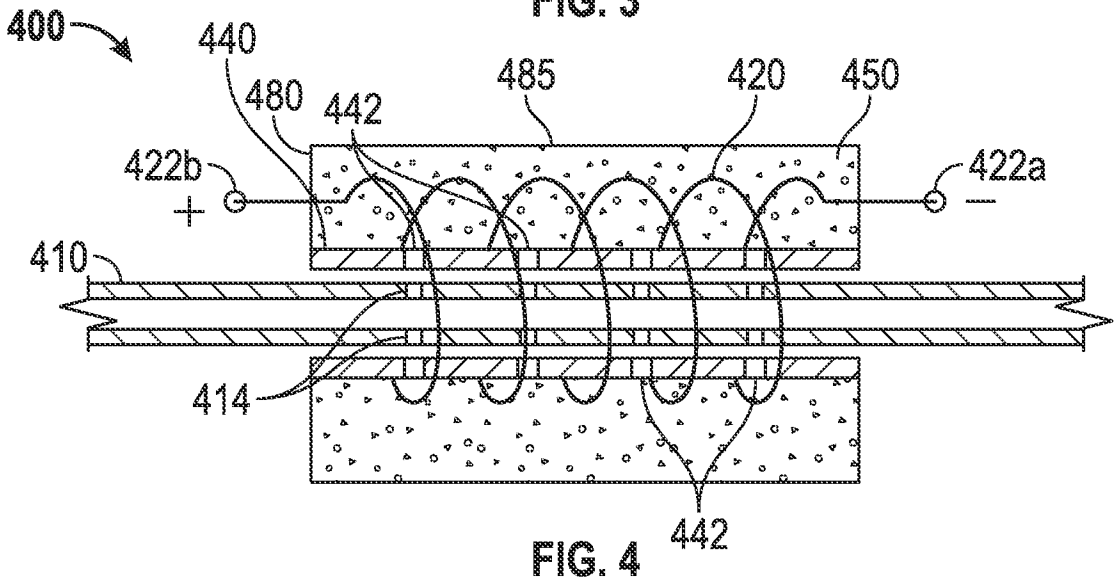

FIG. 4

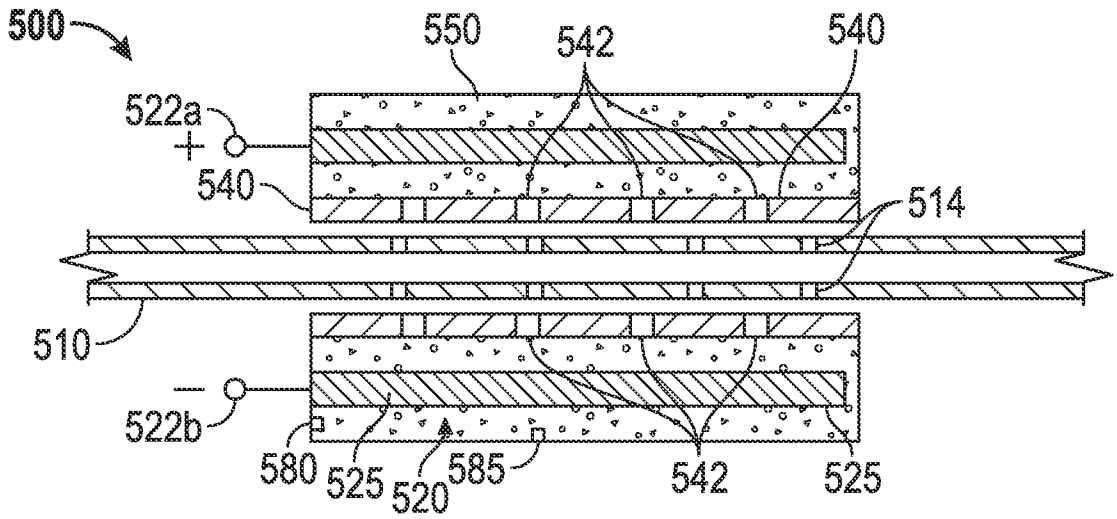

FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/038414

A. CLASSIFICATION OF SUBJECT MATTER

E21B 33/12(2006.01)i, E21B 43/12(2006.01)i

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 33/12; F03G 7/06; F16H 21/50; E21B 33/1295; E21B 23/00; E21B 43/12

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: shape memory device, heating device, power source, glass transition temperature, compressed state and expanded state

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2010-127240 A1 (WEATHERFORD/LAMB, INC.) 04 November 2010 See paragraphs [0082]-[0085],[0090]-[0092] and figure 18A.	1-3,10-13,15
A	WO 2007-121350 A1 (BAKER HUGHES INCORPORATED) 25 October 2007 See paragraphs [0013]-[0017] and figures 1,2.	1-3,10-13,15
A	US 6216779 B1 (REINHARDT, PAUL A.) 17 April 2001 See column 5,lines 14-48 and figures 2,3.	1-3,10-13,15
A	US 2011-0146265 A1 (JOSEPH et al.) 23 June 2011 See paragraphs [0011]-[0013] and figure 1.	1-3,10-13,15
A	US 2007-0144731 A1 (MURRAY et al.) 28 June 2007 See paragraphs [0012]-[0014] and figures 1,2.	1-3,10-13,15

☐ Further documents are listed in the continuation of Box C. ☒ 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
"E" earlier application or patent but published on or after the international filing date
"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)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
17 September 2014 (17.09.2014)	**17 September 2014 (17.09.2014)**

Name and mailing address of the ISA/KR
International Application Division
Korean Intellectual Property Office
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/038414

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☒ Claims Nos.: 6,7
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
Claims 6 and 7 are unclear, because they refer to multiple dependent claim which do not comply with PCT Rule 6.4(a). Therefore, claims 6 and 7 do not meet the requirements of PCT Article 6.

3. ☒ Claims Nos.: 4,5,8,9,14
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required addtional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of any additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/US2014/038414

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