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(54) Title: APPARATUS AND METHODS FOR CLEARING A SUBSEA TUBULAR

(57) Abstract: A tool (300) for clearing a deposit (60) within a fluid flowline (50), including a body (320) having a central axis (325), a first end (320a), a second end (320b) opposite the first end, and a radially outer surface (320c) extending axially from the first end of the second end. In addition, the tool includes a first energy element (124) coupled to the first end (320a), and an electrode (340) extending radially from the radially outer surface of the body. The first energy element (124) and the electrode (340) are each configured to emit energy to dissipate the deposit in the fluid flowline.

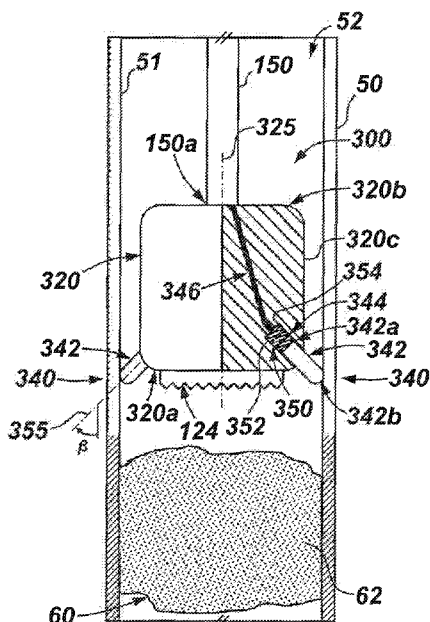


Figure 11



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LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE,
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APPARATUS AND METHODS FOR CLEARING A SUBSEA TUBULAR**CROSS-REFERENCE TO RELATED APPLICATIONS**

[0001] This application claims the benefit of U.S. Provisional Patent Application Serial No. 61/885,282, filed October 1, 2013, and entitled "Apparatus and Methods for Clearing a Subsea Tubular," which is hereby incorporated herein by reference in its entirety.

**STATEMENT REGARDING FEDERALLY SPONSORED
RESEARCH OR DEVELOPMENT**

[0002] Not applicable.

BACKGROUND

[0003] The invention relates generally to clearing blockages in flowlines. More particularly, the invention relates to apparatus and methods for clearing hydrate blockages in subsea hydrocarbon fluid flowlines.

[0004] Offshore oil and gas operations typically employ the use of elongate flowlines to transport hydrocarbons from one point to another. In deepsea operations, the temperature of the ocean environment around the flowline can be as low as 4° C. At such temperatures, gas hydrates can form within the flowline, thereby at least partially obstructing fluid flow therethrough. In some cases, wax and/or asphaltine materials can also form deposits in the flowline that further obstruct fluid flow therethrough. In extreme cases, deposits in a flowline can be sufficient to completely block fluid flow through the flowline, thus rendering the flowline inoperable.

[0005] Typically, deposits formed within flowlines are removed with a clearance tool such as a pipeline "pig". Such tools are usually electrically or hydraulically powered. For at least some electrically powered pigs, flowline obstructions are removed with mechanical means such as, for example, a drill bit disposed on the leading end of the tool. Alternatively, hydraulic tools may be used which rely on pressure differentials across the tool to drive it through the flowline, thus allowing the tool to sweep out any deposits formed therein.

BRIEF SUMMARY OF THE DISCLOSURE

[0006] In light of the foregoing, embodiments disclosed herein are directed to a tool for clearing a deposit within a fluid flowline. In an embodiment, the tool comprises a body having a central axis, a first end, a second end opposite the first end, and a radially outer surface extending axially from the first end to the second end. In addition, the tool comprises a first energy element coupled to the first end. Further, the tool comprises an electrode extending radially from the radially outer surface of the body. The first energy element and the electrode are each configured to emit energy to dissipate the deposit in the fluid flowline.

[0007] Other embodiments disclosed herein are directed to a tool for clearing a deposit from a fluid flowline. In an embodiment, the tool comprises a body having a central axis, a first end, a second end opposite the first end, a radially outer surface extending axially from the first end to the second end, and a first throughbore extending axially from the first end to the second end. In addition, the tool comprises a first energy element coupled to the first end of the body. The first energy element is configured to emit energy to dissipate the deposit in the flowline. Further, the tool comprises a first pumping assembly disposed in the first throughbore and configured to pump fluid through the first throughbore.

[0008] Still other embodiments disclosed herein are directed to a method for clearing a deposit from a flowline. In an embodiment, the method comprises moving a flowline clearance tool through the flowline toward the deposit, wherein the tool comprises a body having a central axis, a first end, a second end opposite the first end, and a radially outer surface extending axially from the first end to the second end, and a first energy element coupled to the first end of the body. In addition, the method comprises positioning the first energy element proximal the deposit. Further, the method comprises directing energy emitted from the first energy element at the deposit. Still further, the method comprises jetting the deposit with fluid pumped through the throughbore of the body while directing energy emitted from the first energy element, and dissipating the deposit.

[0009] Embodiments described herein comprise a combination of features and advantages intended to address various shortcomings associated with certain prior devices, systems, and methods. The foregoing has outlined rather broadly the features and technical advantages of the invention in order that the detailed description of the invention that follows may be better understood. The various characteristics described above, as well as other features, will be readily apparent to those skilled in the art upon reading the following detailed description, and by referring to the accompanying drawings. It should be appreciated by those skilled in the art

that the conception and the specific embodiments disclosed may be readily utilized as a basis for modifying or designing other structures for carrying out the same purposes of the invention. It should also be realized by those skilled in the art that such equivalent constructions do not depart from the spirit and scope of the invention as set forth in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] For a detailed description of the preferred embodiments of the invention, reference will now be made to the accompanying drawings in which:

[0011] Figure 1 is a schematic view of an offshore pipeline system including an embodiment of a flowline clearance tool in accordance with the principles disclosed herein;

[0012] Figure 2 is an enlarged schematic side view of the flowline clearance tool of Figure 1 disposed within the flowline of Figure 1;

[0013] Figure 3 is a schematic end view of the flowline clearance tool of Figure 2 taken along section III-III in Figure 2;

[0014] Figure 4 is an enlarged schematic side view of the flowline clearance tool of Figure 1 with a protective cover coupled thereto to shield the energy element from debris;

[0015] Figures 5-7 are enlarged schematic end views of embodiments of energy elements for use with the flowline clearance tool of Figure 2;

[0016] Figure 8 is an enlarged schematic partial cross-sectional side view of an embodiment of a flowline clearance tool in accordance with the principles described herein;

[0017] Figure 9 is a schematic cross-sectional view of the flowline clearance tool of Figure 8 taken along section IX-IX in Figure 8;

[0018] Figure 10 is an enlarged schematic cross-sectional side view of the flowline clearance tool of Figure 8 taken in section X-X in Figure 8;

[0019] Figure 11 is a schematic partial cross-sectional side view of an embodiment of a flowline clearance tool in accordance with the principles disclosed herein;

[0020] Figure 12 is a schematic partial cross-sectional side view of an embodiment of a flowline clearance tool in accordance with the principles disclosed herein;

[0021] Figure 13 is a schematic partial cross-sectional side view of an embodiment of a flowline clearance tool in accordance with the principles disclosed herein;

[0022] Figure 14 is an enlarged schematic cross-sectional side view of an embodiment of a deployable brake assembly for use with the flowline clearance tool of Figure 13;

[0023] Figure 15 is an enlarged schematic cross-sectional side view of an embodiment of a deployable brake assembly for use with the flowline clearance tool of Figure 13;

[0024] Figure 16 is an enlarged schematic cross-sectional side view of an embodiment of a deployable brake assembly for use with the flowline clearance tool of Figure 13;

[0025] Figure 17 is an enlarged schematic cross-sectional end view along section XVII-XVII in Figure 16;

[0026] Figure 18 is an enlarged schematic cross-sectional side view of an embodiment of a central pumping assembly disposed within the body of the flowline clearance tool of Figure 13;

[0027] Figure 19 is a schematic partial cross-sectional side view of an embodiment of a flowline clearance tool in accordance with the principles disclosed herein;

[0028] Figure 20 is a schematic partial cross-sectional side view of an embodiment of a flowline clearance tool in accordance with the principles disclosed herein;

[0029] Figure 21 is a schematic partial cross-sectional side view of an embodiment of a flowline clearance tool in accordance with the principles disclosed herein;

[0030] Figure 22 is a schematic partial cross-sectional view of an embodiment of a flowline clearance tool in accordance with the principles disclosed herein; and

[0031] Figure 23 is a schematic cross-sectional end view of the flowline clearance tool of Figure 22 taken along section XXIII-XXIII in Figure 22.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0032] The following discussion is directed to various exemplary embodiments. However, one skilled in the art will understand that the examples disclosed herein have broad application, and that the discussion of any embodiment is meant only to be exemplary of that embodiment, and not intended to suggest that the scope of the disclosure, including the claims, is limited to that embodiment.

[0033] Certain terms are used throughout the following description and claims to refer to particular features or components. As one skilled in the art will appreciate, different persons may refer to the same feature or component by different names. This document does not intend to distinguish between components or features that differ in name but not function. The drawing figures are not necessarily to scale. Certain features and components herein may be shown exaggerated in scale or in somewhat schematic form and some details of conventional elements may not be shown in interest of clarity and conciseness.

[0034] In the following discussion and in the claims, the terms "including" and "comprising" are used in an open-ended fashion, and thus should be interpreted to mean "including, but not limited to..." Also, the term "couple" or "couples" is intended to mean either an indirect or direct connection. Thus, if a first device couples to a second device, that connection may be through a direct connection, or through an indirect connection via other devices, components, and connections. In addition, as used herein, the terms "axial" and "axially" generally mean along or parallel to a central axis (e.g., central axis of a body or a port), while the terms "radial" and "radially" generally mean perpendicular to the central axis. For instance, an axial distance refers to a distance measured along or parallel to the central axis, and a radial distance means a distance measured perpendicular to the central axis.

[0035] Referring now to Figure 1, an offshore pipeline system 10 is shown. In this embodiment, system 10 includes a floating production storage and offloading vessel 18 (FPSO 18) disposed at the sea surface 12, a platform 30 is disposed at the sea surface 12, and a plurality of subsea hydrocarbon flowlines 50.

[0036] A pig launcher 20 is disposed on the deck of FPSO 18 that couples to a riser 24 through a flexible line 22. Riser 24 extends into the subsea environment 14 and couples to a flowline termination assembly 26 (FTA 26) disposed near the sea floor 16, thus forming a continuous flow path from FPSO 18 to FTA 26. One flowline 50 is coupled to FTA 26 and extends therefrom to provide a flow path for fluid produced from a subsea well (e.g., hydrocarbons) toward FPSO 18.

[0037] Platform 30 includes a deck 31 and a valve system 34 coupled to deck 31. Valve system 34 provides an opening or pathway which leads into a catenary riser 32 which extends downward from platform 30 into the subsea environment 14 and couples to another subsea flowline 50. In this embodiment, platform 30 is a semi-submersible type platform; however, it should be appreciated that in other embodiments, any other type of offshore platform may be used while still complying with the principles herein. For example, platform 30 may be a jack-up platform, a tension-leg platform, or a Spar platform.

[0038] During operations, deposits 60 of material 62 may form within one or more subsea flowlines 50, thereby obstructing and/or stopping the flow of fluids therethrough. Typically, such deposits 60 of material 62 comprise gas hydrates, waxes, asphaltene deposits, mineral scale, or combination thereof. The formation of deposits 60 within flowlines 50 is undesirable. In particular, deposits 60 reduce the production of fluids through flowlines 50, and in some cases, can lead to overpressurization of flowlines 50. Accordingly, embodiments

described herein are directed to systems, apparatus, and methods for removing and clearing deposits 60 from flowline(s) 50 to ensure that the flow of fluids therethrough is substantially unobstructed.

[0039] Referring still to Figure 1, an embodiment of a flowline clearance tool 100 is shown disposed within a flowline 50 and coupled to an umbilical 150. Tool 100 is inserted into flowline 50 from a suitable insertion point such as, for example, the pig launcher 20 on FPSO 18, FTA 26, or valve system 34 on platform 30. As will be described in more detail below, once installed within flowline 50, tool 100 travels through flowline 50 and clears deposits 60 to ensure fluid flow through line 50 is substantially unobstructed.

[0040] Although deposits 60 are shown in subsea flowlines 50, in general, deposits (e.g., deposits 60 of material 62) can form in a variety of fluid conduits and pipelines such as subsea pipelines, risers (e.g., risers 24, 32), manifolds and associated fluid lines, etc. Further, although embodiments disclosed herein (e.g., tool 100) are shown and described removing and clearing deposits 60 in flowlines 50, in general, embodiments described herein can be used to clear deposits in any type of fluid conduit or pipeline such as subsea pipelines, risers (e.g., risers 24, 32), manifolds and associated fluid lines, etc.

[0041] Referring now to Figure 2, flowline clearance tool 100 is shown. More specifically, tool 100 is shown disposed within flowline 50 which has a throughbore 52 defined by a cylindrical inner surface 51 disposed at a diameter D_{50} . Tool 100 includes a generally cylindrical body 120, an umbilical 150, and an energy element 124. Body 120 has a central or longitudinal axis 125, a first or front end 120a, a second or rear end 120b opposite front end 120a, and a radially outer surface 120c extending axially between ends 120a, b. Body 120 has a maximum outer diameter D_{120} along surface 120c. Maximum outer diameter D_{120} is less than inner diameter D_{50} of flowline 50, thereby allowing tool 100 to be inserted into and moved within throughbore 52 of flowline 50. It should be appreciated that all embodiments of flowline clearance tools described herein have a maximum outer diameter less than the inner diameter of the fluid conduit(s) and pipeline(s) within which they are deployed.

[0042] Umbilical 150 is coupled to rear end 120b of body 120. In this embodiment, umbilical 150 includes at least one electric conductor (e.g., wire) to supply power to tool 100 and/or to communicate signals (e.g., data, information, instructions, etc.) to and from tool 100. In some embodiments, umbilical 150 includes a protective outer layer or jacketing such as, for example, steel and/or non-metallic sheathing. Also, in some embodiments, jacketing may comprise a thermally conductive material. In addition, in other embodiments, umbilical

150 includes steel braiding surrounding the electric conductor(s) housed within. Further, in some embodiments, umbilical 150 may comprise a power conductor (e.g., a wire) that has increased impedance during operation to heat fluid within flowline 50. Still further, as will be described in more detail below, in some embodiments, umbilical 150 may comprise resistance heating elements embedded into the outer diameter of the jacketing to heat fluid within flowline 50. As shown in Figure 2, umbilical 150 has a first end 150a connected to body 120 and a second end (not show) extending through flowline 50 to the insertion point previously described. Thus, in this embodiment, the second end of umbilical 150 is routed to a surface vessel (e.g., FPSO 18 or Platform 30) located at the sea surface 12. However, in other embodiments, the second end of umbilical 150 can be routed subsea such as, for example, to FTA 26 (Figure 1).

[0043] Referring now to Figures 2 and 3, energy element 124 is coupled to front end 120a of body 120. Energy element 124 is energized with electrical power provided by umbilical 150, and emits energy directed at deposit 60 to breakup and/or dissipate deposit 60, thereby removing and clearing deposit 60 from flowline 50. In this embodiment, element 124 comprises a heating element that emits thermal energy when energized. However, in general, the energy element (e.g., energy element 124) can comprise any device or component that emits energy to breakup and/or dissipate a deposit in the flowline (e.g., deposit 60) including, without limitation, thermal, magnetic, acoustic, or harmonic energy. As best shown in Figure 4, in some embodiments, a protective shield or cover 130 is disposed around the energy element (e.g., element 124) to shield and protect the energy element from direct impacts (e.g., of solid material or fluid within flowline 50).

[0044] Referring again to Figure 3, in this embodiment, element 124 includes three concentric, annular thermal coils 126 centered about axis 125 on end 120a. In particular, element 124 comprises an inner annular coil 126', an intermediate annular coil 126'' concentrically disposed about coil 126', and an outer annular coil 126''' disposed about coil 126''. Thus, in this embodiment, energy element 124 includes three concentrically arranged annular thermal coils 126', 126'', 126'''. In other embodiments, the number and configuration of coils (e.g., thermal coils 126) within the thermal energy element (e.g., element 124) can be varied while still complying with the principles disclosed herein. For example, in Figure 5, an alternative embodiment of element 124, referred to and shown herein as element 124A, includes a plurality of radially and circumferentially-spaced segmented coils 127. In particular, element 124A includes four radially outer, uniformly

circumferentially-spaced (i.e., angularly spaced 90° apart) coils 127', and four radially inner, uniformly circumferentially-spaced (i.e., angularly spaced 90° apart) coils 127''. As another example, in Figure 6, another alternative embodiment of element 124, referred to and shown herein as element 124B, includes a plurality of circumferentially-spaced, radially extending coils 128'. In particular, element 124B includes four uniformly circumferentially-spaced (i.e., angularly spaced 90° apart) groups or bundles 128, each containing five radially extending coils 128'. As yet another example, in Figure 7, another alternative embodiment of element 124, referred to and shown herein as element 124C, includes a plurality of radially-spaced coils 129. In particular, element 124C includes a pair of uniformly circumferentially segmented outer coils 129', and a pair of concentric annular inner coils 129''.

[0045] Referring again to Figure 2, during operation, tool 100 moves through flowline 50 until front end 120a is proximate deposit 60. In general, tool 100 can be advanced through flowline 50 in any suitable manner including, without limitation, under the force of gravity, a propulsion system, a tractor-type system, or combinations thereof. Once front end 120a of body 120 is proximate deposit 60, electric current is supplied through umbilical 150 to element 124, which is energized and emits thermal energy directed at deposit 60. Without direct contact between element 124 and deposit 60, the thermal energy is transferred from element 124 to deposit 60 through the fluid therebetween. The temperature of the fluid adjacent deposit 60 is sufficiently increased with element 124 to begin dissipating (e.g., melting) deposit 60, thereby clearing deposit 50 from flowline. For example, for gas hydrate deposits, dissipation begins at a temperature of about 20° C at a pressure of 100 bars.

[0046] Referring now to Figures 8-10, an embodiment of a flowline clearance tool 200 is shown. Similar to tool 100 previously described, tool 200 is employed to remove and clear deposits (e.g., deposits 60) in fluid conduits and pipelines. In Figure 8, tool 200 is deployed in flowline 50 to remove and clear deposit 60.

[0047] In this embodiment, tool 200 includes a generally cylindrical body 220, an umbilical 150, an energy element 124, and a plurality of centralizer assemblies 230. Umbilical 150 and energy element 124 are each as previously described. Body 220 has a central or longitudinal axis 225, a first or front end 220a, a second or rear end 220b opposite front end 220a, and a radially outer surface 220c extending axially between the ends 220a, b. First end 150a of umbilical 150 is coupled to rear end 220b of body 220, and element 124 is coupled to front end 220a of body 220.

[0048] As is best shown in Figures 8 and 9, each recess 224 extends generally radially inward from the surface 220c and axially from end 220a. Each recess 224 is defined by a cylindrical surface 226 extending from the front end 220a and concentrically disposed about an axis oriented at an angle θ with respect to the axis 225. Angle θ preferably ranges from 0 to 45°, and is 10° in this embodiment. As will be described in more detail below, recesses 224 define flow channels for fluids and solids to flow around body 220.

[0049] Centralizer assemblies 230 are uniformly circumferentially-spaced about body 220 and extend radially therefrom. As is best shown in Figure 10, each centralizer assembly 230 is at least partially disposed in a recess 240 in body 220. Each recess 240 extends radially inward from surface 220c to a substantially planar terminal surface 244.

[0050] In this embodiment, each centralizer assembly 230 includes a biasing member 238 disposed in recess 240, an elongate connecting member 234 slidably received by recess 240, and a roller 232 coupled member 234. More specifically, each connecting member 234 has a first or radially inner end 234a disposed in a corresponding recess 240 and a second or radially outer end 234b extending from body 220. Each biasing member 238 is seated in one recess 240 and is compressed between end 234a of one connecting member 234 and terminal surface 244 of the corresponding recess 240. Thus, biasing member 238 biases connecting member 234 radially outward.

[0051] Each roller 232 is rotatably coupled to end 234b of one member 234 with a pin connection 236 such that each roller 232 is free to rotate about an axis of rotation perpendicular to and radially offset from axis 225. By biasing connecting members 234 radially outward, biasing members 238 also biases rollers 232 radially outward into engagement with inner surface 51 of flowline 50. Consequently, a tool 200 moves through flowline 50, rollers 232 roll along inner surface 51.

[0052] In general, each biasing member 238 can comprise any suitable device for biasing roller 232 into engagement with inner surface 51 including, without limitation, a coil spring, a hydraulic ram, a plurality of Belleville washer, etc. In this embodiment, each biasing member 238 is a coil spring.

[0053] In this embodiment, two centralizer assemblies 230 are provided in tool 200. Centralizer assemblies 230 are uniformly circumferentially-spaced (i.e., angularly spaced 180° apart), and thus, generally function to center tool 200 within flowline 50 (i.e., coaxially align body 220 with flowline 50). In other embodiments, more than two centralizer assemblies 230 can be provided. To facilitate centralizing of the corresponding tool, such

centralizer assemblies 230 are preferably uniformly circumferentially-spaced. For example, in one embodiment, four centralizers 230 are included on body 220 and are angularly spaced approximately 90° from one another.

[0054] During deposit removal operations, tool 200 moves through flowline 50 in substantially the same manner as described above for the tool 100 until front end 220a is proximate deposit 60. Tool 200 is centralized within throughbore 52 through engagement of rollers 232 on centralizer assemblies 230 and inner surface 51 of flowline 50. Electrical power is then supplied to element 124 via umbilical 150, thereby allowing element 124 to emit thermal energy sufficient to dissipate deposit 60 as previously described. As deposit 60 dissipates, material 62 homogenizes and mixes with the fluid disposed within throughbore 52. The homogenized fluid is free to flow through recesses 224 in the direction shown by the flow paths 228, thereby allowing tool 200 to more easily advance along flowline 50 while deposit 60 is being dissipated.

[0055] Referring now to Figure 11, embodiment of a flowline clearance tool 300 is shown. Similar to tools 100, 200 previously described, tool 300 is employed to remove and clear deposits (e.g., deposits 60) in fluid conduits and pipelines. In Figure 11, tool 300 is deployed in flowline 50 to remove and clear deposit 60.

[0056] In this embodiment, tool 300 includes a generally cylindrical body 320, an umbilical 150, an energy element 124, and a pair of adjustable directed energy electrode assemblies 340. Umbilical 150 and energy element 124 are each as previously described. Body 320 has a central or longitudinal axis 325, a first or front end 320a, a second or rear end 320b opposite front end 320a, and a radially outer surface 320c extending between ends 320a, b. First end 150a of umbilical 150 is coupled to rear end 320b of body 320 in the same manner as previously described above for tool 100.

[0057] Electrode assemblies 340 are uniformly circumferentially-spaced about body 320 and extend radially therefrom. In particular, each electrode assembly 340 is at least partially disposed in a recess 350 in body 320. Each recess 350 extends radially inward and axially rearward from surface 320c to a substantially planar terminal surface 354. In addition, each recess 350 has a central axis 355 and a cylindrical surface extending between surface 320c and surface 244. Axis 355 is oriented at an angle β relative to the axis 325. Angle β preferably ranges from 0° to 90° , is 45° in this embodiment.

[0058] In this embodiment, each electrode assembly 340 includes an electrode 342 and a biasing member 344. More specifically, each electrode 340 has a first or radially inner end

342a disposed within the corresponding recess 350 and a second or radially outer end 342b extending from body 320. Each biasing member 344 is seated in one recess 350 and is compressed between end 342a of the corresponding electrode 342 and terminal surface 354. Thus, biasing members 344 bias electrodes 340 radially outward and axially forward. By biasing electrodes 342 radially outward and axially forward, biasing members 344 bias ends 342b of electrodes 340 into engagement with inner surface 51 of flowline 50. Consequently, a tool 300 moves through flowline 50, electrodes 340 slide along inner surface 51.

[0059] In general, biasing member 344 can comprise any suitable device for biasing electrode 342 into engagement with inner surface 51 including, without limitation, a coil spring, a hydraulic ram, a plurality of Belleville washer, a magnetic actuator, etc. In this embodiment, biasing member 344 is a coil spring.

[0060] Although each electrode 340 is slidably disposed in the corresponding recess 350 in this embodiment, in other embodiments, the electrodes (e.g., electrodes 340) are threadably engaged within the recesses (e.g., recesses 350).

[0061] Each electrode 342 is energized with electrical power provided by umbilical 150, and emits energy directed at inner surface 51 along flowline 50 to dissipate deposits 60 disposed along wall 51, thereby removing and clearing deposit 60 from flowline 50. In this embodiment, each electrode 342 comprises a heating element that emits thermal energy when energized. However, in general, the electrodes (e.g., electrodes 342) can comprise any device or component that emits energy to breakup and/or dissipate a deposit in the flowline (e.g., deposit 60) including, without limitation, thermal, magnetic, acoustic, or harmonic energy. In this embodiment, electrical power and/or control signals are supplied to each electrode 342 via a conductor 346 extending from umbilical 150 through body 320 to end 342a of the corresponding electrode 342.

[0062] During deposit removal operations, tool 300 moves through flowline 50 in substantially the same manner as described above for the tool 100 until front end 220a is proximate deposit 60. Electrical power is then supplied to electrodes 342 via umbilical 150 and conductors 346, thereby allowing electrodes 342 to emit energy sufficient to dissipate deposit 60 as previously described. Electrical power can also be provided to electrodes 342 as tool 300 moves through flowline 50, thereby allowing electrodes 342 to direct energy toward inner surface 51 of flowline 50 to remove and dissipate any deposits 60 disposed along inner surface 51.

[0063] Referring now to Figure 12, an embodiment of a flowline clearance tool 400 is shown. Similar to tools 100, 200, 300 previously described, tool 400 is employed to remove and clear deposits (e.g., deposits 60) in fluid conduits and pipelines. In Figure 12, tool 300 is deployed in flowline 50 to remove and clear deposit 60.

[0064] In this embodiment, tool 400 includes a generally cylindrical body 420, an umbilical 150, an energy element 124, and a plurality of deployable scrapers 430. Energy element 124 and umbilical 150 are each as previously described. Body 420 has a central or longitudinal axis 425, a first or front end 420a, a second or rear end 420b opposite front end 420a, and a radially outer surface 420c extending between ends 420a, b. End 150a of umbilical 150 is coupled to rear end 420b of body 420 in the same manner as previously described above for tool 100.

[0065] Each deployable scraper 430 includes a first or radially inner end 430a and a second or radially outer end 430b opposite inner end 430a. Further, end 430a of each scraper 430 is pivotally coupled to body 420 such that each scraper 430 has a first or stowed position with ends 430b radially withdrawn from inner surface 51 towards body 420 and the scraper 430 oriented substantially parallel to axis 425, and a second or deployed position with end 430b rotated outwardly away from body 420 towards inner surface 51 and the scraper oriented at an acute angle α relative to axis 425. Angle α preferably ranges from 0° to 90°, and is 45° in this embodiment. Scrapers 430 are provided with one or more actuators configured to actuate scrapers 430 between the stowed positions and deployed positions. In general, any suitable actuator(s) can be used including, without limitation, a electric motor, a hydraulic actuator, etc. End 430b of each scraper 430 includes an engagement surface 432 for engaging and scraping deposits 60 disposed along inner surface 51 of flowline 50.

[0066] During deposit removal operations, tool 400 moves through flowline 50 (with scrapers 430 in the stowed position) in substantially the same manner as described above for the tool 100 until front end 420a is proximate deposit 60. Electrical power is provided to element 124 to dissipate deposit 60 as previously described. In addition, as tool 400 is withdrawn back through flowline 50, scrapers 430 are transitioned to the deployed positions to allow surfaces 432 on ends 430b to engage and scrape deposits 60 of material 62 from the inner surface 51.

[0067] Referring now to Figures 13-18, an embodiment of a flowline clearance tool 500 is shown. Similar to tools 100, 200, 300, 400 previously described, tool 500 is employed to

remove and clear deposits (e.g., deposits 60) in fluid conduits and pipelines. In Figure 13, tool 500 is deployed in flowline 50 to remove and clear deposit 60.

[0068] In this embodiment, tool 500 includes a generally cylindrical body 520, an energy element 124, an umbilical 150, a plurality of centralizer assemblies 230, a plurality of deployable brake assemblies 560, and a central pump assembly 540. Energy element 124, umbilical 150, and centralizer assemblies 230 are each as previously described. Body 520 has a central or longitudinal axis 525, a first or front end 520a, a second or rear end 520b opposite front end 520a, a radially outer surface 520c extending between ends 520a, b, and a central throughbore 524 extending axially between ends 520a, b. Throughbore 524 is defined by a cylindrical surface 526 concentrically aligned with axis 525. Further, in this embodiment, first end 150a of umbilical 150 is coupled to rear end 520b of body 520 with a pair of coupling members 152 that extend to opposite lateral sides of bore 524 at end 520b. As previously described, umbilical 150 houses at least one conductor for supplying electrical power to tool 500 and/or communicating signals to/from tool 500. In this embodiment, the conductor(s) is routed through one of the coupling members 152 into body 520 and to the various components of tool 500 (e.g., assembly 540, element 124, deployable brake assemblies 560, etc.).

[0069] Deployable brake assemblies 560 are uniformly circumferentially-spaced about body 520 and coupled thereto. In addition, brake assemblies 560 are configured to selectively engage within inner surface 51 of flowline 50 to substantially fix the position of tool 500 therein (i.e., to prevent tool 500 from through flowline 50). More specifically, each brake assembly 560 has a first or withdrawn position disengaged (i.e., spaced away) from inner surface 51, and a second or deployed position engaged with and gripping inner surface 51. With brake assemblies 560 in the withdrawn positions, tool 500 can move through flowline 50, however, with brake assemblies 560 in the deployed positions, tool 500 is restricted and/or prevented from moving through flowline 50. Exemplary embodiments for brake assemblies 560 are shown in Figures 14-17 and described in more detail below.

[0070] Referring now to Figure 14, one embodiment of a braking assembly 560, referred to and shown herein as assembly 560A, is shown. Braking assembly 560A is accommodated by a recess 568 extending radially into body 520 from outer surface 520c to a planar terminal surface 565, and a counterbore 569 extending radially from recess 568 and surface 565 to a terminal surface 567.

[0071] In this embodiment, braking assembly 560A includes a braking member 564, a biasing member 566, and a plurality of electromagnets 563. Braking member 564 is selectively moved radially between the withdrawn position (disengaged from inner surface 51 and seated in recess 568) and a deployed position (engaging inner surface 51 and extending from recess 568) by electromagnets 563. Biasing member 566 biases braking member 564 to the withdrawn position. More specifically, braking member 564 has an outer engagement surface 562 including a plurality of radially outwardly projecting teeth 561 designed to engage and grip inner surface 51 when braking member 564 is deployed. Biasing member 566 has a first or inner end 566a coupled to surface 567 in body 520 and a second or outer end 566b coupled to braking member 564. In addition, biasing member 566 biases braking member 564 to the withdrawn position seated in recess 568. However, the biasing force generated by biasing member 566 can be overcome by electromagnetic forces exerted on braking member 564 by electromagnets 563, thereby transitioning braking member 564 to the deployed position. In particular, electromagnets 563 are disposed within body 520 and extend to surface 565. Electromagnets 563 generate a magnetic field when energized with electrical power supplied by conductors 563a coupled to umbilical 150. In this embodiment, member 564 is made from magnetized steel, and electromagnets 563 are configured to apply a repulsive force to member 564 when energized. Thus, when electromagnets 563 are energized, the repulsive force overcomes the biasing force of biasing member 566, and braking member 564 is urged radially outward from recess 568 into engagement with inner surface 51. Engagement of teeth 561 with inner surface 51 resists and/or prevents further movement of tool 500 through flowline 50 in either direction. To disengage braking assembly 560A, the electromagnets 563 are de-energized, thereby allowing braking member 564 to be withdrawn radially inward or away from inner surface 51 by the biasing force generated by biasing member 566.

[0072] Although outer surface 562 of braking member 564 includes teeth 561 in this embodiment, in general, other suitable profile and/or materials may be used on the outer surface of the braking member (e.g., braking member 564) to create sufficient friction with inner surface 51 to effectively resist continued movement of tool 500 therethrough. In this embodiment, biasing member 566 is a coiled spring placed in tension between surface 567 and braking member 564.

[0073] Referring now to Figure 15, another embodiment of braking assembly 560, referred to and shown herein as assembly 560B, is shown. Braking assembly 560B is accommodated by

a recess 578 extending radially into body 520 from outer surface 520c to a planar terminal surface 575, a plurality of counterbores 579 extending radially from recess 578 and surface 575 to a terminal surface 577, and a counterbore 572 extending radially from recess 578 and surface 575 to a terminal surface 572a. Recess 572 is axially positioned between recesses 579 and is defined by a cylindrical surface 572b extending radially from surface 575 to surface 572a.

[0074] In this embodiment, braking assembly 560B includes a braking member 574 and a pair of biasing members 576. Braking member 564 is selectively moved radially between the withdrawn position (disengaged from inner surface 51) and a deployed position (engaging inner surface 51). Biasing members 576 bias braking member 574 to the withdrawn position. More specifically, braking member 574 has a generally T-shaped cross-section and includes a first or outer section 574a including an engagement surface 562 as previously described, and a second or inner section 574b extending radially inward from the section 574a. Outer section 574a is sized to be removably seated within recess 578, and inner section 574b is sized to slidably engage counterbore 572. A pair of annular sealing assemblies 571 are disposed about inner section 574b and form annular seals between section 574b and surface 572b. Consequently, a sealed chamber 573 is formed between section 574b and surface 572a. A port 573a extends through body 520 to surface 572a, and as will be described in more detail below, provides an inlet/outlet for pressurizing/depressurizing chamber 573.

[0075] Each biasing members 567 is at least partially disposed within one recess 579 and includes a first or inner end 576a coupled to the corresponding surface 577 and a second or outer end 576b coupled to outer section 574a of member 574. Biasing members 567 biases braking member 574 radially inward. In this embodiment, biasing members 567 are coil springs placed in tension between surface 577 and member 574.

[0076] To deploy braking assembly 560B, pressure in chamber 573 is sufficiently increased (e.g., by pressurizing hydraulic fluid in chamber 573 via port 573a) to overcome the biasing force generated by biasing members 567, thereby urging braking member 574 radially outward into engagement with inner surface 51. Engagement of teeth 561 with inner surface 51 resists and/or prevents further movement of tool 500 through flowline 50 in either direction. To disengage braking assembly 560B, pressure within chamber 573 is relieved through port 573a, thereby allowing braking member 574 to move radially inward out of engagement with inner surface 51 by the biasing force generated by biasing member 576.

Alternatively, fluid can be pumped out of chamber 573 through port 573a such that a vacuum is created within chamber 573 to draw member 574 radially inward.

[0077] Referring now to Figures 16 and 17, another embodiment of deployable brake assembly 560, referred to and shown herein as assembly 560C, is shown. Braking assembly 560C is accommodated by a recess 588 extending radially into body 520 from outer surface 520c to a planar terminal surface 585, a counterbore 589 extending radially from recess 588 and surface 585 to a terminal surface 587, and a counterbore 592 extending radially from recess 588 and surface 565.

[0078] In this embodiment, braking assembly 560C includes a braking member 584, a biasing member 586, and a drive assembly 590. Braking member 584 is selectively moved radially between the withdrawn position (disengaged from inner surface 51, and seated in recess 588 and counterbore 592) and a deployed position (engaging inner surface 51 and extending from recess 588) by drive assembly 590. Biasing member 586 biases braking member 584 to the withdrawn position.

[0079] Braking member 584 has a first or outer section 584a including an engagement surface 562 as previously described, and a second or inner section 584b extending radially inward from section 584a. Outer section 584a moves radially into and out of recess 588, while inner section 584b moves radially within counterbore 592. A toothed rack 583 is provided along the outer surface of inner section 584b and, as will be described in more detail below, engages a mating drive gear 582 of drive assembly 590.

[0080] Referring still to Figures 16 and 17, drive assembly 590 is disposed within a chamber 593 open to counterbore 592, and includes drive gear 582 and an actuator 594 coupled to drive gear 582. In particular, gear 582 is mounted on the driveshaft of actuator 594. Actuator 594 drives the rotation of drive gear 582 in a first rotational direction 591a and a second rotational direction 591b opposite the first rotational direction 591a. As is best shown in Figure 16, gear 582 includes a plurality of teeth 581 configured to intermesh with mating teeth on rack 583. As will be described in more detail below, gear 582 has a first or engaged position intermeshed with rack 583 and a second or disengaged position spaced apart from rack 583. Thus, with gear 582 in the engaged position, as actuator 594 rotates gear 582 in the first direction 591a, member 584 moves radially outward, and as actuator 594 rotates gear 582 in the second direction 591b, member 584 moves radially inward. In general, actuator 594 can be any suitable device for driving the rotation of gear 582 including, without

limitation, an electric motor, a hydraulic motor, or the like. In this embodiment, actuator 594 is an electric motor.

[0081] As is best shown in figure 17, a retaining plug 596 is disposed within chamber 593 and includes a recess 597. In addition, an actuator biasing member 598 is disposed in chamber 593 and coupled to the end of actuator 594 opposite gear 582 and body 520. Biasing member 598 is compressed between actuator 594 and body 520, and thus, biases actuator 594 and gear 582 downward as shown in Figure 17. A clutch 595 is also disposed within chamber 593. Clutch 595 has a stem 595a that is slidably disposed in mating recess 597. Clutch 595 selectively moves gear 582 between the disengaged and engaged positions. In particular, clutch 595 is selectively relative to plug 596, engages gear 582, and moves gear 582 between the engaged and disengaged positions. In this embodiment, clutch 595 is moved with an electromagnet (not shown) similar to that previously described above for assembly 560A. In particular, when the electromagnet is energized (i.e., provided electrical power), it exerts a repulsive force on clutch 595 that urges clutch 595 upward in Figure 17 into engagement with gear 582. The repulsive force overcomes the biasing force exerted on actuator 594 by biasing member 598, and thus, gear 582 and actuator 594 are urged upward as shown in Figure 17 to engage gear 582 and rack 583. When the electromagnet is not energized, the repulsive force ceases, clutch 595 moves downward in Figure 17, and biasing member 598 pushes actuator 594 and gear 582 downward in Figure 17, thereby moving gear 582 out of engagement with rack 583.

[0082] Although the repulsive force generated by an energized electromagnet is used to overcome the biasing force generated by biasing member 598 and move gear 582 into engagement with rack 582 in this embodiment, in other embodiments, forces generated by different means can be used to overcome the biasing force generated by biasing member 598. For example, pressurized hydraulic fluid in recess 597 can be used to exert forces on clutch 595 sufficient to overcome the biasing force generated by biasing member 598 and move actuator 595, actuator 594, and gear 582 upward in Figure 17. Regardless of the means employed to move clutch 595, assembly 560C is preferably configured such that if power is lost in tool 500, gear 582 is biased out of engagement with rack 583.

[0083] Referring now to Figure 16, biasing member 586 is disposed in recess 589 and has a first or inner end 586a coupled to the surface 587 and a second or outer end 586b coupled to outer section 584a of member 584. Biasing member 586 is in tension between section 584a and surface 587, and thus, biases member 584 to the withdrawn position. Thus, braking

member 584 is biased to the withdrawn position, and gear 582 is biased to the disengaged position.

[0084] Referring again to Figures 16 and 17, to deploy assembly 560C, clutch 595 moves gear 582 into engagement with rack 583 (i.e., the engaged position), and gear 582 is rotated by actuator 594 in the first direction 591a, thereby moving member 584 radially outward into engagement with inner surface 51. Engagement of teeth 561 with inner surface 51 resists and/or prevents further movement of tool 500 through flowline 50 in either direction. Gear 582 is maintained in the engaged position with clutch 595 and member 584 is maintained in engagement with inner surface 51 with actuator 594 as long as braking is desired. To disengage braking assembly 560C, gear 582 (in the engaged position) is rotated with actuator 594 in the second direction 591b to move member 584 radially inward out of engagement with inner surface 51. Alternatively, gear 582 can be moved out of engagement with rack 583 (i.e., to the disengaged position), thereby allowing biasing member 586 to pull braking member 584 radially inward out of engagement with wall 51.

[0085] Referring now to Figure 18, as previously described, flowline clearance tool 500 includes central pump assembly 540 positioned within throughbore 524 of body 520. Pump assembly 540 pumps fluid through throughbore 524 in either direction (i.e., up or down in Figure 13). In this embodiment, pump assembly 540 includes a generally cylindrical outer housing 542, an inner motor housing 544, an impeller 546, and a plurality of support fins 548. Outer housing 542 and inner motor housing 544 are coaxially aligned with axis 525 of body 520.

[0086] Outer housing 540 has a first or front end 542a, a second or rear end 542b opposite front end 542a, a radially outer surface 520c extending between ends 520a, b, and a radially inner surface 542d extending between ends 520a, b. In this embodiment, outer housing 542 is secured within throughbore 524 via the engagement of external threads disposed on outer surface 542c and corresponding internal threads on surface 526 defining throughbore 524. However, in other embodiments, housing 542 can be secured within throughbore 524 by other suitable means such as, for example, an interference fit. Further, in some embodiments, housing 540 is releasably secured within throughbore 524 such that it may be easily removed therefrom during, for example, repair and/or maintenance operations.

[0087] Inner motor housing 544 has a first or front end 544a, a second or rear end 544b opposite front end 544a, and a radially outer surface 544c extending between ends 544a, b. Motor housing 544 is secured within outer housing 542 with front end 544a axially

positioned proximate front end 542a. In this embodiment, a plurality of support fins 548 secure housing 544 within housing 542. Each fin 548 extends from the radially inner surface 542d of outer housing 542 to the radially outer surface 544c of motor housing 544, thus fixing the position of housing 544 within housing 542. In addition, each fin 548 is oriented parallel to axis 525, and has a first or front end 548a and a second or rear end 548b opposite front end 548a. A ramped surface 549 extends from the front end 548a to reduce drag on fin 548 when fluid is flowing within throughbore 524 during operation. In this embodiment, a total of three fins 548 uniformly angularly spaced 120° apart are provided. A power coupling 550 is disposed on one of fins 548 proximate its rear end 548b. Power coupling 550 delivers electrical power from the internal cabling and/or conductor(s) routed through umbilical 150 to a motor (not shown) disposed within housing 544.

[0088] Referring still to Figure 18, impeller 546 extends axially from front end 544a of housing 544, and includes a central body 545 with a first or front end 545a and a second or rear end 545b opposite front end 545a. Body 545 is coupled to an output shaft of a motor (not shown) disposed within the housing 544 such that when the motor is energized, both the shaft and body 545 are rotated about axis 525. A plurality of vanes 547 extend radially outward from body 545. Vanes 547 are oriented such that fluid disposed within throughbore 524 is pumped axially upward or toward rear end 520b of body 520 when body 545 rotates about axis 525 in a direction of rotation 543, and fluid disposed within throughbore 524 is pumped axially downward or toward front end 520a of body 520 when body 545 rotates about axis 525 in a direction of rotation 541.

[0089] Referring now to Figures 13-18, during operation, tool 500 moves along flowline 50 until front end 520a is proximate deposit 60. In this embodiment, tool 500 is propelled along flowline 50 through rotation of impeller 546 in direction 543. As tool 500 traverses along flowline 50, centralizers 230 engage inner surface 51 as previously described to substantially center tool 500 within flowline 50. Once front end 520a of body 520 is proximate deposit 60, electric current is supplied through umbilical 150 to element 124, which is energized and emits thermal energy directed at deposit 60. As previously described, the temperature of the fluid adjacent deposit 60 is sufficiently increased with element 124 to begin dissipating (e.g., melting) deposit 60, thereby clearing deposit 50 from flowline.

[0090] As thermal energy is transferred to deposit 60, pumping assembly 540 is simultaneously operated to draw fluid away from deposit 60 and through throughbore 524. In particular, impeller 546 is rotated in direction 543, thereby pumping fluid through

throughbore 524 from front end 520a to rear end 520b of body 520. In addition, energy elements 522 disposed along surface 526 emit energy (e.g., thermal, acoustic, magnetic, etc.), thereby curtailing the formation of deposits 60 behind tool 500. To maintain the position of tool 500 within flowline 50 as pumping assembly 540 is operated, brake assemblies 560 are deployed as previously described.

[0091] Referring now to Figure 19, an embodiment of a flowline clearance tool 600 is shown. Similar to tools 100, 200, 300, 400, 500 previously described, tool 600 is employed to remove and clear deposits (e.g., deposits 60) in fluid conduits and pipelines. In Figure 19, tool 600 is deployed in flowline 50 to remove and clear deposit 60.

[0092] In this embodiment, tool 600 includes a generally cylindrical body 620, an energy element 124, an umbilical 150, a central pumping assembly 540, a plurality of flow channels 224, and a plurality of centralizer assemblies 230. Energy element 124, umbilical 150, pumping assembly 540, flow channels 224, and centralizer assemblies 230 are each as previously described. Body 620 has a central or longitudinal axis 625, a first or front end 620a, a second or rear end 620b opposite front end 620a, a radially outer surface 620c extending between ends 620a, b, and a throughbore 624 extending between ends 620a, b. Throughbore 624 is defined by a cylindrical surface 626 extending between ends 620a, b, and concentrically disposed about axis 625. First end 150a of umbilical 150 is coupled to rear end 620b of body 620 with a pair of coupling members 152 in the same manner as previously described above for tool 500.

[0093] During operation, tool 600 moves along flowline 50 until front end 620a is proximate deposit 60. In this embodiment, tool 600 is propelled along flowline 50 with pump assembly 540. As tool 600 traverses along flowline 50, centralizers 230 engage inner surface 51 as previously described to substantially center tool 600 within flowline 50. Once front end 620a of body 620 is proximate deposit 60, electric current is supplied through umbilical 150 to element 124, which is energized and emits thermal energy directed at deposit 60. As previously described, the temperature of the fluid adjacent deposit 60 is sufficiently increased with element 124 to begin dissipating (e.g., melting) deposit 60, thereby clearing deposit 50 from flowline. Simultaneous with the transfer of thermal energy to deposit 60, pumping assembly 540 pumps fluid downward through throughbore 624 against deposit 60 (e.g., by rotating impeller 546 in direction 541 as shown in Figure 18). After contacting the deposit 60, the fluid is forced radially outward and upward through flow paths 628 defined by channels 224. As a result, fluid is jetted or sprayed against deposit 60 to further facilitate the

dissipation and breakup of deposit 60, which can then be carried away (in solid or liquid form) through flow paths 628.

[0094] The fluid pumped through throughbore 624 and flow paths 628 can comprise the fluid within flowline and/or chemicals, such as hydrate inhibitors, that enhance the dissipation of deposit 60 or prevent the formation of gas hydrates. Examples of such chemicals include, without limitation, methanol, monoethylene glycol, and xylene.

[0095] Referring now to Figure 20, an embodiment of a flowline clearance tool 700 is shown. Similar to tools 100, 200, 300, 400, 500, 600 previously described, tool 700 is employed to remove and clear deposits (e.g., deposits 60) in fluid conduits and pipelines. In Figure 20, tool 700 is deployed in flowline 50 to remove and clear deposit 60.

[0096] In this embodiment, tool 700 includes a generally cylindrical body 720, an energy element 124, an umbilical 150, an energy element 124, a central pumping assembly 540, a plurality of centralizer assemblies 230, and a plurality of energy elements 722 disposed along umbilical 150. Energy element 124, umbilical 150, pumping assembly 540, and centralizer assemblies 230 are each as previously described.

[0097] Body 720 has a central or longitudinal axis 725, a first or front end 720a, a second or rear end 720b opposite front end 720a, a radially outer surface 720c extending between ends 720a, b, and a throughbore 724 extending between ends 720a, b. Throughbore 724 is defined by a cylindrical surface 726 extending between ends 720a, b and concentrically disposed about axis 725. First end 150a of umbilical 150 is coupled to rear end 720b of body 720 with a pair of coupling members 152 in the same manner as previously described above for tool 500. Energy elements 722 are substantially the same as energy elements 124, 522, but are positioned along the outside of umbilical 150 and are electrically coupled to the conductor(s) routed through umbilical 150. When electrical power is supplied to energy elements 722, they emit energy (e.g., thermal energy) to dissipate deposits of material 62 disposed along inner surface 51 and/or to curtail the formation of deposits of material 62 uphole of tool 700. Thus, during operation, as tool 700 dissipates deposit 60 with energy element 124 in the manner previously described, energy elements 722 dissipate deposits 60 of material 62 along inner surface 51 and/or curtail further formation of such deposits 60 rearward of tool 700.

[0098] Referring now to Figure 21, an embodiment of a flowline clearance tool 800 is shown. Similar to tools 100, 200, 300, 400, 500, 600, 700 previously described, tool 800 is employed to remove and clear deposits (e.g., deposits 60) in fluid conduits and pipelines. In Figure 21, tool 800 is deployed in flowline 50 to remove and clear deposit 60.

[0099] In this embodiment, tool 800 includes a generally cylindrical body 820, an energy element 124, an umbilical 150, a central pumping assembly 540, a plurality of circumferentially-spaced centralizer assemblies 830, and a plurality of modules 850 disposed along umbilical 150. Energy element 124, umbilical 150, and pumping assembly 540 are each as previously described.

[0100] Body 820 has a central or longitudinal axis 825, a first or front end 820a, a second or rear end 820b opposite front end 820a, a radially outer surface 820c extending between ends 820a, b, and a throughbore 824 also extending between ends 820a, b and concentrically disposed about axis 825. Throughbore 824 is defined by a cylindrical surface 824 extending axially between ends 820a, b.

[0101] Each centralizer assembly 830 comprises a fin 832 extending radially outward from body 820. In particular, each fin 832 includes a first or radially inner end 832a secured to body 820 and a second or radially outer end 832b distal body 820. Outer end 832b has an engagement surface 834 positioned radially adjacent inner surface 51 of flowline 50 during operations. Surfaces 834 of one or more fins 832 slidably engage inner surface 51 of flowline 50 as tool 800 moves therethrough to centralize tool 800 within flowline 50 during operations. In this embodiment, each fin 832 also includes a ramped surface 836 extending between ends 832a, b. Surfaces 836 reduce drag forces as tool 800 moves through flowline 50.

[0102] Referring still to Figure 21, modules 850 are disposed along umbilical 150 and are electrically coupled to the conductor(s) routed through umbilical 150. As is schematically shown in Figure 21, modules 850 house a variety of components/systems to facilitate the operation of tool 800. In this embodiment, each module includes sensors 850a, fluid storage reservoirs or vessels 850b, power generation device(s) (e.g., batteries) 850c, and control systems 850d. The sensors 850a provided in each module 850 preferably include sensors that measure pressure, temperature, and flow rate within flowline 50. The fluid storage vessel 850b in each module 850 preferably stores chemicals and/or solvents (e.g., hydrate inhibitors) to enhance removal of deposits 60 of material 62. The power generation device(s) 850c in modules 850 provide electrical power to tool 800, as needed, and the control systems 850d in modules 850 control the functions of tool 800. In particular, in some embodiments, each control system 850d comprises a programmable logic computer ("PLC") that controls activation/deactivation of many of the features of tool 800 (e.g., through digital ladder-logic), such as, for example, energy element 124, pumping assembly 540, brake assemblies 360

(shown in Figure 13-17), etc. Thus, by including control system(s) 850d within modules 850, at least some of the control logic necessary to operate tool 800 may be carried out subsea, thereby offering the potential to reduce the number of communication cables that must be routed from the tool 800, through the umbilical 150, and back to the surface. In general, modules 850 can be removably mounted to umbilical or integral with umbilical 150.

[00103] During operation, tool 800 moves along flowline 50 until front end 820a is proximate deposit 60. Fins 832 slidably engage inner surface 51 to ensure tool 800 is centralized within flowline 50. With front end 820a proximate deposit 60, electrical power is routed to element 124 to facilitate the dissipation of deposit 60 as previously described. In this embodiment, operation of tool 800 is further enhanced by the equipment disposed within modules 850. For example, in some embodiments, power is provided by one or more modules 850 and delivered to tool 800 such that element 124 may generate sufficient energy to dissipate plugs 60 of material 62. As another example, chemicals, such as, for example monoethylene glycol and/or xylene are distributed from one or more of modules 850 to enhance the removal of deposits 60 and/or prevent the formation of new deposits 60. It should also be appreciated that positioning of power sources, chemical storage, etc. within modules 850 spaced apart along umbilical (as opposed to body 820), tool 800 is capable of negotiating tighter bends or curves.

[00104] Referring now to Figures 22 and 23, an embodiment of a flowline clearance tool 900 is shown. Similar to tools 100, 200, 300, 400, 500, 600, 700, 800 previously described, tool 900 is employed to remove and clear deposits (e.g., deposits 60) in fluid conduits and pipelines. In Figures 22 and 23, tool 900 is deployed in flowline 50 to remove and clear deposit 60.

[00105] In this embodiment, tool 900 includes a generally cylindrical body 920, a hydraulic propulsion module 970, a plurality of fin centralizer assemblies 930, an energy element 124, an umbilical 150, a module 850, a plurality of deployable brake assemblies 560, and a central pumping assembly 540. Energy element 124, umbilical 150, module 850, brake assemblies 560, and pumping assembly 540 are each as previously described.

[00106] Body 920 has a central or longitudinal axis 925, a first or front end 920a, a second or rear end 920b opposite front end 920a, a radially outer surface 920c extending between ends 920a, b, and a throughbore 924 extending between ends 920a, b. Throughbore 924 is defined by a substantially cylindrical surface 926 extending between ends 920a, b and concentrically disposed about axis 925. First end 150a of umbilical 150 is coupled to rear end 920b of body

920 with a pair of coupling members 152 in the same manner as previously described above for tool 500

[00107] Centralizer assemblies 930 are substantially the same as centralizer assemblies 830 previously described with the exception that a compliant ring 938 coupled to and extending circumferentially between each pair of circumferentially adjacent fins 832 to further aid in centralizing tool 900 within flowline 50. In some embodiments, ring 938 comprises a compliant material such that it may deflect or deform in order accommodate bends or obstacles within flowline 50. Further, as is best shown in Figure 23, in this embodiment ring 938 further includes a plurality of notches 932 which enhance the ability of ring 938 to deflect and/or deform during operation.

[00108] Module 970 is disposed along umbilical 150 rearward of body 920 and includes a body 972 having a central or longitudinal axis 975, a first or front end 972a, a second or rear end 972b opposite front end 972a, a radially outer surface 972c extending between ends 972a, b, and a throughbore 974 extending between ends 972a, b. Throughbore 974 is defined by a cylindrical surface 976 extending between ends 972a, b and concentrically disposed about axis 975. Pumping assembly 540 is mounted to surface 976 within throughbore 974.

[00109] During operation, tool 900 moves along flowline 50 until front end 920a is proximate deposit 60. Fins 832 slidably engage inner surface 51 to ensure tool 800 is centralized within flowline 50. With front end 620a proximate deposit 60, electrical power is routed to element 124 to facilitate the dissipation of deposit 60 as previously described. If it becomes desirable to either reverse the direction of travel of tool 900, such as during retrieval operation, central pumping module 540 disposed within module 970 is actuated in order to induce fluid flow within throughbore 974 from end 972b to end 972a, thus provided rearward propulsion for the tool 900.

[00110] In the manner described, embodiments of flowline clearance tools and methods of using the same in accordance with the principles described herein facilitate the dissipation and removal of deposits (e.g., deposit 60, hydrates, etc.) disposed within flowlines (e.g., flowline 50) to maintain sufficient fluid flow therethrough. Additionally, at least some embodiments of a flowline clearance tool according the principles disclosed herein may be used to clear deposits from flowlines which contain tight bends or curves which were not previously accessible to conventional tools.

[00111] While select features have been shown for certain embodiments described herein, it should be appreciated that any one feature or combination of features disclosed herein may be

utilized on a flowline clearance tool (e.g., tool 100, 200, 300, 400, 500, 600, 700, 800, 900) while still complying with the principles disclosed herein. For example, in some embodiments, energy element 124 is used in combination with flow channels 224, centralizer assemblies (e.g., assemblies 230, 830, or 930), energy electrode assemblies 340, deployable scrapers 430, central pump assembly 540, deployable brakes 560, modules 850, energy elements 722, hydraulic propulsion module 970, and/or combinations thereof. As another example, in some embodiments, centralizer assemblies (e.g., assemblies 230, 830, or 930) may be used in combination with energy element 124, flow channels 224, energy electrode assemblies 340, deployable scrapers 430, central pump assembly 540, deployable brakes 560, modules 850, energy elements 722, hydraulic propulsion module 970, and/or combinations thereof. As yet another example, in some embodiments, deployable brake assembly 560 (e.g., assembly 560A, 560B, 560C) may be used in combination with energy element 124, channels 224, energy electrode assemblies 340, deployable scrapers 430, central pump assembly 540, centralizer assemblies (e.g., assemblies 230, 830, or 930), modules 850, energy elements 722, hydraulic propulsion module 970, and/or combinations thereof. As still another example, in some embodiments, energy electrode assemblies 340 may be used in combination with energy element 124, flow channels 224, centralizer assemblies (e.g., assemblies 230, 830, or 930), deployable scrapers 430, central pump assembly 540, deployable brakes 560, modules 850, energy elements 722, hydraulic propulsion module 970, and/or combinations thereof.

[00112] While preferred embodiments have been shown and described, modifications thereof can be made by one skilled in the art without departing from the scope or teachings herein. The embodiments described herein are exemplary only and are not limiting. Many variations and modifications of the systems, apparatus, and processes described herein are possible and are within the scope of the invention. For example, the relative dimensions of various parts, the materials from which the various parts are made, and other parameters can be varied. Accordingly, the scope of protection is not limited to the embodiments described herein, but is only limited by the claims that follow, the scope of which shall include all equivalents of the subject matter of the claims. Unless expressly stated otherwise, the steps in a method claim may be performed in any order. The recitation of identifiers such as (a), (b), (c) or (1), (2), (3) before steps in a method claim are not intended to and do not specify a particular order to the steps, but rather are used to simplify subsequent reference to such steps.

CLAIMS

What is claimed is:

1. A tool for clearing a deposit within a fluid flowline, the tool comprising:
a body having a central axis, a first end, a second end opposite the first end, and a radially outer surface extending axially from the first end to the second end;
a first energy element coupled to the first end; and
an electrode extending radially from the radially outer surface of the body;
wherein the first energy element and the electrode are each configured to emit energy to dissipate the deposit in the fluid flowline.
2. The tool of claim 1, wherein the first energy element comprises a thermal coil configured to emit thermal energy.
3. The tool of claim 2, further comprising an umbilical coupled to the second end of the body, wherein the umbilical includes a wireline and a conductor for transferring electrical power or control signals to the tool.
4. The tool of claim 1, further comprising a deployable scraper having a first end pivotally coupled to the body and a second end opposite the first end;
wherein the deployable scraper has a first position with the second end distal an inner surface of the flowline and a second position with the second end proximal the inner surface.
5. The tool of claim 1, further comprising:
an umbilical coupled to the second end of the body;
a plurality of second energy elements disposed along the umbilical, wherein each of the plurality of second energy elements is configured to emit energy.
6. The tool of claim 1, further comprising a centralizer assembly extending radially outward from the radially outer surface of the body and configured to radially centralize the tool in the flowline.

7. The tool of claim 6, wherein the centralizer assembly comprises:
- a connecting member having a first end and a second end opposite the first end, wherein the first end is at least partially disposed within a recess in the radially outer surface of the body;
 - a roller rotatable coupled to the second end of the connecting member;
 - a biasing member disposed within the recess and configured to bias the roller into engagement with an inner surface of the flowline.
8. The tool of claim 6, wherein the centralizer assembly comprises a fin having a first end and a second opposite the first end;
- wherein the first end is coupled to the radially outer surface of the body and the second end slidingly engages an inner surface of the flowline.
9. The tool of claim 6, wherein the centralizer assembly comprises:
- a plurality of circumferentially spaced fins extending radially outward from the body, wherein each fin has a first end coupled to the body and a second end opposite the first end;
 - a compliant ring further comprising a plurality of compliant ring sections, each extending circumferentially between adjacent fins, and each of the compliant ring sections including a radially outer engagement surface to engage an inner surface of the flowline.
10. The tool of claim 1, wherein the radially outer surface body includes a plurality of flow channels.
11. The tool of claim 1, further comprising:
- an umbilical coupled to the second end of the body; and
 - a module coupled to the umbilical and spaced apart from the body, wherein the module includes one or more of a power generation device, a control system, a sensor, and a fluid storage tank.
12. The tool of claim 1, further comprising a protecting cover disposed about the first energy element.

13. A tool for clearing a deposit from a fluid flowline, the tool comprising:
a body having a central axis, a first end, a second end opposite the first end, a radially outer surface extending axially from the first end to the second end, and a first throughbore extending axially from the first end to the second end;
a first energy element coupled to the first end of the body, wherein the first energy element is configured to emit energy to dissipate the deposit in the flowline; and
a first pumping assembly disposed in the first throughbore and configured to pump fluid through the first throughbore.
14. The tool of claim 13, wherein the first energy element comprises a thermal coil configured to emit thermal energy.
15. The tool of claim 14, further comprising an umbilical coupled to the second end of the body, wherein the umbilical includes a wireline and a wire for communicating with the tool.
16. The tool of claim 13, wherein the first pumping assembly includes an impeller and a motor coupled to the impeller, wherein the motor is configured to rotate the impeller to move fluids through the first throughbore.
17. The tool of claim 16, wherein the motor of the first pumping assembly is configured to rotate the impeller in a first direction to move fluids through the first throughbore from the first end of the body to the second end of the body and to rotate the impeller in a second direction to move fluids through the first throughbore from the second end of the body to the first end.
18. The tool of claim 13, further comprising a second energy element disposed within the first throughbore and configured to thermal emit energy therefrom.
19. The tool of claim 13, further comprising a deployable brake assembly coupled to the body, wherein the deployable brake assembly is configured to releasably engage an inner surface of the flowline and restrict movement of the tool through the flowline.

20. The tool of claim 19, wherein the deployable brake assembly comprises:
- a braking member at least partially disposed within a recess in the radially outer surface of the body;
 - a biasing member disposed within the recess and coupled to the braking member; and
 - an electromagnet disposed within the recess and configured to bias the braking member radially outward from the recess when energized;
- wherein the deployable brake assembly has a first position with the electromagnets energized and the braking member in contact with the inner surface of the flowline and a second position with the electromagnets de-energized and the braking member withdrawn from the inner surface of the flowline.
21. The tool of claim 19, wherein the deployable brake assembly comprises:
- a braking member at least partially disposed within a recess in the radially outer surface of the body, wherein the braking member includes a first section having an engagement surface and a second section at least partially received within a hydraulic chamber disposed within the recess; and
 - a biasing member disposed within the recess and coupled to the first section;
- wherein the deployable brake assembly has a first position with hydraulic pressure supplied to the hydraulic chamber and the engagement surface is in contact with the inner surface of the flowline and a second position with hydraulic pressure relieved from the hydraulic chamber and the engagement surface withdrawn from the inner surface of the flowline.
22. The tool of claim 19, wherein the deployable brake assembly comprises:
- a braking member at least partially disposed within a recess in the radially outer surface of the body, wherein the braking member includes a first section with an engagement surface and a second section including a rack;
 - a motor disposed within the recess and including a driveshaft; and
 - a drive gear coupled to the shaft, wherein the drive gear has a first position matingly engaging the rack and a second position disengaged from the rack;
- wherein the braking member an engaged position with the engagement surface in contact with an inner surface of the flowline and a disengaged position with the engagement surface withdrawn from the inner surface;

wherein the drive gear is configured to transition the braking member between the engaged position and the disengaged position by rotating in the first position.

23. The tool of claim 22, wherein the drive gear is biased to the second position and the braking member is biased to the disengaged position.

24. The tool of claim 22, further comprising a clutch coupled to the driver gear and configured to transition the drive gear between the first position and the second position.

25. The tool of claim 13, further comprising a plurality of second energy elements disposed along the umbilical, wherein each of the plurality of second energy elements is configured to emit thermal energy.

26. The tool of claim 13, further comprising a centralizer assembly extending radially outward from the body and configured to centralize the tool within the flowline.

27. The tool of claim 13, wherein the radially outer surface of the body includes a plurality circumferentially-spaced of flow channels.

28. The tool of claim 13, further comprising a module coupled to the umbilical proximal the body, wherein the module includes one or more of a power generation device, a control system, a sensor, and a fluid storage tank.

29. The tool of claim 13, further comprising
a propulsion module coupled to the umbilical proximal the body, wherein the propulsion module has a first end, a second end opposite the first end, and a throughbore extending from the first end to the second end;
a second pumping assembly disposed within the throughbore of the propulsion module and configured to move fluid through the throughbore of the propulsion module.

30. A method for clearing a deposit from a flowline, the method comprising:
(a) moving a flowline clearance tool through the flowline toward the deposit, wherein the tool comprising:

a body having a central axis, a first end, a second end opposite the first end, a radially outer surface extending axially from the first end to the second end, and a first throughbore extending axially from the first end to the second end; and

a first energy element coupled to the first end of the body;

- (b) positioning the first energy element proximal the deposit;
- (c) directing energy emitted from the first energy element at the deposit;
- (d) jetting the deposit with fluid pumped through the throughbore of the body during (c); and
- (e) dissipating the deposit during (c) and (d).

31. The method of claim 30, further comprising maintaining the position of the body relative to the flowline during (d).

32. The method of claim 30, wherein (d) comprises pumping fluid through the throughbore from the second end to the first end with a pumping assembly disposed within the throughbore.

33. The method of claim 30, wherein (c) comprises emitting thermal energy from the first energy element and transferring the thermal energy to the deposit.

34. The method of claim 30, wherein (a) comprises moving fluid through the throughbore from the first end to the second end with a pumping assembly disposed in the throughbore.

35. The method of claim 30, further comprising emitting a hydrate inhibitor from the tool into the inner passage of the flowline.

36. The method of claim 30, further comprising emitting energy from a plurality of second energy elements disposed along the umbilical to curtail the formation of deposits uphole of the tool.

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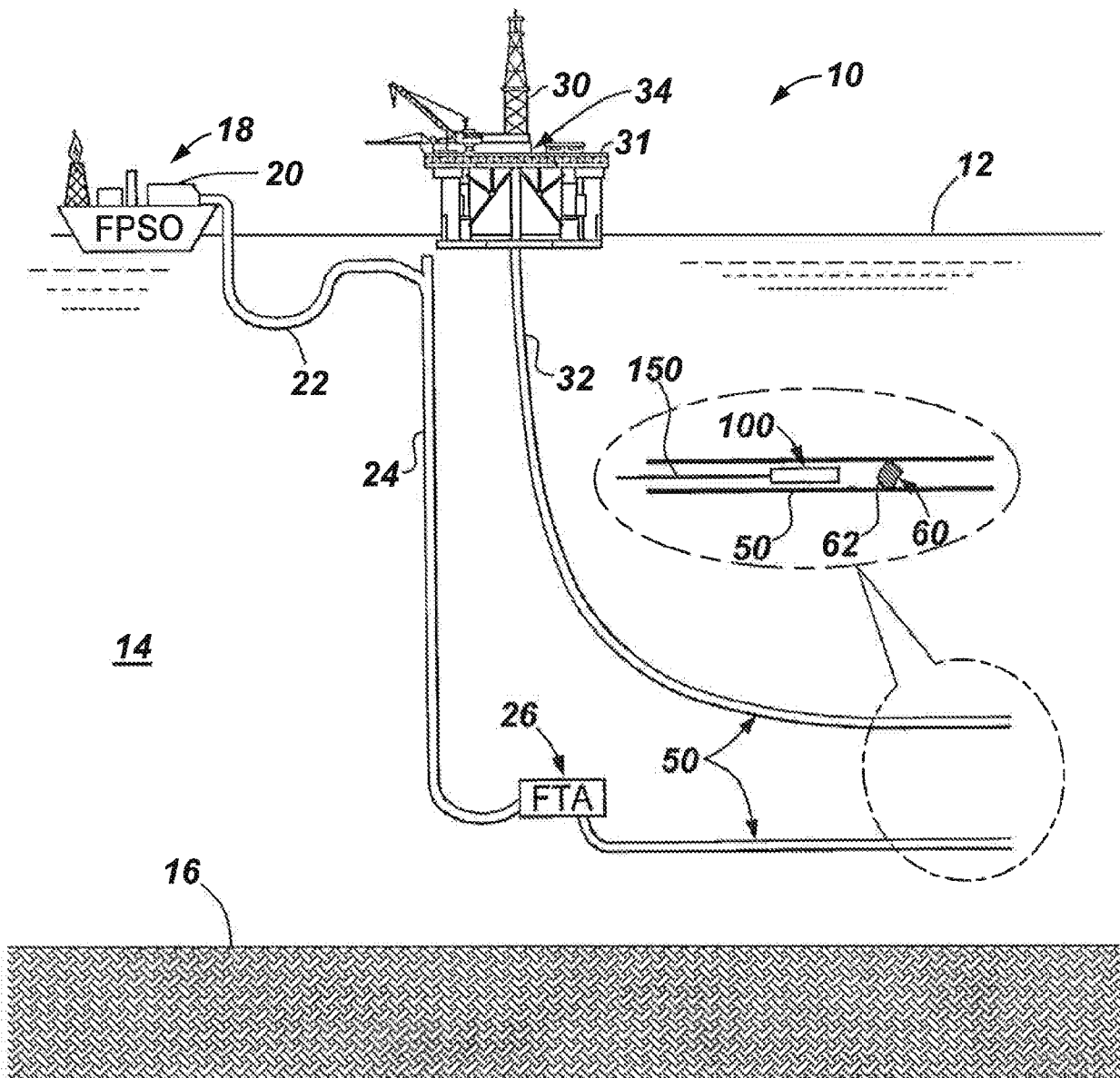


Figure 1

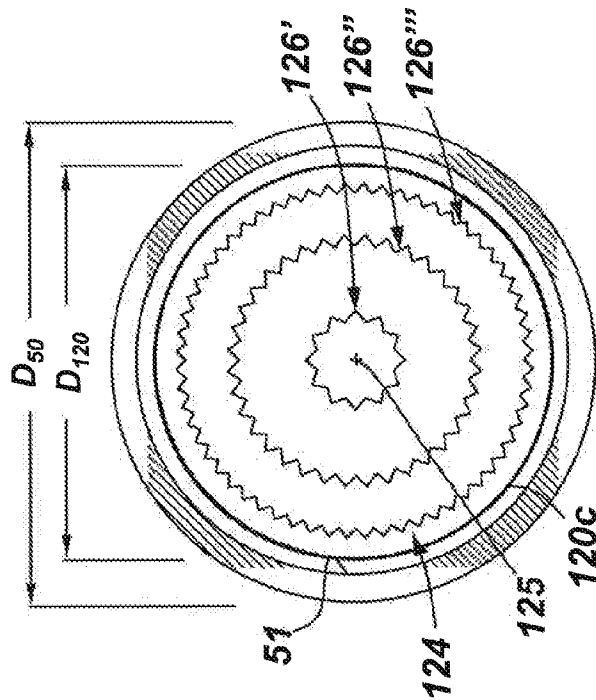


Figure 3

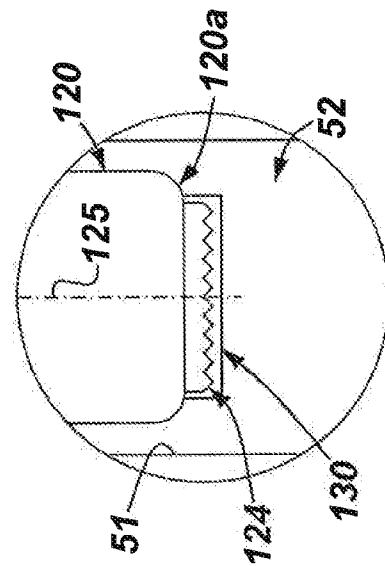


Figure 4

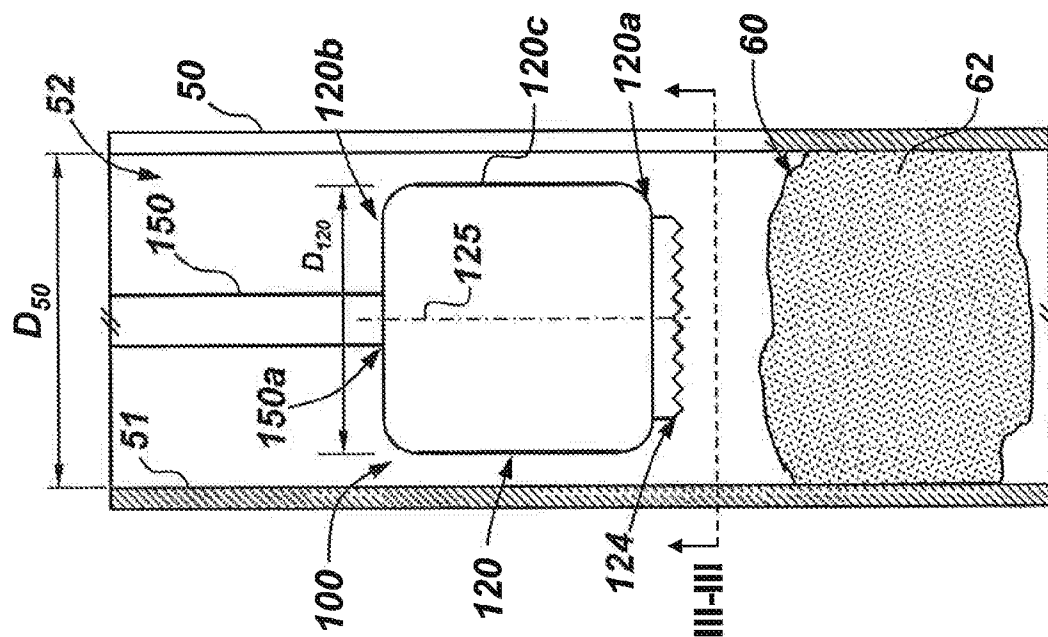


Figure 2

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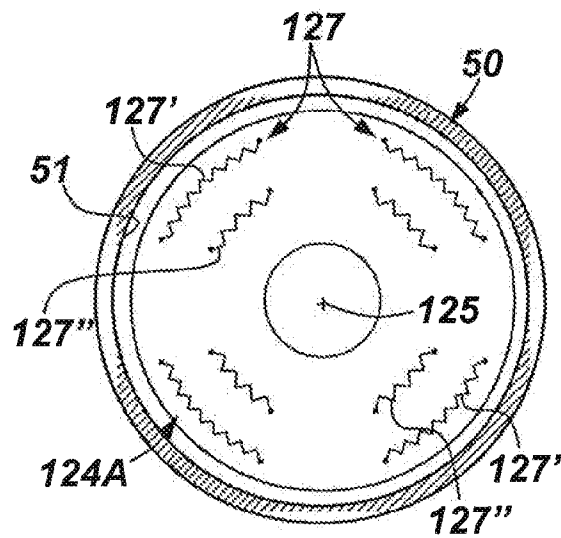


Figure 5

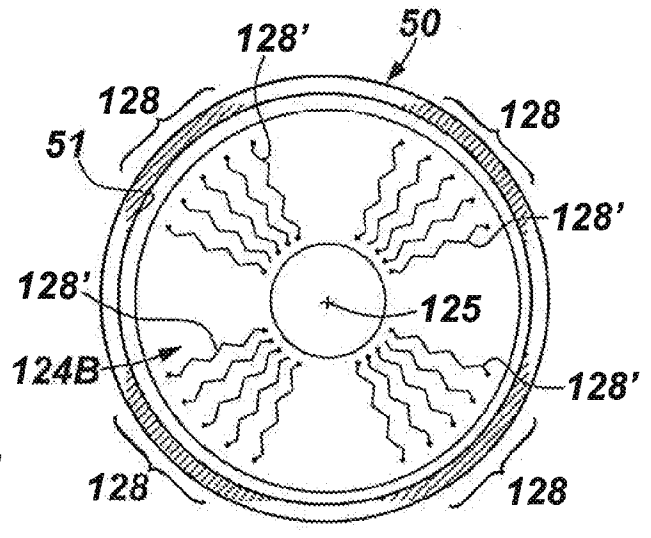


Figure 6

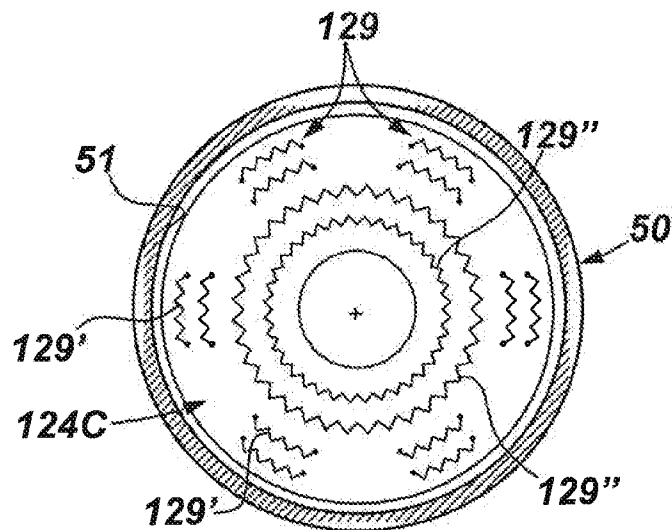


Figure 7

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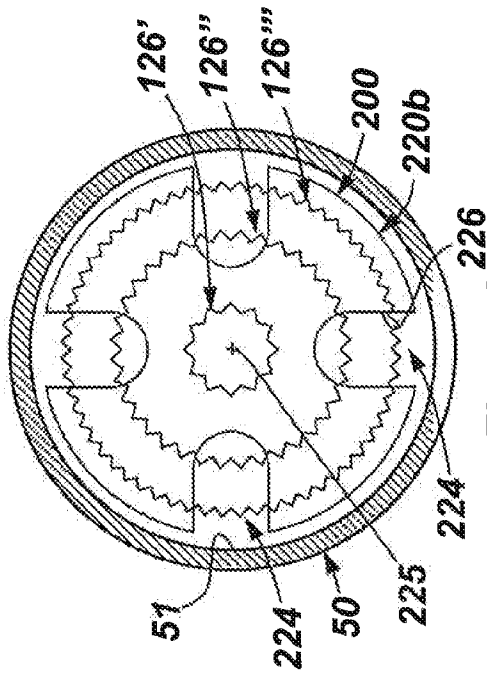


Figure 9

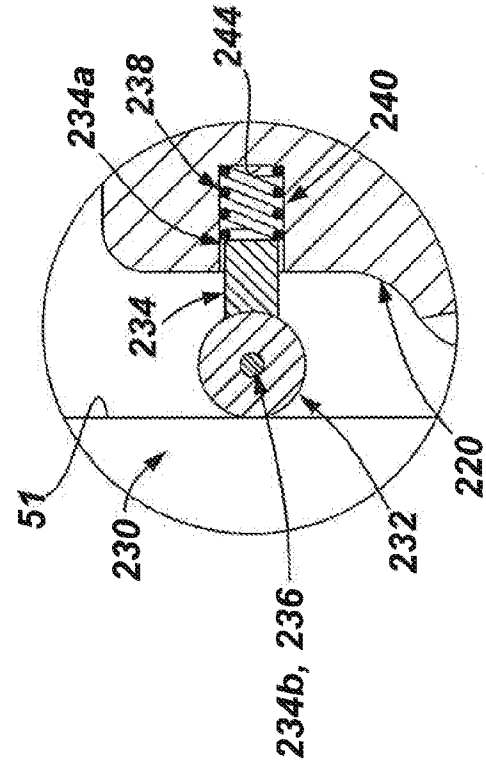


Figure 10

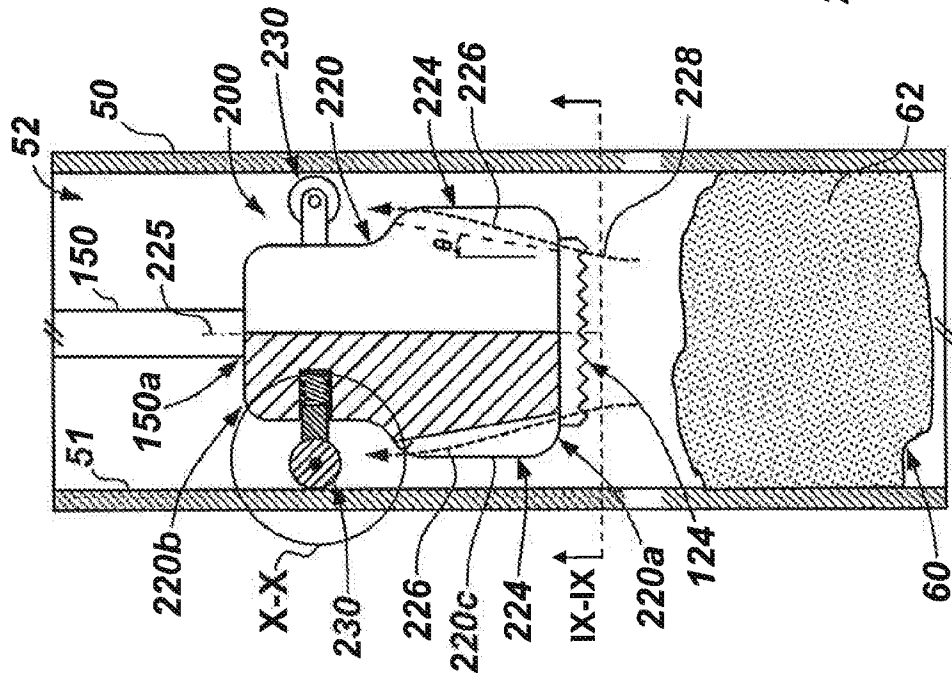


Figure 8

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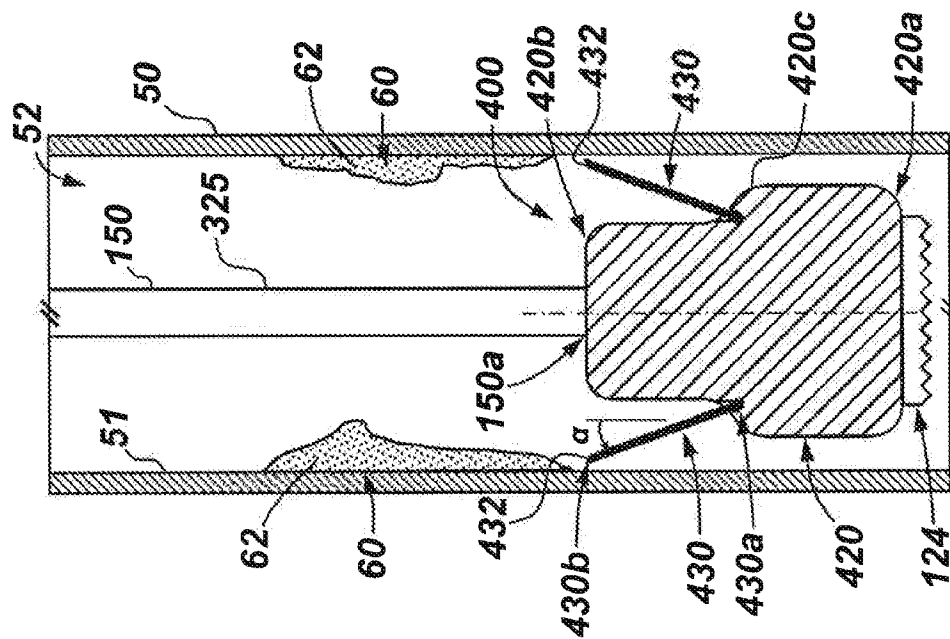


Figure 12

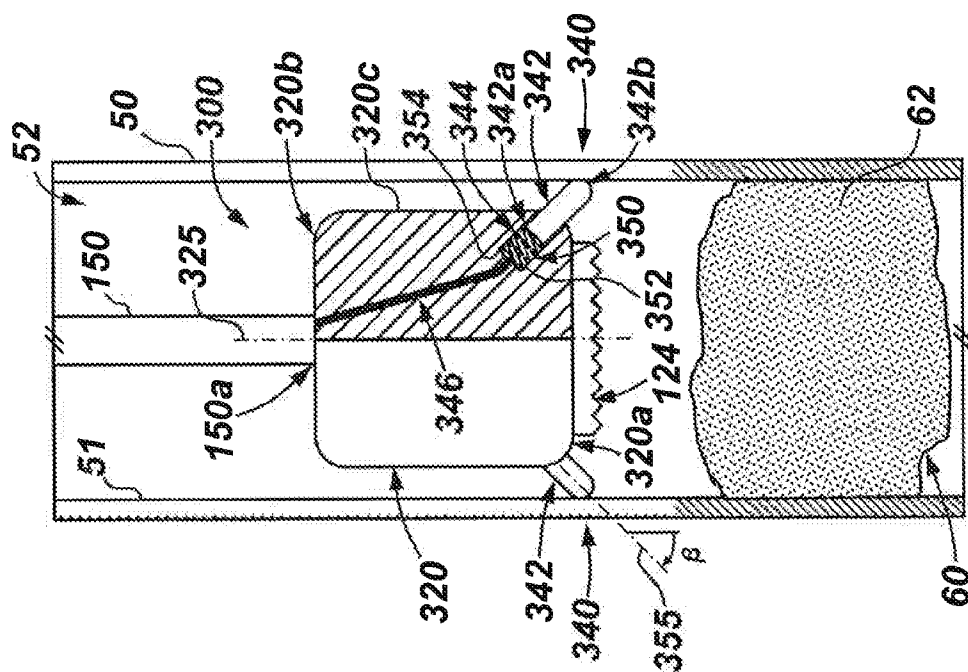


Figure 1

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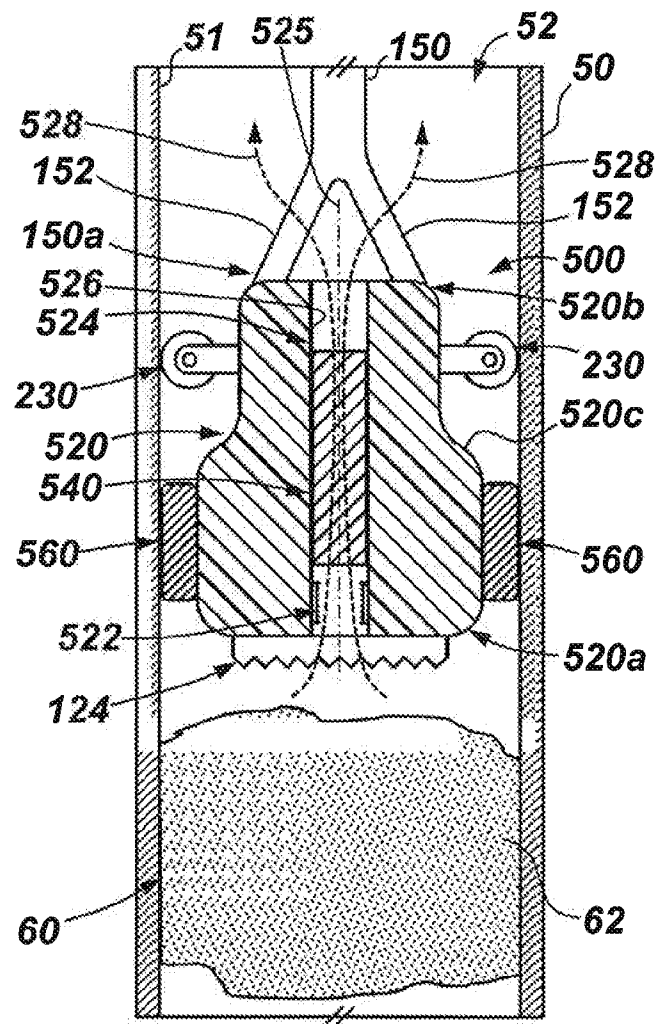


Figure 13

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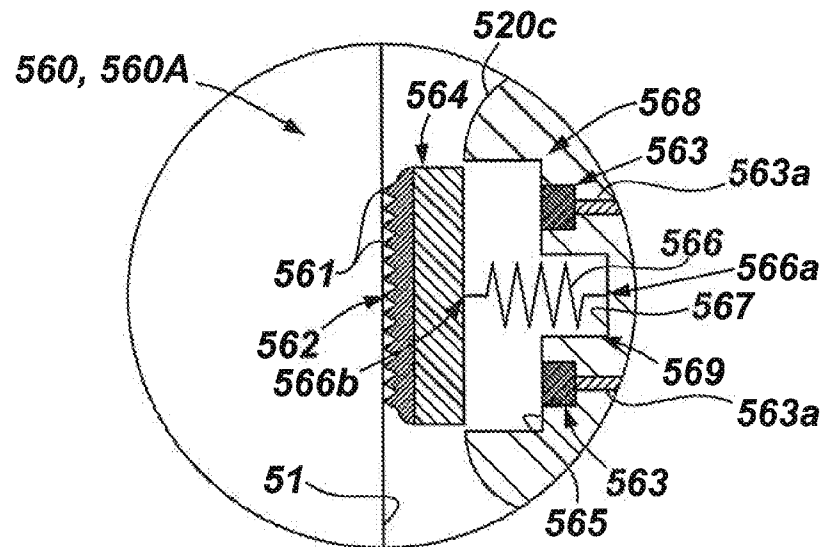


Figure 14

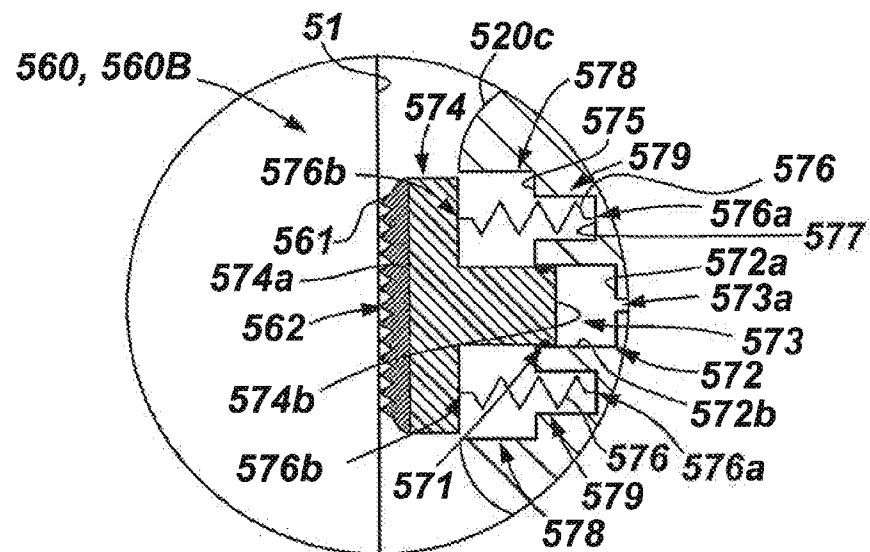


Figure 15

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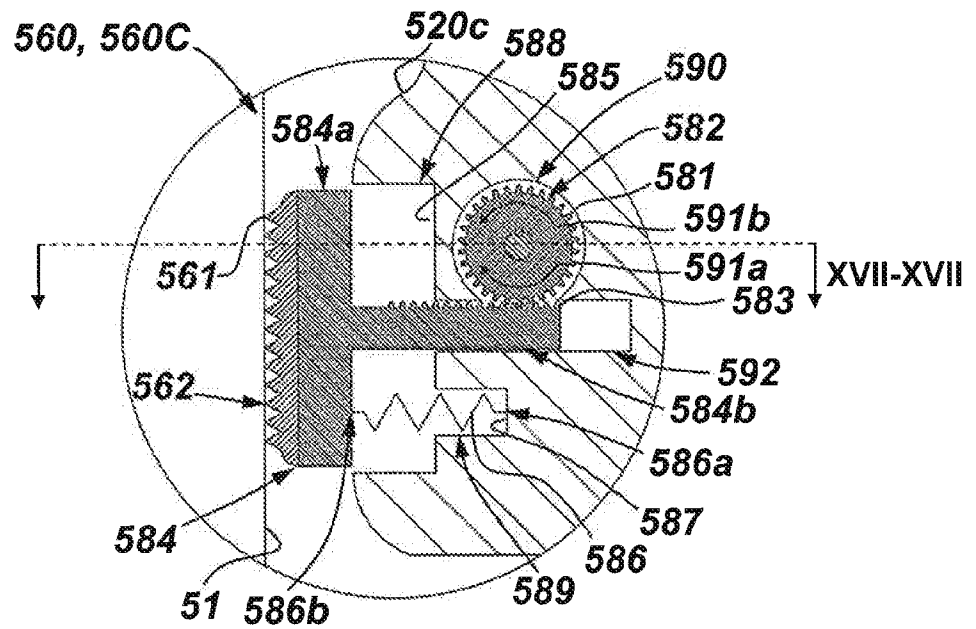


Figure 16

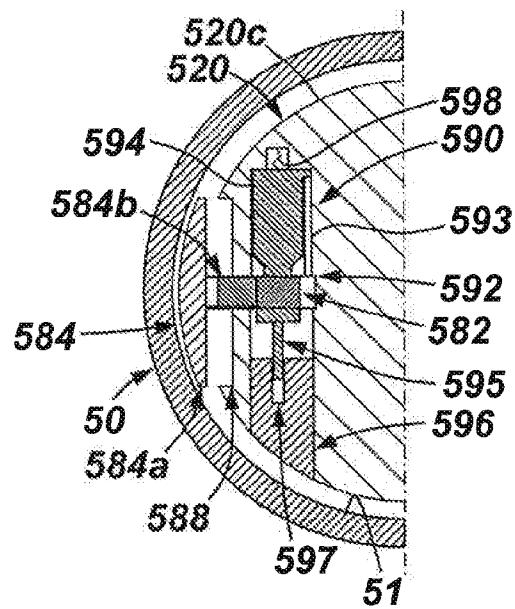


Figure 17

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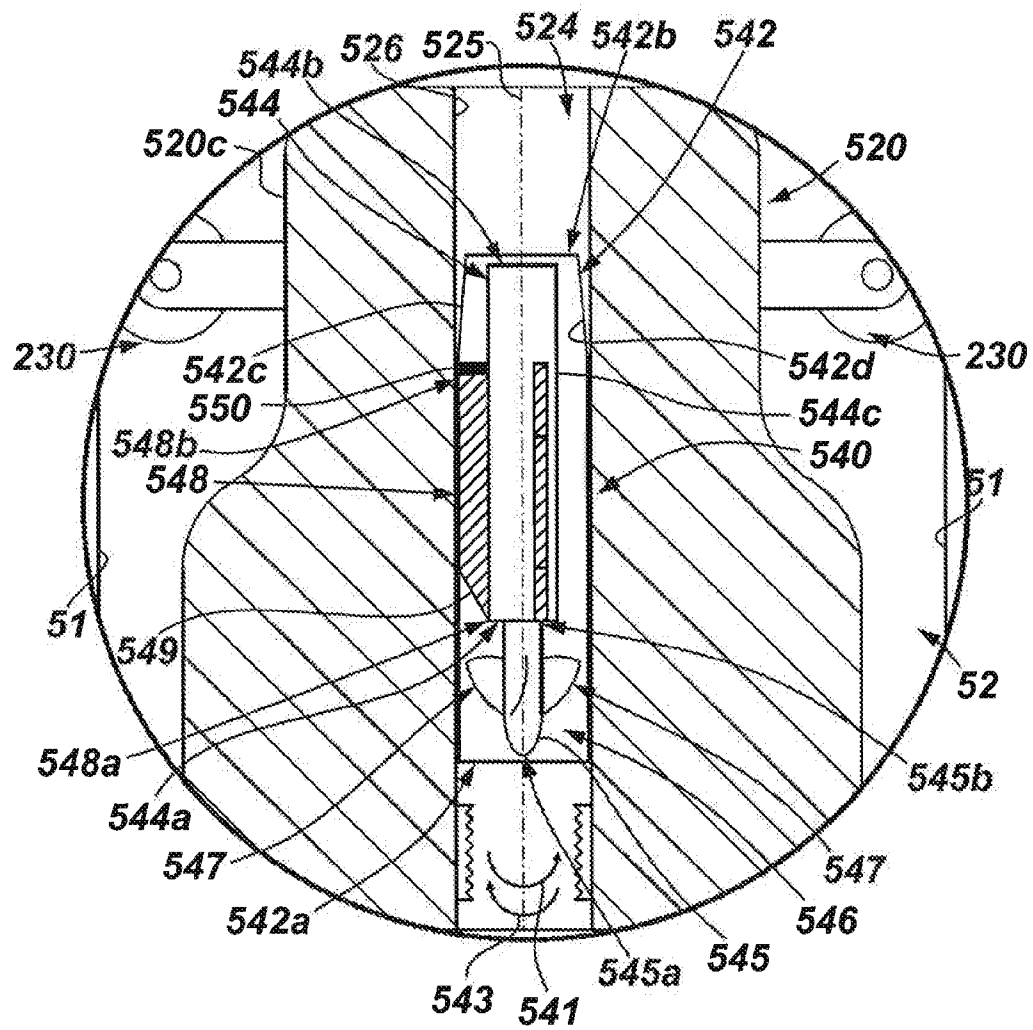


Figure 18

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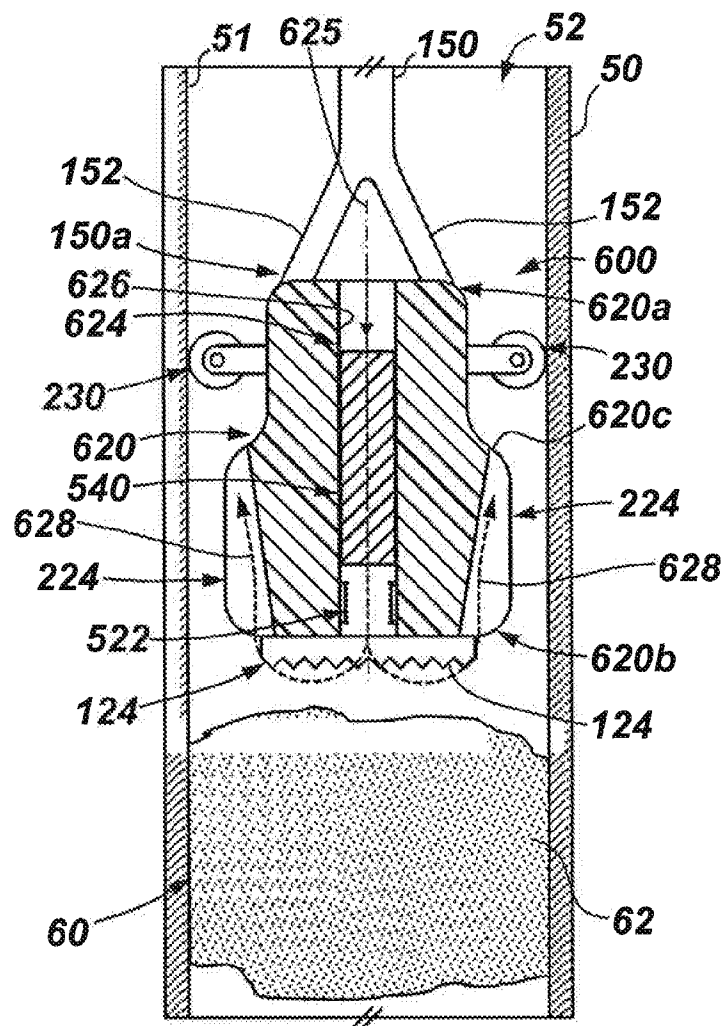


Figure 19

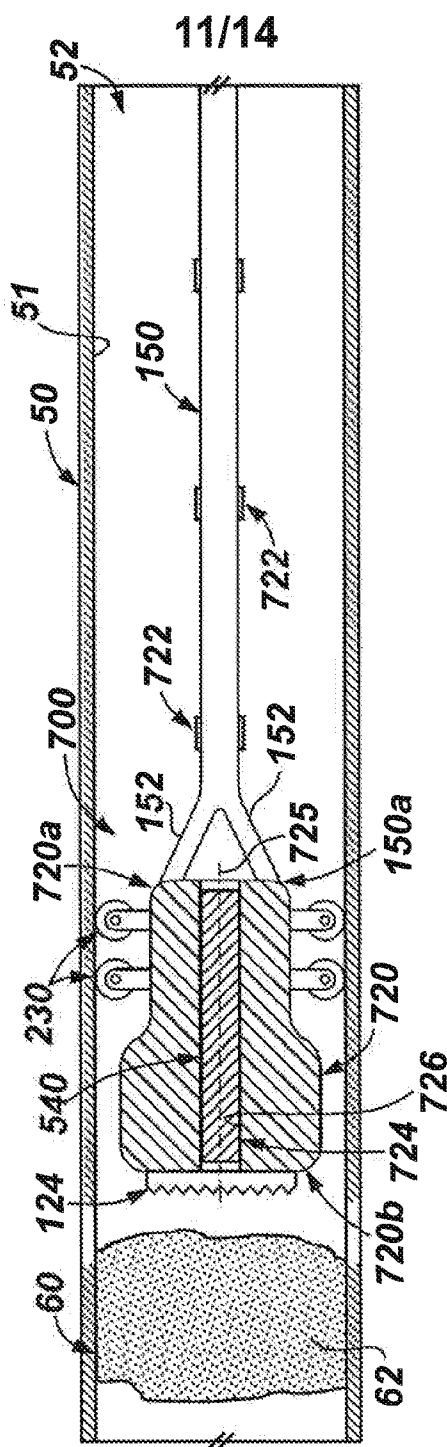


Figure 20

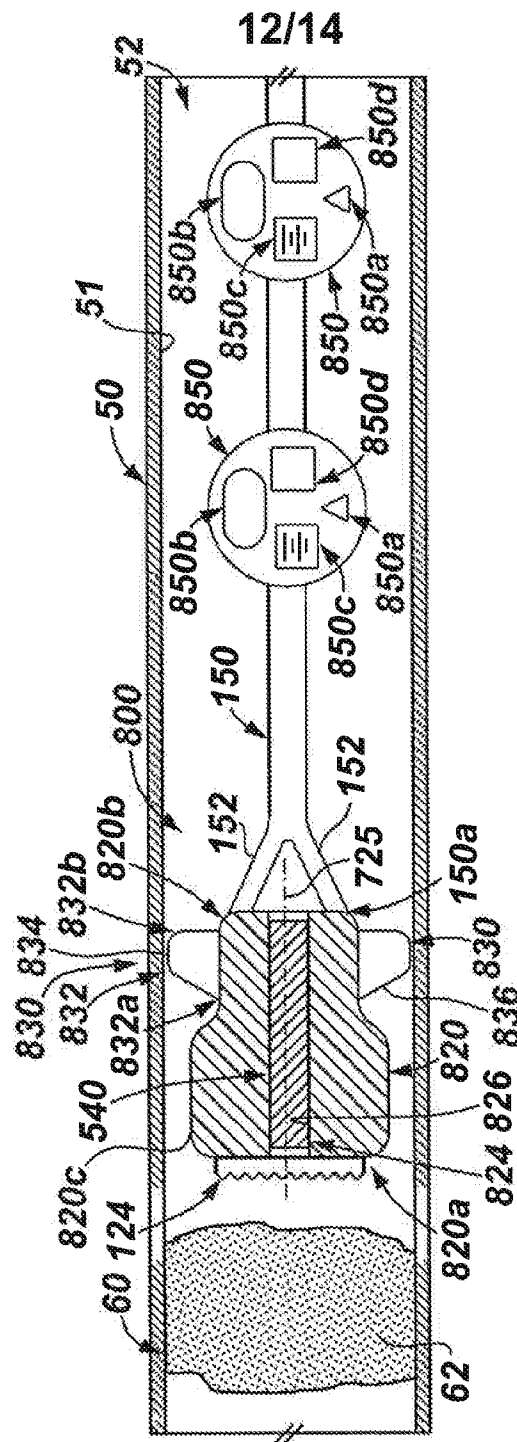


Figure 21

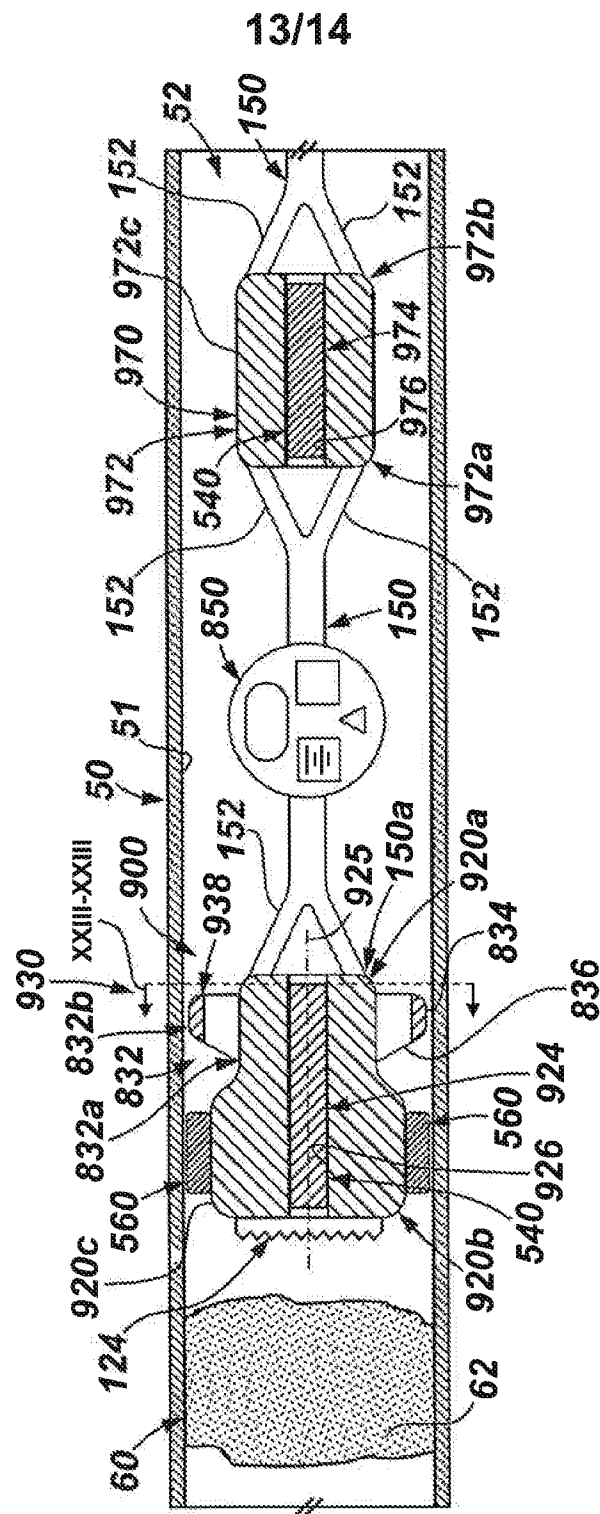


Figure 22

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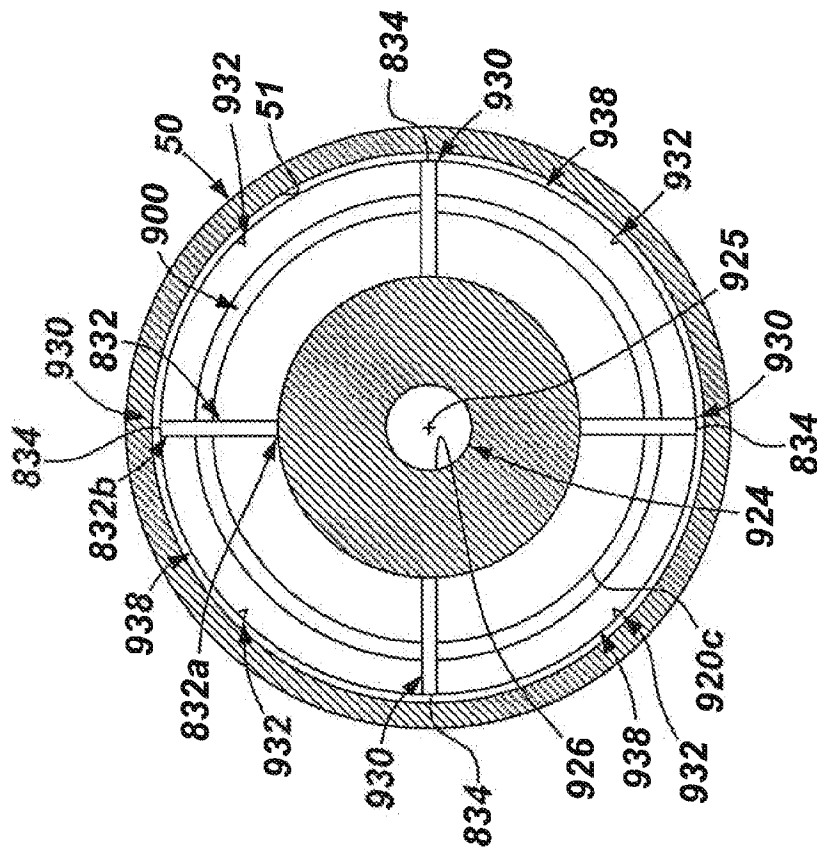


Figure 23

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2014/054479

A. CLASSIFICATION OF SUBJECT MATTER

INV. B08B7/00 B08B9/043 E21B37/00 B08B9/051 B08B9/047
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)

B08B 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)

EP0-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 5 948 171 A (GROTHAUS MICHAEL G [US]) 7 September 1999 (1999-09-07)	1-12
Y	column 1, lines 56-59	13-29
A	column 2, lines 37-53 column 4, lines 23-28 figure 1	30-36
A	----- FR 2 886 560 A1 (COMMISSARIAT ENERGIE ATOMIQUE [FR]) 8 December 2006 (2006-12-08) page 4, line 3 - line 16 page 5, lines 5-8 page 8, line 27 - page 9, line 15 figure 1a figure 3 ----- -/--	1-12



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

17 February 2015

Date of mailing of the international search report

25/02/2015

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
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Authorized officer

Posten, Katharina

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2014/054479

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DE 195 43 473 A1 (TUB TAUCH UND BAGGERTECH GMBH [DE]) 13 June 1996 (1996-06-13) column 1, lines 30-61 column 3, lines 41-56 figure 1	1-12
A	----- SU 777 394 A1 (INST PROEKT GORODSKIKH INZH SO [SU]) 7 November 1980 (1980-11-07) figure 1	1-12
Y	----- WO 2011/132817 A1 (UNIV SEOUL NAT R & DB FOUND [KR]; AHN SUNG HOON [KR]; LEE GIL YONG [KR]) 27 October 2011 (2011-10-27)	13-29
A	abstract figure 1 -----	30-36

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/054479

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.:
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:
3. ☐ Claims Nos.:
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:

see additional sheet

1. ☒ As all required additional 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 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.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-12

A tool for clearing a deposit within a fluid flowline, the tool comprising: an electrode extending radially from the radially outer surface of the tool body.

2. claims: 13-36

A tool for clearing a deposit from a fluid flowline, the tool comprising: a pumping assembly disposed in a throughbore of the tool body.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2014/054479

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5948171	A	07-09-1999	NONE
FR 2886560	A1	08-12-2006	NONE
DE 19543473	A1	13-06-1996	DE 19543473 A1 13-06-1996 GB 2296024 A 19-06-1996 NO 955009 A 13-06-1996 RU 2114981 C1 10-07-1998
SU 777394	A1	07-11-1980	NONE
WO 2011132817	A1	27-10-2011	KR 20110117022 A 26-10-2011 WO 2011132817 A1 27-10-2011 WO 2011132925 A2 27-10-2011