

TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW,
KM, ML, MR, NE, SN, TD, TG).

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))*

Published:

- *with international search report (Art. 21(3))*

JOINTED PIPE INCLUDING AN RF HEATING SYSTEM

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Application No. 16/914639, filed on June 29, 2020, which is incorporated herein by reference in its entirety.

BACKGROUND

[0002] In the resource exploration and recovery industry, it is often times desirable to apply heat to a formation in order to more readily extract formation fluids. In formations that produce heavy oils, heat is applied to stimulate flow. An application of heat may also be used to stimulate extraction of oil from shale. Steam assisted gravity drainage (SAGD) system utilize steam injection in order to stimulate flow. Radio frequency (RF) heating arrangements may also be employed.

[0003] An RF heating system is run into a formation on a wireline. Constructing a wireline RF system is time consuming and expensive. Also, the wireline RF heating system includes a heating system that runs continuously from the wellhead to the end of the wireline. Thus, such systems, when operated, may heat, at a constant heating rate, all resource bearing zones in the formation. Accordingly, the industry would welcome an RF heating system that would be easier to construct, less expensive and which could tailor heat input to different zones in the formation.

SUMMARY

[0004] Disclosed is a subterranean radio frequency (RF) heating system including a first tubular member having a first end, a second end, an outer surface, and an inner surface. The first tubular member is made from a first electrically conductive material. A second tubular member is arranged radially inwardly of the inner surface of the first tubular member. The second tubular member includes a first end portion, a second end portion, an outer surface portion and an inner surface portion. The first end portion includes a first connector portion and the second end portion includes a second connector portion. The second tubular member is formed from a second electrically conductive material. A first electrically insulated spacer is arranged between the inner surface of the first tubular member and the outer surface portion of the second tubular member adjacent the first end and first end portion. A second electrically insulated spacer is arranged between the inner surface of the

first tubular member and the outer surface portion of the second tubular member adjacent the second end and the second end portion.

[0005] Also disclosed is a resource exploration and recovery system including a first system having a control system, and a second system including a subterranean radio frequency (RF) heating system. The RF heating system includes a first tubular member having a first end, a second end, an outer surface, and an inner surface. The first tubular member is made from a first electrically conductive material. A second tubular member is arranged radially inwardly of the inner surface of the first tubular member. The second tubular member includes a first end portion, a second end portion, an outer surface portion and an inner surface portion. The first end portion includes a first connector portion and the second end portion includes a second connector portion. The second tubular member is formed from a second electrically conductive material. A first electrically insulated spacer is arranged between the inner surface of the first tubular member and the outer surface portion of the second tubular member adjacent the first end and first end portion. A second electrically insulated spacer is arranged between the inner surface of the first tubular member and the outer surface portion of the second tubular member adjacent the second end and the second end portion.

[0006] Still further disclosed is a method of heating a formation includes introducing a radio frequency (RF) heating system including a first tubular member and a second tubular member arranged radially inwardly of and electrically insulated from the first tubular member into a formation, and electrically stimulating the one of the first tubular member and the second tubular member to produce an RF heating zone about the other of the first tubular member and the second tubular member.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] The following descriptions should not be considered limiting in any way. With reference to the accompanying drawings, like elements are numbered alike:

[0008] FIG. 1 depicts a resource exploration and recovery system including a jointed pipe having a radio frequency (RF) heating system, in accordance with an aspect of an exemplary embodiment;

[0009] FIG. 2 is a cross-sectional side view of a jointed pipe having an RF heating system, in accordance with an exemplary aspect;

[0010] FIG. 3 is a cross-sectional view of the jointed pipe of FIG. 2 taken along the line 3-3;

[0011] FIG. 4 is a cross-sectional side view of a jointed pipe having an RF heating system, in accordance with another exemplary aspect;

[0012] FIG. 5 is a cross-sectional view of the jointed pipe of FIG. 4 taken along the line 5-5;

[0013] FIG. 6 is a cross-sectional side view of a jointed pipe having an RF heating system, in accordance with yet another exemplary aspect;

[0014] FIG. 7 is a cross-sectional view of the jointed pipe of FIG. 2 taken along the line 7-7;

[0015] FIG. 8 depicts a cross-sectional side view of a jointed pipe having an RF heating system, in accordance with still yet another exemplary aspect; and

[0016] FIG. 9 depicts an RF heating system in accordance with yet still another exemplary embodiment.

DETAILED DESCRIPTION

[0017] A detailed description of one or more embodiments of the disclosed apparatus and method are presented herein by way of exemplification and not limitation with reference to the Figures.

[0018] A resource exploration and recovery system, in accordance with an exemplary embodiment, is indicated generally at 10, in FIG. 1. Resource exploration and recovery system 10 should be understood to include well drilling operations, resource extraction and recovery, CO₂ sequestration, and the like. Resource exploration and recovery system 10 may include a first system 14 which, in some environments, may take the form of a surface system 16 operatively and fluidically connected to a second system 18 which, in some environments, may take the form of a subterranean system. First system 14 may include a control system 23 that may provide power to, monitor, communicate with, and/or activate one or more downhole operations as will be discussed herein. Surface system 16 may include additional systems such as pumps, fluid storage systems, cranes and the like (not shown).

[0019] Second system 18 may include a tubular string 30, formed from a plurality of interconnected, jointed tubular members, one of which is indicated at 32, which extends into a wellbore 34 formed in a formation 36. Wellbore 34 includes an annular wall 38 which may be defined by a casing tubular 40 or by a surface (not separately labeled) of formation 36. Plurality of the jointed tubulars 32 include a subterranean radio frequency (RF) heating system 50 operatively connected to control system 23 and which is selectively activated to heat formation 36 and/or formation fluids in order to promote fluid flow.

[0020] In accordance with an exemplary embodiment depicted in FIGS. 2 and 3, RF heating system 50 includes a first tubular member 56 and a second tubular member 60 arranged radially inwardly of first tubular member 56. First tubular member 56 includes a first end 64 and a second end 65. An intermediate portion 66 defining a continuous outer surface 68 and a continuous inner surface 70 extends between first end 64 and second end 65. Continuous inner surface 70 defines a conduit 72 that receives second tubular member 60. In an embodiment, second end 65 defines a pin end connector 76 and first end 64 defines a box end connector 78. First tubular member 56 is formed from a first electrically conductive material.

[0021] Second tubular member 60 includes a first end portion 86 and a second end portion 87. An intermediate portion 88 defining a continuous outer surface portion 90 and a continuous inner surface portion 92 extends between first end portion 86 and second end portion 87. Continuous inner surface portion 92 defines a conduit portion 94. Conduit portion 94 and conduit 72 extend along a central longitudinal axis “L”. Second end portion 87 includes a first connector portion that defines a pin end connector 96 and first end portion 86 includes a second connector portion that defines a box end connector 98. Second tubular member 60 is formed from a second electrically conductive material. First and second electrically conductive materials may be similar or, depending upon a desired heat output may be distinct.

[0022] Second tubular member 60 is maintained a fixed distance from continuous inner surface 70 by a first electrically insulating spacer 102 and a second electrically insulating spacer 104. While shown as including two electrically insulating spacers, the number of electrically insulating spacers may vary. As each spacer 102, 104 is substantially similarly formed, a description will follow with respect to spacer 102 with an understanding that electrically insulating spacer 104 includes similar structure. First electrically insulating spacer 102 includes an outer circumferential edge 106 that engages continuous inner surface 70 and a central opening 108 that receives second tubular member 60. In an embodiment, spacers 102 and 104 ensure that first and second tubular members 56 and 60 only touch at select locations. For example, first and second tubular members 56 and 60 only be connected at terminal end portions (not separately labeled) of tubular string 30.

[0023] In an embodiment, control system 23 may apply an electrical current to, for example, second tubular member 60. The electrical current may induce a radio frequency (RF) response in first tubular member 56 causing in RF heating system 50 to generate heat that is passed radially outwardly and into formation 36. The heat generated by RF heating

system 50 may be uniform along an entire length of tubular string 30. Alternatively, by varying the type of electrically conductive materials used to form first tubular member 56 and/or second tubular member 60, different portions of tubular string 30 may generate different heat outputs. Further, select portions of tubular string 30 may not generate heat at all.

[0024] Reference will now follow to FIGS. 4 and 5 in describing an RF heating system 114 in accordance with another exemplary embodiment. RF heating system 114 includes a first tubular member 116 and a second tubular member 120 arranged radially inwardly of first tubular member 116. First tubular member 116 defines a first electrical conductor and includes a first end 124 and a second end 125. An intermediate portion 126 defining a continuous outer surface 128 and a continuous inner surface 130 extends between first end 124 and second end 125. Continuous inner surface 130 defines a conduit 132 that extends along a central longitudinal axis “L” and which receives second tubular member 120. In an embodiment, second end 125 defines a pin end connector 134 and first end 124 defines a box end connector 136. First tubular member 116 is formed from a first electrically conductive material.

[0025] Second tubular member 120 defines a second electrical conductor that extends along longitudinal axis “L” and includes a first end portion 142 and a second end portion 143. An intermediate portion 144 defining a continuous outer surface portion 146 extends between first end portion 142 and second end portion 143. First end portion 142 includes a first connector portion that defines a female electrical connector 149 and second end portion 143 includes a second connector portion that defines a male electrical connector 151. Second tubular member 120 may include a substantially solid cross-section and be formed from a second electrically conductive material. First and second electrically conductive materials may be similar or, depending upon a desired heat output may be distinct.

[0026] Second tubular member 120 is maintained a fixed distance from continuous inner surface 130 by a first electrically insulating spacer 156, a second electrically insulating spacer 157, and a third electrically insulating spacer 159. While shown as including three electrically insulating spacers, the number of spacers may vary. As each spacer 156, 157, and 159 is substantially similarly formed, a detailed description will follow with respect to spacer 156 with an understanding that electrically insulating spacers 157 and 159 include similar structure.

[0027] First electrically insulating spacer 156 includes an outer circumferential edge 162 that engages continuous inner surface 130 of first tubular member 116 and a central opening 164 that receives second tubular member 120. In an embodiment, spacers 156, 157, and 159 ensure that first and second tubular members 116 and 120 only touch at select locations. For example, first and second tubular members 116 and 120 only connect at terminal end portions (not separately labeled) of tubular string 30.

[0028] In an embodiment, control system 23 may apply an electrical current to, for example, second tubular member 120. The electrical current may induce a radio frequency (RF) response in first tubular member 116 causing in RF heating system 114 to generate heat that is passed radially outwardly and into formation 36. The heat generated by RF heating system 114 may be uniform along an entire length of tubular string 30. Alternatively, by varying the type of electrically conductive materials used to form first tubular member 116 and/or second tubular member 120, different zones or portions of tubular string 30 may generate different heat outputs.

[0029] Reference will now follow to FIGS. 6 and 7 in describing an RF heating system 178 in accordance with yet another exemplary aspect. RF heating system 178 includes a first tubular member 180, a second tubular member 182, and a third tubular member 184. Second and third tubular members 182 and 184 are arranged radially inwardly of first tubular member 180. First tubular member 180 includes a first end 188 and a second end 189. An intermediate portion 190 defining a continuous outer surface 192 and a continuous inner surface 194 extends between first end 188 and second end 189. Continuous inner surface 194 defines a conduit 195 that extends along a central longitudinal axis “L” and which receives second tubular member 182 and third tubular member 184. In an embodiment, second and third tubular member 182 and 184 are equally spaced from central longitudinal axis “L”. Of course, it should be understood that the spacing of second and third tubular members relative to longitudinal axis “L” may vary. In an embodiment, second end 189 defines a pin end connector 198 and first end 188 defines a box end connector 200. First tubular member 180 is formed from a first electrically conductive material.

[0030] Second tubular member 182 includes a first end portion 204 and a second end portion 205. An intermediate portion 206 defining a continuous outer surface portion 208 that extends between first end portion 204 and second end portion 205. Second end portion 205 includes a first connector portion that defines a male electrical connector 210 and first end portion 204 includes a second connector portion that defines a female electrical connector 212. Second tubular member 182 may include a substantially solid cross-section

and be formed from a second electrically conductive material. First and second electrically conductive materials may be similar or, depending upon a desired heat output may be distinct.

[0031] Third tubular member 184 includes a first end section 215 and a second end section 216. An intermediate portion 217 extends between first end section 215 and second end section 216 defining a substantially continuous outer surface portion 219. First end section 214 defines a female electrical connector 222 and second end section 216 defines a male electrical connector 223. Third tubular member 184 may include a substantially solid cross-section and be formed from a third electrically conductive material. Third electrically conductive material may be similar or identical to first and second electrically conductive materials or, depending upon a desired heat output may be distinct.

[0032] Second tubular member and third tubular members 182 and 184 are maintained a fixed distance from continuous inner surface 194 by a first electrically insulating spacer 226, a second electrically insulating spacer 227, and a third electrically insulating spacer 228. While shown as including three electrically insulating spacers, the number of spacers may vary. As each spacer 226, 227, and 228 is substantially similarly formed, a detailed description will follow with respect to spacer 226 with an understanding that electrically insulating spacers 227 and 228 include similar structure.

[0033] First electrically insulating spacer 226 includes an outer circumferential edge 231 that engages continuous inner surface 194 of first tubular member 180, a first opening 233 and a second opening 234. First opening 223 is receptive of second tubular member 182 and second opening 234 is receptive of third tubular member 184. In an embodiment, spacers 226, 227, and 228 ensure that second and third tubular members 184 and 186 only touch first tubular member 180 at select locations. For example, second and third tubular members 184 and 186 only touch first tubular member 180 at terminal end portions (not separately labeled) of tubular string 30.

[0034] In an embodiment, control system 23 may apply an electrical current to, for example, second and third tubular members 184 and 186. The electrical current may induce a radio frequency (RF) response in first tubular member 180 causing RF heating system 178 to generate heat that is passed into formation 36. The heat generated by RF heating system 178 may be uniform along an entire length of tubular string 30. Alternatively, by varying the type of electrically conductive materials used to form first tubular member 180, second tubular member 182, and/or third tubular member 184, different zones or portions of tubular string 30 may generate different heat outputs.

[0035] Reference will now follow to FIG. 8, wherein like reference numbers represent corresponding parts in the respective views in describing another exemplary aspect of RF heating system 178. In an embodiment, conduit portion 94 may define a flow path 250 for fluid passing from surface system 16. The fluid may be heated by RF heating system 50 to produce steam which may then be introduced into formation 36. Thus, instead of expending energy at surface system 16 to produce steam, introduce the steam into tubular string 30, and flow the steam to a point of injection; the fluid may be heated to a selected temperature by, for example, RF heating system 50 just prior to injection. In this manner, the exemplary embodiments reduce losses associated with steam flow along tubular string 30 and reduces an amount of energy needed at surface system 16 to produce and deliver steam to a point of injection.

[0036] In accordance with another exemplary aspect, first electrically insulating spacer 102 may include one or more passages such as shown at 260 and second electrically insulating spacer 104 may include one or more passages such as shown at 264. As such, another flow 268 may be arranged radially outwardly of flow path 250, with fluid flowing through passages 260 and 264. Another flow path 268 may deliver fluid, which may be heated to produce steam, into formation 36. In accordance with yet another exemplary aspect, a first fluid may pass along flow path 250 and a second fluid may pass along another flow path 268. The first and second fluids may be heated by RF heating system 178 and combined to initiate a chemical reaction, such as an exothermic reaction, that produces additional heat. The combined heated fluid may be injected into formation 36 as part of a treatment operation.

[0037] FIG. 9 depicts an RF heating system 300 in accordance with another exemplary aspect. RF heating system 300 includes a first tubular member 304 shown in the form of casing tubular 40 and a second tubular member 310 which may take the form of a wireline 312. Wireline 312 supports a number of electrically insulating spacers 320 and 322. Spacers 320 and 322 are run into wellbore 34 with wireline 312 and maintain a desired spacing between first tubular member 304 and second tubular member 310. Each spacer 320, 322 may include corresponding passages, two of which are shown at 340 and 342. Of course, the number and orientation of the passages may vary.

[0038] In an embodiment, control system 23 may apply an electrical current to, for example, second tubular member 310. The electrical current may induce a radio frequency (RF) response in first tubular member 304 resulting in RF heating system 300 generating heating zone having a selected intensity that acts on formation 36. Alternatively, RF heating

system 300 may generate heat that is passed into fluid passing along wellbore 34. The heat generated by RF heating system 300 may be uniform along an entire length of casing tubular 40. Alternatively, by varying the type of electrically conductive materials used to form first tubular member 304 and/or second tubular member 310 or portions of casing tubular 40 may generate different RF heating zones having various intensities.

[0039] In an embodiment, the RF heating system may extend continuously from surface system 16 to a toe (not shown) of wellbore 34. RF heating system may deliver a uniform heat value or intensity to formation 36 and/or fluid passing through the first and/or second tubulars. In another exemplary aspect, the RF heating system may be designed to deliver different heat values or intensities depending on depth and/or desired heating characteristics. In yet another exemplary aspect, the RF heating system may be arranged in discrete zones along tubular string 30. That is, the RF heating system need not be continuous. That is, the RF heating system may establish a first RF heating zone through a first plurality of tubulars having a first intensity and a second RF heating zone through a second plurality of tubular, spaced from the first RF heating zone, having a second intensity

[0040] As an example, the RF heating system may be employed to connect various jewelry components arranged along tubular string 30. The RF heating system may establish connections between packers, valves, telescopic joints, screens, drills, mills, or other mechanisms, components or the like that may be run into a wellbore. Still further, it should be understood that the connections between adjoining first tubulars, adjoining second tubulars and, if present, adjoining third tubular may vary and should not be considered to be limited to the connections shown and described herein.

[0041] Set forth below are some embodiments of the foregoing disclosure:

[0042] Embodiment 1. A subterranean radio frequency (RF) heating system comprising: a first tubular member having a first end, a second end, an outer surface, and an inner surface, the first tubular member being made from a first electrically conductive material; a second tubular member arranged radially inwardly of the inner surface of the first tubular member, the second tubular member including a first end portion, a second end portion, an outer surface portion and an inner surface portion, the first end portion including a first connector portion and the second end portion including a second connector portion, the second tubular member being formed from a second electrically conductive material; a first electrically insulated spacer arranged between the inner surface of the first tubular member and the outer surface portion of the second tubular member adjacent the first end and first end portion; and a second electrically insulated spacer arranged between the inner surface of the

first tubular member and the outer surface portion of the second tubular member adjacent the second end and the second end portion.

[0043] Embodiment 2. The subterranean RF heating system according to any prior embodiment, wherein the first end of the first tubular member comprises a box end connector and the second end of the first tubular member comprises a pin end connector, and the first connector portion on the second tubular member comprises a box end connector and the second connector portion of the second tubular member comprises a pin end connector.

[0044] Embodiment 3. The subterranean RF heating system according to any prior embodiment, wherein the second tubular member comprises an electrical conductor.

[0045] Embodiment 4. The subterranean RF heating system according to any prior embodiment, wherein the first connector portion on the second tubular member is a female electrical connector arranged at the first end and the second connector portion on the second tubular member is a male electrical connector arranged at the second end.

[0046] Embodiment 5. The subterranean RF heating system according to any prior embodiment, wherein the subterranean radio frequency (RF) heating system includes a third tubular member, the second tubular member comprises a first electrical conductor and the third tubular member comprises a second electrical conductor, each of the first electrical conductor and the second electrical conductor being radially outwardly spaced from a central longitudinal axis of the first tubular member.

[0047] Embodiment 6. The subterranean RF heating system according to any prior embodiment, wherein the first tubular member comprises a casing tubular.

[0048] Embodiment 7. A resource exploration and recovery system comprising: a first system including a control system; and a second system including a subterranean radio frequency (RF) heating system comprising: a first tubular member having a first end, a second end, an outer surface, and an inner surface, the first tubular member being made from a first electrically conductive material; a second tubular member arranged radially inwardly of the inner surface of the first tubular member, the second tubular member including a first end portion, a second end portion, an outer surface portion and an inner surface portion, the first end portion including a first connector portion and the second end portion including a second connector portion, the second tubular member being operably connected to the control system and formed from a second electrically conductive material; a first electrically insulated spacer arranged between the inner surface of the first tubular member and the outer surface portion of the second tubular member adjacent the first end and first end portion; and a second electrically insulated spacer arranged between the inner surface of the first tubular

member and the outer surface portion of the second tubular member adjacent the second end and the second end portion, wherein the control system selectively activates the first tubular member and the second tubular member to produce RF heating in the formation having a selected heat value.

[0049] Embodiment 8. The resource exploration and recovery system according to any prior embodiment, wherein the first end of the first tubular member comprises a box end connector and the second end of the first tubular member comprises a pin end connector and the first connector portion of the second tubular member comprises a box end connector and the second connector portion of the second tubular member comprises a pin end connector.

[0050] Embodiment 9. The resource exploration and recovery system according to any prior embodiment, wherein the second tubular member comprises an electrical conductor.

[0051] Embodiment 10. The resource exploration and recovery system according to any prior embodiment, wherein the first connector portion on the second tubular member is a female electrical connector arranged at the first end and the second connector portion on the second tubular member is a male electrical connector arranged at the second end.

[0052] Embodiment 11. The resource exploration and recovery system according to any prior embodiment, wherein the second tubular member comprises a first electrical conductor and a second electrical conductor, each of the first electrical conductor and the second electrical conductor being radially outwardly spaced from a central axis of the first tubular member.

[0053] Embodiment 12. The resource exploration and recovery system according to any prior embodiment, wherein the first tubular member comprises a casing tubular.

[0054] Embodiment 13. The resource exploration and recovery system according to any prior embodiment, wherein a first plurality of the plurality of interconnected tubulars includes the subterranean RF heating system having the selected heat value and a second plurality of the plurality of interconnected tubulars includes a subterranean RF heating system including a second heat value.

[0055] Embodiment 14. The resource exploration and recovery system according to any prior embodiment, wherein the second tubular member is formed from a first material and the second tubular member is formed from a second material that is distinct from the first material.

[0056] Embodiment 15. A method of heating a formation comprising: introducing a radio frequency (RF) heating system including a first tubular member and a second tubular

member arranged radially inwardly of and electrically insulated from the first tubular member into a formation; and electrically stimulating the one of the first tubular member and the second tubular member to produce an RF heating zone about the other of the first tubular member and the second tubular member.

[0057] Embodiment 16. The method according to any prior embodiment, further comprising: running the RF heating system into the formation as part of a string of interconnected tubulars.

[0058] Embodiment 17. The method according to any prior embodiment, further comprising: electrically stimulating the first tubular member and the second tubular member of the RF heating system to produce the RF heating zone having a first intensity and electrically stimulating a first tubular member and a second tubular member of another RF heating system connected to the RF heating system to produce another RF heating zone having a second intensity that is distinct from the first intensity.

[0059] Embodiment 18. The method according to any prior embodiment, wherein the RF heating system is operated to create the RF heating zone in a first portion of the formation and the another RF heating system is operated to produce the another RF heating zone in a second portion of the formation that does not adjoin the first portion of the formation.

[0060] Embodiment 19. The method according to any prior embodiment, further comprising: introducing a fluid into one of the first tubular member and the second tubular member; heating the fluid with the RF heating system to produce a heated fluid; and injecting the heated fluid into a formation.

[0061] Embodiment 20. The method according to any prior embodiment, further comprising: introducing the first fluid into the first tubular member and a second fluid into the second tubular member.

[0062] The use of the terms “a” and “an” and “the” and similar referents in the context of describing the invention (especially in the context of the following claims) are to be construed to cover both the singular and the plural, unless otherwise indicated herein or clearly contradicted by context. Further, it should be noted that the terms “first,” “second,” and the like herein do not denote any order, quantity, or importance, but rather are used to distinguish one element from another.

[0063] The terms “about” and “substantially” are intended to include the degree of error associated with measurement of the particular quantity based upon the equipment available at the time of filing the application. For example, “about” and/or “substantially” can include a range of $\pm 8\%$ or 5% , or 2% of a given value.

[0064] The teachings of the present disclosure may be used in a variety of well operations. These operations may involve using one or more treatment agents to treat a formation, the fluids resident in a formation, a wellbore, and / or equipment in the wellbore, such as production tubing. The treatment agents may be in the form of liquids, gases, solids, semi-solids, and mixtures thereof. Illustrative treatment agents include, but are not limited to, fracturing fluids, acids, steam, water, brine, anti-corrosion agents, cement, permeability modifiers, drilling muds, emulsifiers, demulsifiers, tracers, flow improvers etc. Illustrative well operations include, but are not limited to, hydraulic fracturing, stimulation, tracer injection, cleaning, acidizing, steam injection, water flooding, cementing, etc.

[0065] While the invention has been described with reference to an exemplary embodiment or embodiments, it will be understood by those skilled in the art that various changes may be made, and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the claims. Also, in the drawings and the description, there have been disclosed exemplary embodiments of the invention and, although specific terms may have been employed, they are unless otherwise stated used in a generic and descriptive sense only and not for purposes of limitation, the scope of the invention therefore not being so limited.

What is claimed is:

1. A subterranean radio frequency (RF) heating system (50) comprising:
a first tubular member (116) having a first end (124), a second end (125), an outer surface, and an inner surface, the first tubular member (116) being made from a first electrically conductive material;
a second tubular member (120) arranged radially inwardly of the inner surface of the first tubular member (116), the second tubular member (120) including a first end portion (142), a second end portion (143), an outer surface portion and an inner surface portion, the first end portion (142) including a first connector portion and the second end portion (143) including a second connector portion, the second tubular member (120) being formed from a second electrically conductive material;
a first electrically insulated spacer (102) arranged between the inner surface of the first tubular member (116) and the outer surface portion of the second tubular member (120) adjacent the first end (124) and first end portion (142); and
a second electrically insulated spacer (102) arranged between the inner surface of the first tubular member (116) and the outer surface portion of the second tubular member (120) adjacent the second end (125) and the second end portion (143).
2. The subterranean RF heating system (114) according to claim 1, wherein the first end (124) of the first tubular member (116) comprises a box end connector (136) and the second end (125) of the first tubular member (116) comprises a pin end connector (134), and the first connector portion on the second tubular member (120) comprises a box end connector (136) and the second connector portion of the second tubular member (120) comprises a pin end connector (134).
3. The subterranean RF heating system (114) according to claim 1, wherein the second tubular member (120) comprises an electrical conductor.
4. The subterranean RF heating system (114) according to claim 3, wherein the first connector portion on the second tubular member (120) is a female electrical connector (149) arranged at the first end (124) and the second connector portion on the second tubular member (120) is a male electrical connector (151) arranged at the second end (125).
5. The subterranean RF heating system (114) according to claim 1, wherein the subterranean radio frequency (RF) heating system (50) includes a third tubular member (184), the second tubular member (120) comprises a first electrical conductor and the third tubular member (184) comprises a second electrical conductor, each of the first electrical

conductor and the second electrical conductor being radially outwardly spaced from a central longitudinal axis of the first tubular member (116).

6. The subterranean RF heating system (114) according to claim 1, wherein the first tubular member (116) comprises a casing tubular (40).

7. A resource exploration and recovery system (10) comprising:
a first system (14) including a control system (23); and
a second system (18) including a subterranean radio frequency (RF) heating system (50) comprising:

a first tubular member (116) having a first end (124), a second end (125), an outer surface, and an inner surface, the first tubular member (116) being made from a first electrically conductive material;

a second tubular member (120) arranged radially inwardly of the inner surface of the first tubular member (116), the second tubular member (120) including a first end portion (142), a second end portion (143), an outer surface portion and an inner surface portion, the first end portion (142) including a first connector portion and the second end portion (143) including a second connector portion, the second tubular member (120) being operably connected to the control system (23) and formed from a second electrically conductive material;

a first electrically insulated spacer (102) arranged between the inner surface of the first tubular member (116) and the outer surface portion of the second tubular member (120) adjacent the first end (124) and first end portion (142); and

a second electrically insulated spacer (102) arranged between the inner surface of the first tubular member (116) and the outer surface portion of the second tubular member (120) adjacent the second end (125) and the second end portion (143), wherein the control system (23) selectively activates the first tubular member (116) and the second tubular member (120) to produce RF heating in the formation (36) having a selected heat value.

8. The resource exploration and recovery system (10) according to claim 7, wherein the first end (124) of the first tubular member (116) comprises a box end connector (136) and the second end (125) of the first tubular member (116) comprises a pin end connector (134) and the first connector portion of the second tubular member (120) comprises a box end connector (136) and the second connector portion of the second tubular member (120) comprises a pin end connector (134).

9. The resource exploration and recovery system (10) according to claim 7, wherein the second tubular member (120) comprises a first electrical conductor and a second

electrical conductor, each of the first electrical conductor and the second electrical conductor being radially outwardly spaced from a central axis of the first tubular member (116).

10. The resource exploration and recovery system (10) according to claim 7, wherein the first tubular member (116) comprises a casing tubular (40).

11. The resource exploration and recovery system (10) according to claim 7, wherein a first plurality of the plurality of interconnected tubulars includes the subterranean RF heating system (114) having the selected heat value and a second plurality of the plurality of interconnected tubulars includes a subterranean RF heating system (114) including a second heat value.

12. A method of heating a formation (36) comprising:
introducing a radio frequency (RF) heating system (50) including a first tubular member (116) and a second tubular member (120) arranged radially inwardly of and electrically insulated from the first tubular member (116) into a formation (36); and
electrically stimulating the one of the first tubular member (116) and the second tubular member (120) to produce an RF heating zone about the other of the first tubular member (116) and the second tubular member (120).

13. The method of claim 12, further comprising: running the RF heating system (114) into the formation (36) as part of a string of interconnected tubulars.

14. The method of claim 13, further comprising: electrically stimulating the first tubular member (116) and the second tubular member (120) of the RF heating system (114) to produce the RF heating zone having a first intensity and electrically stimulating a first tubular member (116) and a second tubular member (120) of another RF heating system (114) connected to the RF heating system (114) to produce another RF heating zone having a second intensity that is distinct from the first intensity.

15. The method of claim 12, further comprising:
introducing a fluid into one of the first tubular member (116) and the second tubular member (120);
heating the fluid with the RF heating system (114) to produce a heated fluid; and
injecting the heated fluid into a formation (36).

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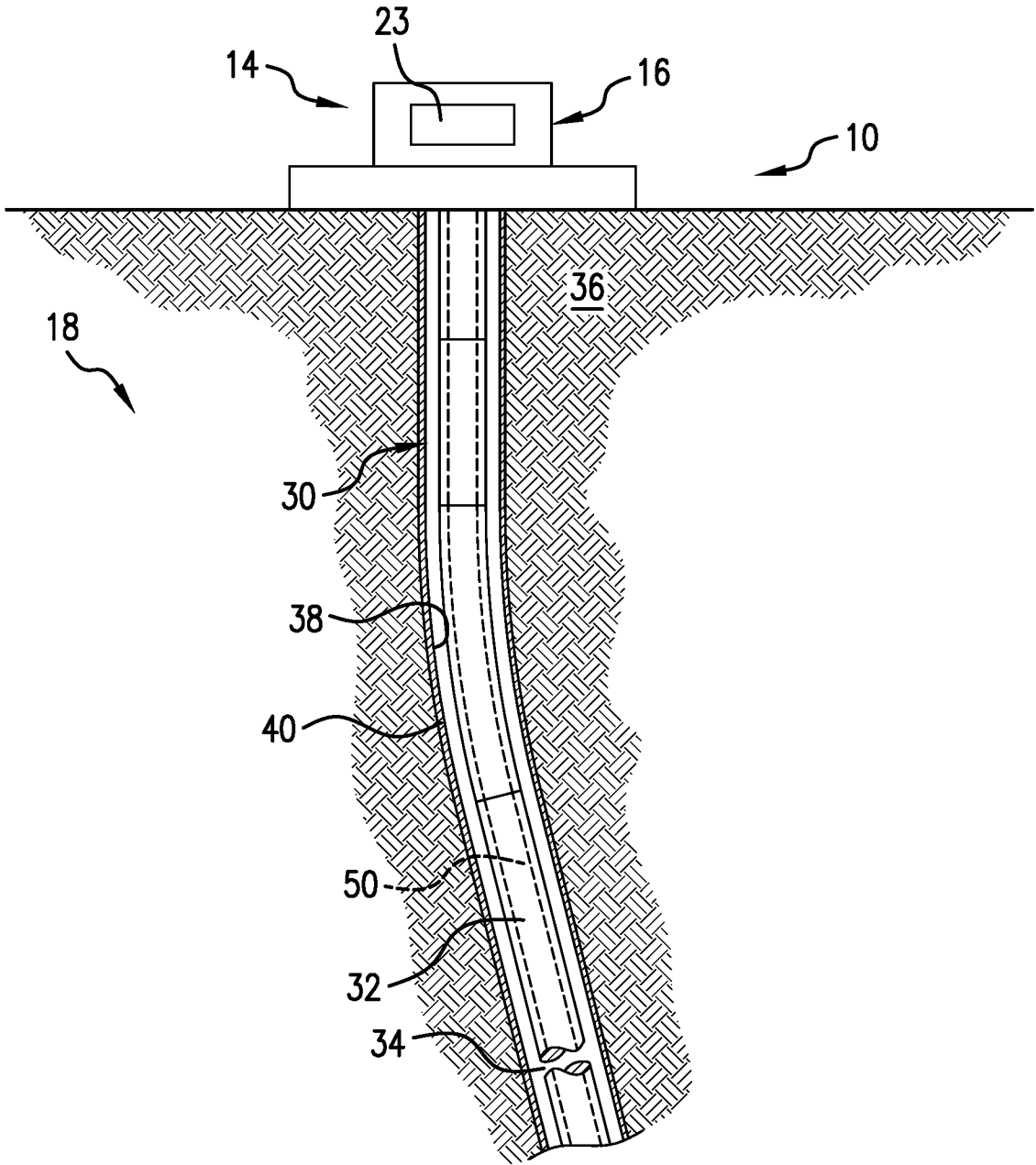


FIG. 1

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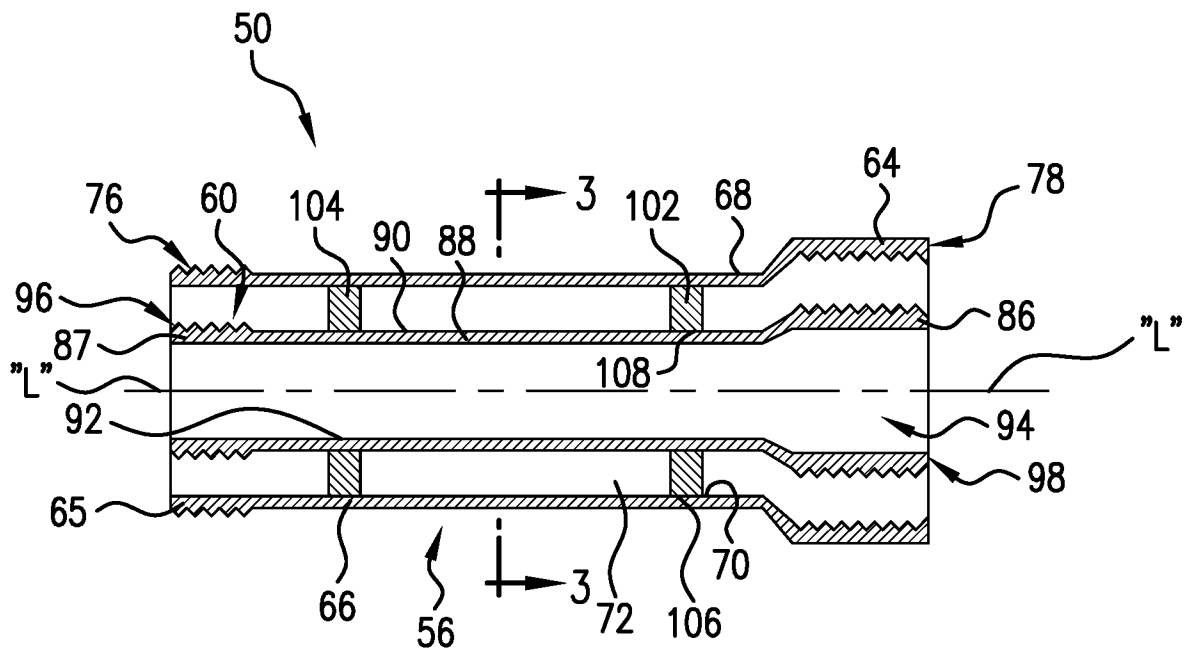


FIG. 2

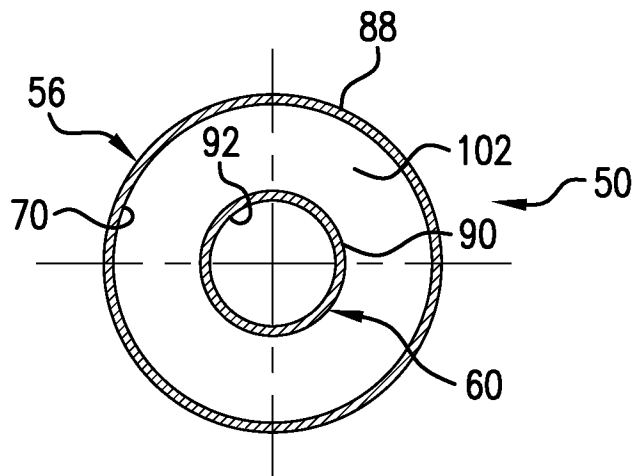


FIG. 3

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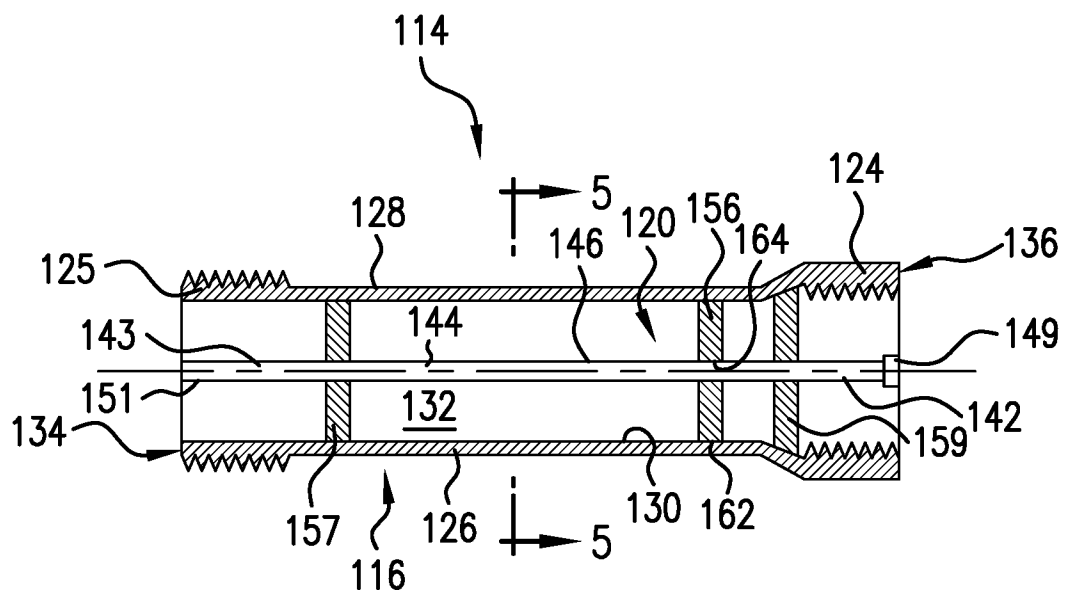


FIG. 4

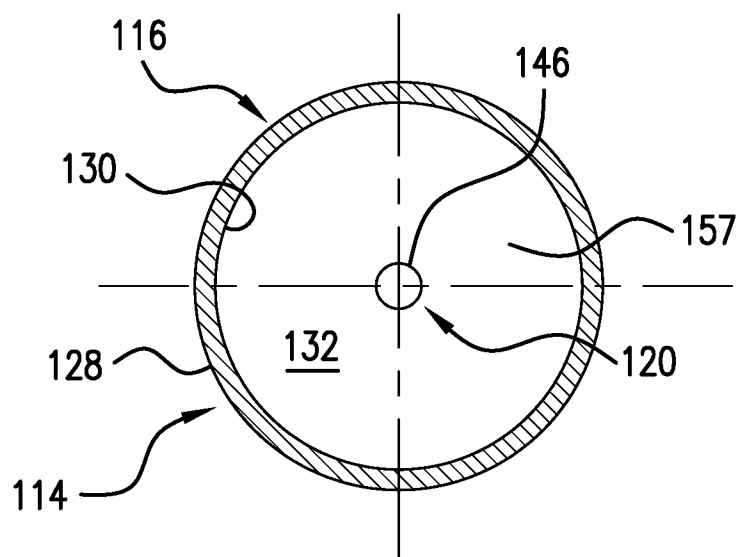


FIG. 5

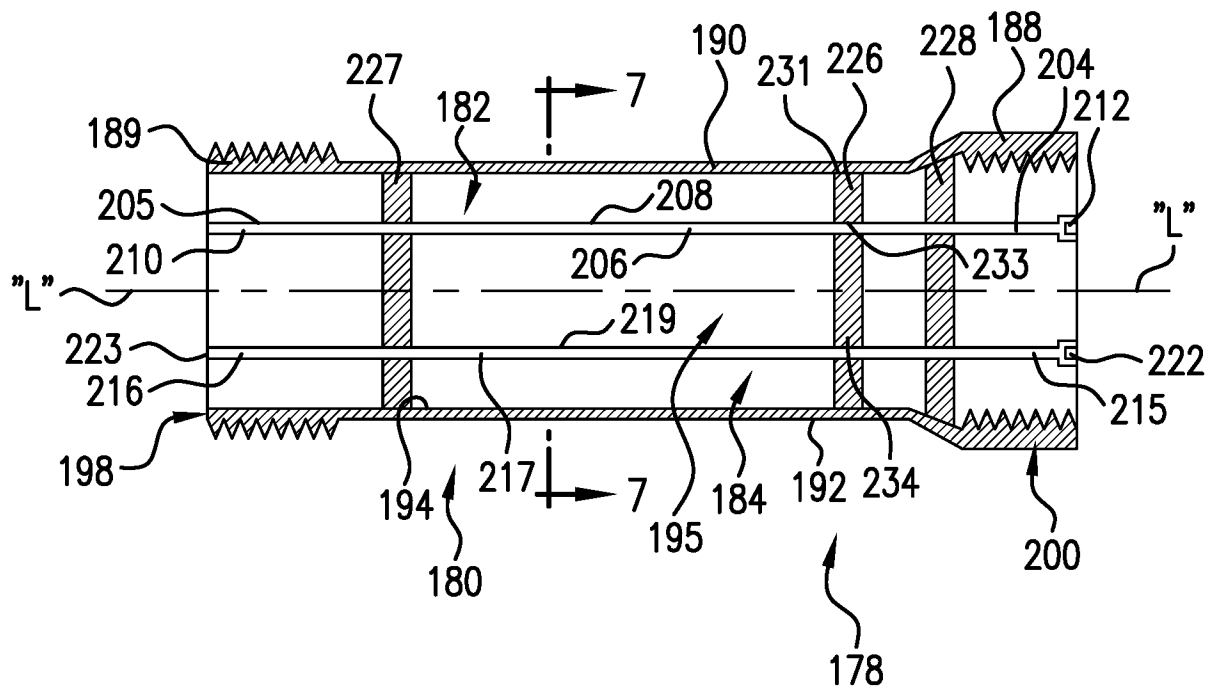


FIG.6

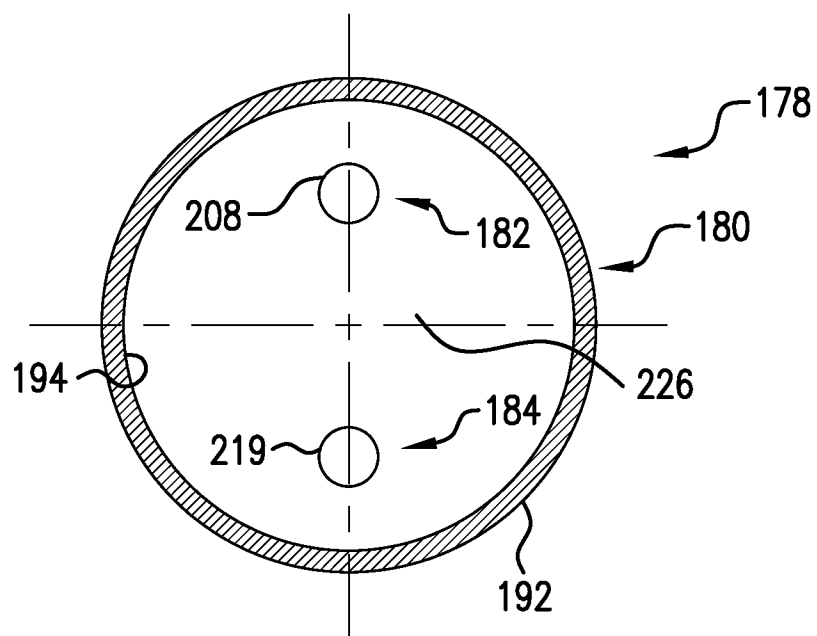


FIG.7

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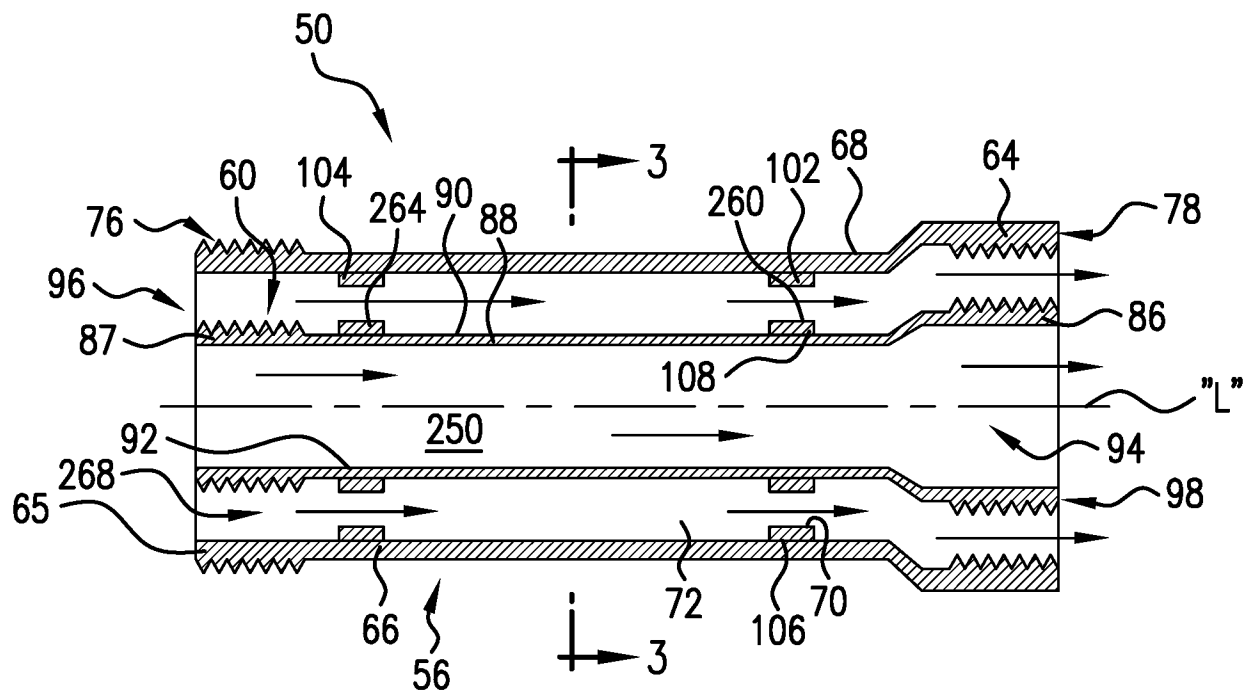


FIG.8

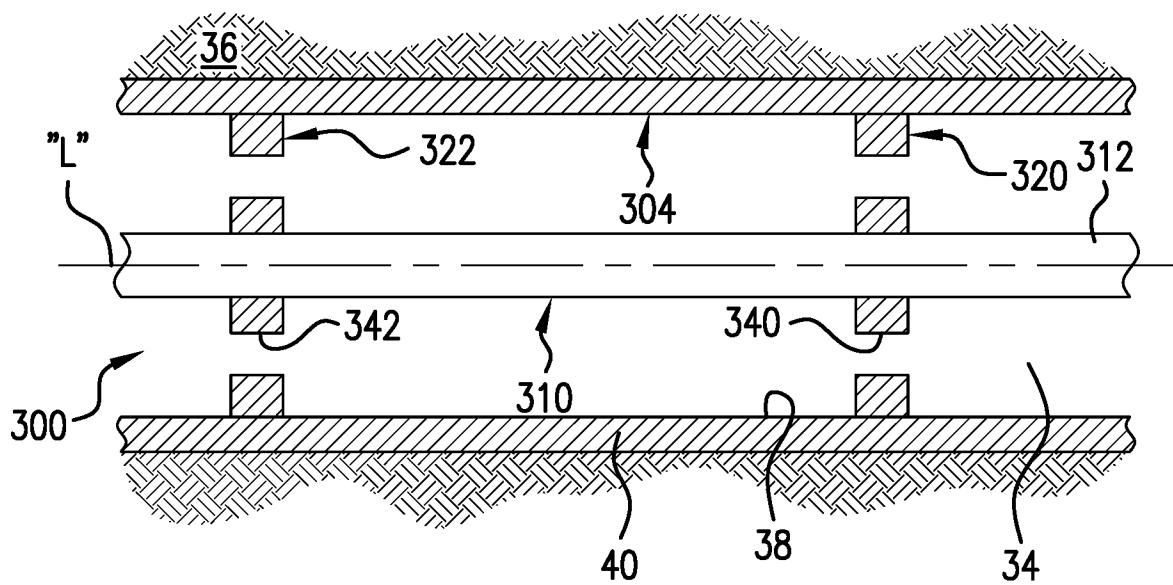


FIG.9

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2021/038058

A. CLASSIFICATION OF SUBJECT MATTER E21B 43/24(2006.01)i; E21B 36/00(2006.01)i; E21B 17/00(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 43/24(2006.01); E21B 36/00(2006.01); E21B 36/04(2006.01); F16L 9/14(2006.01); F16L 9/22(2006.01) 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: radio frequency, heating, tubular, electrically insulated spacer, connector portion, electrical conductor		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2014-0216726 A1 (HARRIS CORPORATION) 07 August 2014 (2014-08-07) paragraphs [0012], [0035]-[0036], [0058], [0066], [0074] and figures 1-2, 9, 13, 15	12-13
Y		1-11,14-15
Y	US 2014-0326504 A1 (HAY et al.) 06 November 2014 (2014-11-06) paragraphs [0018]-[0027], [0035]-[0036] and figures 2-3, 8	1-11,14-15
Y	US 2012-0006444 A1 (TUPPER et al.) 12 January 2012 (2012-01-12) paragraph [0051] and figure 6	5,9
A	WO 2007-084763 A2 (PYROPHASE, INC.) 26 July 2007 (2007-07-26) claims 1, 20 and figures 7-8	1-15
A	CN 106761628 A (PETROCHINA COMPANY LIMITED) 31 May 2017 (2017-05-31) claims 1-5 and figure 1	1-15
☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
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Date of the actual completion of the international search 05 October 2021		Date of mailing of the international search report 06 October 2021
Name and mailing address of the ISA/KR Korean Intellectual Property Office 189 Cheongsa-ro, Seo-gu, Daejeon 35208, Republic of Korea Facsimile No. +82-42-481-8578		Authorized officer PARK, Tae Wook Telephone No. +82-42-481-3405

INTERNATIONAL SEARCH REPORT
Information on patent family members

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				US	8408294	B2	02 April 2013
				WO	2007-084763	A3	28 February 2008
CN	106761628	A	31 May 2017	None			