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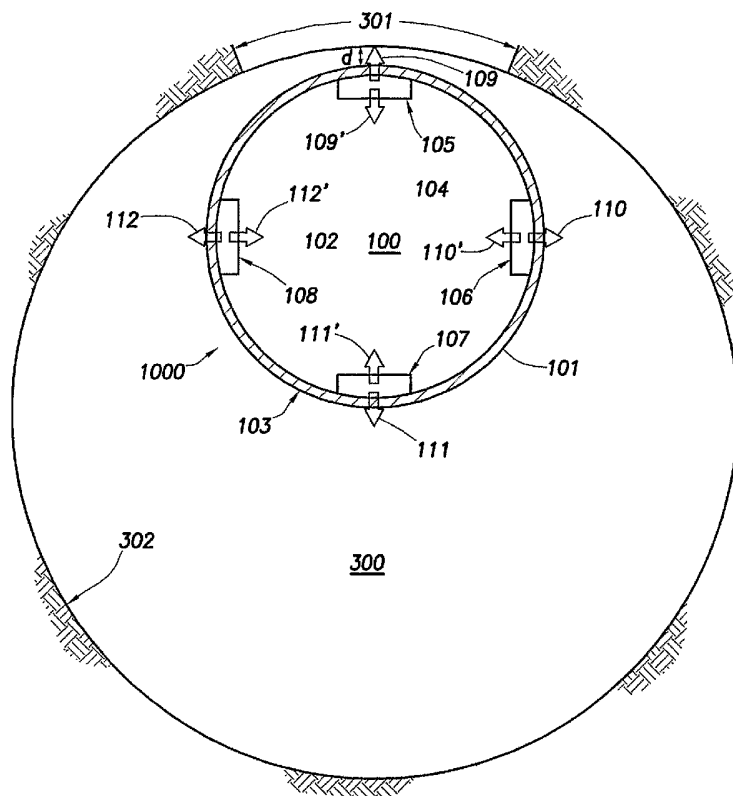
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(54) Title: METHOD AND APPARATUS FOR REDUCING A SKIN EFFECT IN A DOWNHOLE ENVIRONMENT



(57) Abstract: A method for reducing a skin effect in a downhole environment is provided, including the step of radiating vibrational waves at a wellbore wall such that the vibrational waves have at least one direction of greatest vibrational energy transfer directed toward the wall, thereby reducing the skin effect. An apparatus for reducing a skin effect in a downhole environment is also provided. The apparatus includes at least one vibrational wave source having at least one direction of greatest vibrational energy transfer, and a means for positioning the vibrational wave source proximate a wellbore wall.



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METHOD AND APPARATUS FOR REDUCING A SKIN EFFECT IN A DOWNHOLE ENVIRONMENT

BACKGROUND

The present invention relates to apparatuses and methods for treating a downhole environment, and more specifically, to apparatuses and methods for reducing a skin effect in a downhole environment.

In any typical hydrocarbon well, damage to the surrounding formation can impede fluid flow and cause production levels to drop. While many damage mechanisms plague wells, one of the most pervasive problems is particles clogging the formation pores that usually allow hydrocarbon flow. These clogging particles can also obstruct fluid pathways in screens; preslotted, predrilled, or cemented and perforated liners; and gravel packs that may line a well. Clogging particles may even restrict fluid flow in open-hole wells. Drilling mud, drilled solid invasion, or even the porous formation medium itself may be sources for these particles. In particular, *in situ* fines mobilized during production can lodge themselves in the formation pores, preslotted liners, screens and gravel packs, sealing them to fluid flow. Referred to as the "skin effect," this damage is often unavoidable and can arise at any stage in the life of a typical hydrocarbon well. The hydrocarbon production industry has thus developed well-stimulation techniques to repair affected wells or at least mitigate skin-effect damage.

The two classic stimulation techniques for formation damage, matrix acidizing and hydraulic fracturing, suffer from limitations that often make them impractical. Both techniques require the operator to pump customized fluids into the well, a process that is expensive, invasive and difficult to control. In matrix acidizing, pumps inject thousands of gallons of acid into the well to dissolve away precipitates, fines, or scale on the inside of tubulars, in the pores of a screen or gravel pack, or inside the formation. Any tool, screen, liner or casing that comes into contact with the acid must be protected from its corrosive effects. A corrosion inhibitor must be used to prevent tubulars from corrosion. Also, the acid must be removed from the well. Often, the well must also be flushed with pre- and post-acid solutions. Aside from the difficulties of determining the proper chemical composition for these fluids and pumping them down the well, the environmental costs of matrix acidizing can render the process undesirable. Screens, preslotted liners and gravel packs may also be flushed with a brine solution to remove solid particles. While this brine treatment is cheap

and relatively easy to complete, it offers only a temporary and localized respite from the skin effect. Moreover, frequent flushing can damage the formation and further decrease production. In hydraulic fracturing, a customized fluid is ejected at extremely high pressure against the wellbore walls to force the surrounding formation to fracture. The customized gel-based fluid contains a proppant to hold the fractures open to fluid flow. While this procedure is highly effective at overcoming near-borehole skin effects, it requires both specialized equipment and specialized fluids and therefore can be costly. Fracturing can also result in particle deposition in the formation because the gels involved may leave residue in the vicinity of the fractures.

The hydrocarbon production industry developed acoustic stimulation as an alternative to the classic stimulation techniques. In acoustic stimulation used for near-borehole cleaning, high-intensity, high-frequency acoustic waves transfer vibrational energy to the solid particles clogging formation pores. The ensuing vibrations of the solid particles loosen them from the pores. Fluid flow, including production-fluid flow out of the formation or injection-fluid flow into the formation from the well, may cause the particles to migrate out of the pores, clearing the way for greater fluid flow. Acoustic stimulation may also be used to clean preslotted liners, screens and gravel packs. Near-wellbore cleaning by acoustic stimulation has shown great promise in laboratory experiments, and the industry has developed several tools using this technique for use in real-world wells.

Acoustic stimulation tools require a compact source of acoustic waves that may be used downhole. Current tools, however, often radiate acoustic waves over 360 degrees or in an uncontrolled direction in an attempt to reduce the skin effect along the circumference of a wellbore wall at a given depth all at one time. These tools must consume large quantities of energy to radiate waves of sufficient intensity to vibrate the solid particles along the circumference of the wellbore wall. Supplying this energy downhole to create the necessary high-intensity acoustic waves is no easy feat, and thus current tools are poorly suited for removing particles from the formation.

SUMMARY

The present invention relates to apparatuses and methods for treating a downhole environment, and more specifically, to apparatuses and methods for reducing a skin effect in a downhole environment. An example method for reducing a skin effect in a downhole environment may comprise the step of radiating vibrational waves at a wellbore wall such

that the vibrational waves have at least one direction of greatest vibrational energy transfer directed toward the wall, thereby reducing the skin effect.

An example apparatus for reducing a skin effect in a downhole environment may comprise at least one vibrational wave source having at least one direction of greatest vibrational energy transfer and a means for positioning the vibrational wave source proximate a wellbore wall. Some example apparatuses for reducing a skin effect in a downhole environment may comprise a vibrational wave source having at least one direction of greatest vibrational energy transfer and at least one standoff contactor, wherein the at least one standoff contactor maintains a standoff distance between the vibrational wave source and a wellbore wall. These example apparatuses may also include a decentralizer, wherein the decentralizer positions the vibrational wave source proximate the wellbore wall and a wireline, wherein the wireline may be used to place the vibrational wave source in the well.

Other example apparatuses for reducing a skin effect in a downhole environment may also comprise a vibrational wave source having at least one direction of greatest vibrational energy transfer and at least one standoff contactor, wherein the at least one standoff contactor maintains a standoff distance between the vibrational wave source and a wellbore wall. These example apparatuses may include a rotator-resolver, wherein the rotator-resolver orients the vibrational wave source such that the at least one direction of greatest vibrational energy transfer is directed toward the wellbore wall. These example apparatuses may also include at least two articulated joints connecting the vibrational wave source to the rotator-resolver and at least one retractable arm, wherein the at least one retractable arm positions the vibrational wave source proximate the wellbore wall.

An example apparatus for reducing a skin effect in a downhole environment may comprise a vibrational wave source having at least one direction of greatest vibrational energy transfer and at least one standoff contactor, wherein the at least one standoff contactor maintains a standoff distance between the vibrational wave source and a wellbore wall. These apparatuses may also include a rotator-resolver, wherein the rotator-resolver orients the vibrational wave source such that the at least one direction of greatest vibrational energy transfer is directed toward the wellbore wall. The example apparatuses may include a vibrational wave source pad attached to the rotator-resolver and at least one retractable arm, wherein the at least one retractable arm positions the vibrational wave source proximate the wellbore wall.

Another example apparatus for reducing a skin effect in a downhole environment may comprise a plurality of vibrational wave sources wherein each vibrational wave source has at least one direction of greatest vibrational energy transfer. The example apparatuses may also include at least one standoff contactor, wherein the at least one standoff contactor maintains a standoff distance between the plurality of vibrational wave sources and a wellbore wall and a rotator-resolver, wherein the rotator-resolver orients the plurality of vibrational wave sources such that the at least one direction of greatest vibrational energy transfer is directed toward the wellbore wall. These apparatuses may also include a vibrational wave source pad attached to the rotator-resolver and at least one retractable arm, wherein the at least one retractable arm positions the plurality of vibrational wave sources proximate the wellbore wall.

The features and advantages of the present invention will be readily apparent to those skilled in the art upon a reading of the description of the exemplary embodiments, which follows.

BRIEF DESCRIPTION OF DRAWINGS

A more complete understanding of the present disclosure and advantages thereof may be acquired by referring to the following description taken in conjunction with the accompanying drawings, wherein:

Figure 1 illustrates a cross-sectional view of an example of an oval-mode acoustic wave source in a well.

Figure 2 illustrates the vibratory mode for an example of an oval-mode acoustic wave source.

Figure 3 illustrates a cross-sectional view of an example of a vibrational wave source in a well.

Figure 4 illustrates an example apparatus for reducing a skin effect including a wireline in a downhole environment.

Figure 5 illustrates an example apparatus including coiled tubing in a downhole environment.

Figure 6 illustrates an example apparatus including coiled tubing in a downhole environment.

Figure 7 illustrates an enlarged view of an example apparatus in a downhole environment generating a standing wave pattern.

Figure 8 illustrates an example apparatus including an actuator to adjust the standoff distance between the vibrational wave source and the wellbore wall, a means for detecting accretions of particles, and a means for monitoring energy transfer from the vibrational wave source to the wall.

Figure 9 illustrates an example apparatus including an accelerometer to monitor energy transfer from the vibrational wave source to the wellbore wall.

Figure 10 illustrates an example apparatus including multiple vibrational wave sources in a downhole environment.

Figure 11A illustrates a cross-sectional view of example apparatus including multiple vibrational wave sources in a downhole environment.

Figure 11B illustrates a cross-sectional view of example apparatus including multiple vibrational wave sources in a downhole environment.

Figure 11C illustrates an example apparatus including multiple vibrational wave sources in a downhole environment.

Figure 12 illustrates an example apparatus including multiple vibrational wave sources and a means for determining by how much the skin effect has been reduced.

While the present invention is susceptible to various modifications and alternative forms, specific exemplary embodiments thereof have been shown by way of example in the drawings and are herein described in detail. It should be understood, however, that the description herein of specific embodiments is not intended to limit the invention to the particular forms disclosed, but on the contrary, the intention is to cover all modifications, equivalents and alternatives falling within the spirit and scope of the invention as defined by the appended claims.

DETAILED DESCRIPTION

The present invention relates to apparatuses and methods for treating a downhole environment, and more specifically, to apparatuses and methods for reducing a skin effect in a downhole environment. We provide a system for positioning a vibrational wave source downhole to optimally reduce a skin effect. The system may treat a variety of structures and materials located downhole, including, but not limited to, porous materials such as screens, gravel packs, frac packs or geologic formations. Moreover, the system may also treat openhole wells and wells with cemented and perforated casings or slotted liners.

An exemplary apparatus for reducing a skin effect in a downhole environment includes at least one vibrational wave source and a means for positioning the vibrational wave source proximate a wellbore wall. The vibrational wave source has at least one direction of greatest energy transfer. Figure 1 shows a well 300 containing an example apparatus 1000 including a vibrational wave source 100. As persons of ordinary skill in the art will realize, the void in well 300 around vibrational wave source 100 may be filled with fluids such as completion fluids, hydrocarbons, and other formation fluids. For some example apparatuses, the column of fluid in the well should be lighter than the reservoir pressure in order to allow fluid inflow from the reservoir. However, in many drilling situations that are more conducive to forming mud cake and accreting fines, borehole pressure can exceed formation pressure, as in overbalanced drilling. In Figure 1, apparatus 1000 uses an oval-mode acoustic wave source 104 as a vibrational wave source. United States Patent No. 6,412,354 B1, assigned to the assignee of this disclosure, discloses an oval-mode acoustic wave source that may be modified for use in apparatus 1000. Other acoustic wave sources, such as pistons, tuning forks, cantilever bars and wobble plates, may alternatively serve as vibrational wave sources. Oval-mode acoustic wave source 104 has been selected only for the purpose of describing the apparatus for reducing a skin effect in a downhole environment.

Oval-mode acoustic wave source 104 includes a housing 101 and a vibratory mechanism, denoted generally by the numeral 102. The vibratory mechanism 102 causes housing 101 to expand and contract at acoustic frequencies. As a result, housing 101 produces acoustic waves that propagate radially outward from an outer surface 103 of housing 101. Housing 101 may be cylindrical, and vibratory mechanism 102 may have four piezoelectric transducers 105, 106, 107, and 108 spaced equally around the circumference of housing 101. When subject to a changing voltage at opposite ends, piezoelectric transducers 105, 106, 107, and 108 may expand and contract, causing vibrations in housing 101 that create the desired vibrational waves. Arrows 109, 109', 110, 110', 111, 111', 112, and 112' in Figure 1 indicate the directions of expansion and contraction of piezoelectric transducers 105, 106, 107, and 108. This radial configuration of the piezoelectric transducers represents only one configuration out of many possible choices. For example, an axial configuration of the piezoelectric transducer with a moment arm coupled to housing 101 may be preferred for some example apparatuses 1000.

Figures 2A through 2F include a time series of diagrams showing the motion of housing 101. These diagrams illustrate an example vibratory mode for oval-mode acoustic wave source 104. The progression in time of the vibratory mode can be seen when the figures are viewed in succession in a clockwise direction, starting with Figure 2A. Vibratory mechanism 102 for this oval-mode acoustic wave source 104 may include a first and second pair of opposing piezoelectric transducers 201 and 202. The first pair of opposing piezoelectric transducers 201 expands and contracts along the directions indicated by arrows 203 in phase. The second pair of opposing piezoelectric transducers 202 expands and contracts in phase along the directions indicated by arrows 204 but 180 degrees out of phase with the first pair of opposing piezoelectric transducers 201. The motion of housing 100 begins with Figure 2A. The first pair of opposing piezoelectric transducers 201 expands, pulling housing 101 in the directions indicated by arrows 203. Simultaneously, the second pair of opposing piezoelectric transducers 202 contracts, pulling housing 101 in the directions indicated by arrows 204. The result of this pulling can be seen in Figure 2B: housing 101 assumes an oval shape, with the elongated axis of the oval along the directions of arrows 203.

Once the first pair of opposing piezoelectric transducers 201 has expanded to its maximum size, and the second pair of opposing piezoelectric transducers 202 has contracted to its minimum size, housing 101 has experienced its maximum overall distortion in this direction. First pair of opposing piezoelectric transducers 201 then begins to contract, and second pair of opposing piezoelectric transducers 202 begins to expand, as shown in Figure 2C. Housing 101 returns to its original circular shape, as shown in Figure 2D. Then first pair of opposing piezoelectric transducers 201 contracts, and second pair of opposing piezoelectric transducers 202 expands, distorting housing 101 again. Housing 101 may then assume another oval shape, this time with the elongated axis of the oval along the directions of arrows 204, as shown in Figure 2E. Once housing 101 has experienced a second maximum overall distortion, first pair of opposing piezoelectric transducers 201 will begin to expand, and second pair of opposing piezoelectric transducers 202 will begin to contract, as Figure 2F illustrates. Housing 101 will then return to the circular shape shown in Figure 2A. As a person of ordinary skill in the art will realize, a driver located outside housing 101 may power and control the first and second pairs of opposing piezoelectric transducers.

The housing motion repeats with the repeated motion of the first and second pair of opposing piezoelectric transducers, causing the oval-mode vibrations that drive the desired

vibrational waves. Returning to Figure 1, housing 101 will experience the greatest localized distortion at the locations of each of the piezoelectric transducers 105, 106, 107, and 108. The maximum amplitude of the vibrational waves produced by the oval-mode acoustic wave source 104 thus propagates radially away from the outer surface 103 of housing 101 along the directions indicated by arrows 109, 110, 111, and 112. Oval-mode acoustic wave source 104 will accordingly transmit the greatest vibrational energy possible along the directions indicated by arrows 109, 110, 111, and 112. Each of the arrows 109, 110, 111, and 112 thus points in a direction of greatest vibrational energy transfer. Again, other vibrational wave sources may be substituted for the oval-mode acoustic wave source. These vibrational wave sources should have at least one direction of greatest vibrational energy transfer.

Figure 1 also illustrates an exemplary position for vibrational wave source 100 within well 300. The means for positioning, discussed in detail later in this disclosure, allows vibrational wave source 100 to achieve this position. The direction of greatest vibrational energy transfer in the direction along arrow 109 may be directed toward a portion 301 of the wellbore wall 302. If vibrational wave source 100 is cylindrical, as in certain example apparatuses, portion 301 will take a rectangular "strip" shape. In operation according to an example method, vibrational wave source 100 may direct its greatest vibrational energy on the particles blocking the pores of the formation at portion 301. If a preslotted liner, screen, gravel pack or other intervening structure or material is present at portion 301, the vibrational wave source 100 may direct its greatest vibrational energy on blocking particles in or on that structure or material as well as at portion 301. The vibrational energy transfers from vibrational wave source 100 to the blocking particles and causes them to vibrate. This vibration may loosen the blocking particles from their positions clogging fluid pathways out of the formation or intervening structure or material. Fluid flow, such as production-fluid flow out of the formation or injection-fluid flow into the formation, may flush away these particles, and fluid-production levels may then increase. The flushing fluid may flow during radiation of acoustic waves or after, as desired.

This embodiment of a method according to the present invention may be repeated at a second portion 303 of wellbore wall 302 to expand the width of the cleaned area along the circumference of the well, as shown in Figure 3. The apparatus may comprise a means for orienting the vibrational wave source in the well, as discussed in detail later in this disclosure. If the apparatus does include an orienting means, vibrational wave source 100 should first be

reoriented so that at least one direction of greatest vibrational energy transfer is directed toward the second portion 303. Then, vibrational wave source 100 must be repositioned at second portion 303. Alternatively, the apparatus may move vibrational wave source 100 continuously through well 300 such that vibrational wave source 100 radiates vibrational waves at the wellbore wall as it passes through the well. For such a continuous-operation method to be successful, vibrational wave source 100 must move along well 300 slowly enough that it radiates vibrational waves at a particular portion of wellbore wall 302 for long enough to loosen blocking particles. The length of time needed to loosen blocking particles will depend on the particular skin effect present in the well.

Once vibrational wave source 100 is activated, it will remove the solid particles from second portion 303 just as it did at portion 301. The process may be repeated at any location along the circumference of wellbore wall 302. It is not necessary, however, to clean all of wellbore wall 302 because fluid in the formation can migrate radially, axially and circumferentially to the nearest cleaned portion of wellbore wall 302. Example apparatuses may therefore achieve improved production flow rates using shorter operation times and lower power than tools that clean the entire circumference of wellbore wall 302. Example apparatuses may also allow for cleaning in situations when the power available is insufficient to adequately stimulate the wellbore wall around its full circumference. Because its outer diameter is smaller than the inner diameter of well 300, vibrational wave source 100 can fit through other passages having inner diameters smaller than the inner diameter of well 300, such as through the landing nipple inside production tubing 401 shown in cross-section in Figure 4. The desired cleaning rate will determine the suitable size for vibrational wave source 100, as persons of ordinary skill in the art having the benefit of this disclosure will realize. Use of longer or wider vibrational wave sources will result in greater cleaning rates than smaller acoustic wave sources, for example, assuming that adequate power is available.

In certain exemplary embodiments, vibrational wave source 100 will produce vibrational waves with frequencies in the range of about 8 kHz to about 40 kHz. In certain preferred embodiments, the vibrational waves will have frequencies ranging from about 10 kHz to about 20 kHz. Bursts of vibrational waves with intervening periods of inactivation are preferred so that fluid flow, such as production-fluid flow from the formation into the well or injection-fluid flow from the well into the formation, can flush away the loosened particles. The activation period for the vibrational wave source should last approximately 2,000 to

approximately 20,000 cycles to bring the motion of the solid particles to the full resonance amplitude. Longer activation periods are acceptable, however, and may even be desirable in wells with severe skin-effect damage. The inactivation period between bursts should be selected empirically to optimize cleaning relative to the permeability of the skin effect.

Certain example apparatuses include a means for placing the vibrational wave source in a well. A suitable placement means will be apparent to persons of ordinary skill in the art having the benefit of this disclosure. The placement means may be a prior-art wireline, as shown in Figure 4. Wireline 400 supplies the power necessary to operate vibrational wave source 402. Wireline 400 may also transmit the control telemetry needed to operate the vibrational wave source 402. Example apparatuses incorporating a wireline 400 may also comprise a driver unit located in a tool body 403 that is placed downhole with the wireline 400 and vibrational wave source 402. Tool body 403 may contain a conventional electrical converter that converts wireline power to power at the preferred driver frequency. Tool body 403 also may contain control circuitry that permits adjustment of the activation and inactivation periods. As will be apparent to persons of ordinary skill in the art having the benefit of this disclosure, apparatuses utilizing a wireline will require procedures to overcome friction along the wellbore wall surface in highly deviated or horizontal wells.

Apparatus 1000 includes a means for positioning vibrational wave source 100 proximate the wellbore wall to focus the vibrational energy at only one portion of the wellbore wall at a time. This position helps apparatus 1000 avoid dispersing vibrational energy over the entire circumference of the wellbore wall. A suitable positioning means will depend on the chosen placement means, as persons of ordinary skill in the art having the benefit of this disclosure will realize. The positioning means may include a decentralizer. In particular, apparatuses may include a decentralizer with at least one bowed spring member that pushes against one side of the wellbore wall to position the vibrational wave source proximate an opposing side of the wellbore wall. Figure 4 illustrates an exemplary apparatus that comprises such a "bow-spring decentralizer," labeled with numeral 404.

The means for placing the vibrational wave source in a well also may be prior-art coiled tubing, as shown in Figures 5 and 6. Electrical cables can pass through the bore or in the wall of the coiled tubing to supply the electrical power necessary to operate the vibrational wave source. The electrical cables may also transmit the control telemetry needed to operate the vibrational wave source. Apparatuses incorporating coiled tubing may also

include a driver unit located in a tool body that is placed downhole with the coiled tubing and vibrational wave source. The contents of this tool body may parallel the contents of tool body 403. With coiled tubing, however, the tool body may contain additional controls for adjusting the spatial location of vibrational wave source 100 relative to its circumferential position in the well. Because coiled tubing is generally used in horizontal wells, the bow-spring decentralizer shown in Figure 4 may be most useful with wireline apparatuses. Coiled tubing apparatuses, however, may also include a bow-spring or powered decentralizer, as persons of ordinary skill in the art having the benefit of this disclosure will realize. Example apparatuses including coiled tubing may be better for the continuous-operation method described earlier, as the motion of vibrational wave source 100 can be more smooth with coiled tubing than with wireline. Other alternative means for placing the vibrational wave source in a well may be used. For example, the means for placing the vibrational wave source in a well also may be a prior-art well tractor. The well tractor may be used in conjunction with another means for placing the vibrational wave source in a well, such as a wireline, or even independently. The best choice for a means for placing the vibrational wave source in the well will depend, in part, on the configuration of the well.

In certain example apparatuses 1000, vibrational wave source 100 may be not only positioned proximate the wellbore wall but also oriented to direct the at least one direction of greatest vibrational energy transfer toward the wellbore wall. Certain example apparatuses therefore include a means for orienting the vibrational wave source in the well. In certain example apparatuses 1000, this orienting means will comprise a rotator-resolver that rotates the vibrational wave source to the desired circumferential orientation. To control the circumferential orientation of vibrational wave source 100, the tool body may include conventional equipment sufficient to detect the orientation of vibrational wave source 100 and to instruct the rotator-resolver to readjust that orientation. The tool body may contain controls to adjust the spacing between vibrational wave source 100 and the wellbore wall. A suitable design for the rotator-resolver will be apparent to persons of ordinary skill in the art having the benefit of this disclosure. Further, other means for orienting the vibrational wave source may be apparent to those of ordinary skill in the art having the benefit of this disclosure. These orienting means may be more useful when vibrational wave source 100 stops at a particular location to radiate waves, rather than moving continuously the orienting

means. The orienting means, however, may be successfully used in the continuous-operation method if vibrational wave source 100 moves slowly enough.

In certain example apparatuses including a rotator-resolver, the decentralizer may include a member with at least two articulated joints connecting the vibrational wave source to the rotator-resolver and at least one retractable arm. The retractable arm may position the vibrational wave source proximate the wellbore wall. Figure 5 illustrates an apparatus including such a decentralizer, a rotator-resolver, and coiled tubing in a horizontal well 508. In horizontal wells, the vibrational wave source may be directed toward the top wellbore wall, closest to the ground level surface, as may generally be desired. While this apparatus may be particularly suitable for highly deviated or horizontal wells, however, it may also be used in vertical wells. Vibrational wave source 500 may attach to member 501 with articulated joint 502. A second articulated joint 503 may connect member 501 to rotator-resolver 504. Rotator-resolver 504 may also connect to tool body 505, which may contain controls for vibrational wave source 500 and rotator-resolver 504. Once vibrational wave source 500 is at the desired circumferential orientation, retractable arms 506 and 506' unfold and position vibrational wave source 500 proximate wellbore wall 507. While Figure 5 displays an embodiment according to the present invention with two retractable arms 506 and 506', an embodiment need only use at least one retractable arm.

In example apparatuses including a rotator-resolver, the decentralizer may comprise a vibrational wave source pad and at least one retractable arm. Figure 6 illustrates an apparatus including this decentralizer, a rotator-resolver and coiled tubing in use in a horizontal well 606. This apparatus may be particularly useful in highly deviated or horizontal wells. In Figure 6, vibrational wave source 600 couples to vibrational wave source pad 601 via retractable arm 602. Alternatively, vibrational wave source 600 may directly couple to vibrational wave source pad 601, and retractable arm 602 may couple vibrational wave source pad 601 to tool body 604. While the apparatus shown in Figure 6 uses only one retractable arm, an apparatus using this particular decentralizer may incorporate more retractable arms if necessary. Vibrational wave source pad 601 may couple to rotator-resolver 603. Rotator-resolver 603 may join to tool body 604, which may contain a driver for vibrational wave source 600 and controls for rotator-resolver 604. Once the vibrational wave source is at the desired circumferential orientation and is proximate the portion of the wall to

be cleaned, retractable arm 602 unfolds and positions vibrational wave source 600 proximate wellbore wall 605.

Certain example apparatuses may further include at least one standoff contactor that maintains a standoff distance between the vibrational wave source and the wellbore wall. Figures 4, 5 and 6 illustrate apparatuses that include at least one standoff contactor 550. The standoff distance is labeled by the letter "*d*." Each standoff contactor 550 may have at least one contact point that touches the wellbore wall. As persons of ordinary skill in the art having the benefit of this disclosure will realize, an appropriate size for the standoff distance will depend on the extent of the skin effect at the portion of the wellbore wall and the speed of sound downhole, as discussed later in this disclosure. In certain exemplary embodiments, the standoff distance will be in the range of about 1.5 inches to about 0.125 inch. In certain preferred embodiments, the standoff distance will be in the range of about 0.25 inch to about 0.20 inch.

In certain exemplary embodiments, the standoff distance may be varied to optimize reduction of the skin effect. The effectiveness of cleaning can be greatly enhanced if the apparatus is positioned at a standoff distance from the wellbore wall such that the vibrational wave source creates a standing wave pattern between the vibrational wave source and the wellbore wall. Figure 7 shows two example standing wave patterns of the lowest harmonic mode. Pattern A illustrates an acoustic standing wave traveling through fluid in a well. The dots represent fluid molecules and suspended particles forming the standing wave pattern. Pattern B represents the propagation of the suspended particle motion. Vibrational wave source 700 emits an incident vibrational wave 701, with a wavelength λ . Incident vibrational wave 701 reflects at wellbore wall 702 and returns to vibrational wave source 700 as reflected vibrational wave 703. If the standoff distance *d* between vibrational wave source 700 and wellbore wall 702 of the wellbore is equal to an integer multiple of $\lambda/2$, the incident vibrational wave 701 and reflected vibrational wave 703 will produce a stationary pattern of constructive interference, or a standing wave pattern.

To create this standing wave pattern, standoff contactor 550 should be sized to keep the vibrational wave source at a distance equal to an integer multiple of $\lambda/2$ away from the wellbore wall. While the distance between vibrational wave source 700 and wall 702 may be any integer multiple of $\lambda/2$ to produce a standing wave pattern, in practice, lower-order harmonics produce better cleaning results: the acoustic aspect ratio of vibrational waves in

lower-order harmonics tends to result in deeper penetration into the formation or intervening structure or material. Moreover, vibrational waves in lower-order harmonics undergo fewer cycles per unit time, thereby decreasing the acoustic attenuation per unit distance of the vibrational waves. Once a standing wave pattern is generated, the intensity of the vibrational waves is enhanced at the wellbore wall: the intensity of the reflected vibrational wave 701 adds to the intensity of the incident vibrational wave 702, resulting in a pressure amplitude that is greater than the pressure caused by the incident wave along a thin pressure zone near the wellbore wall. This pressure zone can be seen in Pattern A. The pressure zone may be further amplified by using a vibrational wave source that can focus generated waves on the wellbore wall. Some example apparatuses may therefore include a vibrational wave source that can focus its waves on the wall of the wellbore, such as a vibrational wave source that includes focused transducers.

The standoff distance can be chosen at the surface based on the anticipated skin effect properties and estimated speed at which the vibrational waves will travel in the wellbore wall. However, the standoff distance required to establish a standing wave pattern may vary with variations in the speed of sound downhole. As persons of ordinary skill in the art are aware, the speed of sound in downhole fluids will vary with the temperature and pressure of the downhole fluids, often increasing with depth in a borehole. Variations in the formation fluid constituents, fluids present in the well or particles present in these fluids can cause the speed of sound downhole to change. In particular, the speed of sound might change as the skin effect is reduced. If the standoff distance can be adjusted downhole, a standing wave can be maintained despite fluctuations in the speed of sound. Figure 8 shows a vibrational wave source pad 801 with an actuator 802 that controls the standoff distance d between the vibrational wave source 803 and wellbore wall 302 to obtain the offset necessary to create a standing wave pattern. Actuator 802 may move vibrational wave source 803 relative to contact points on standoff contactors 804 that touch wellbore wall 302. Standoff contactors 804 also may help position the vibrational wave source 803 once retractable arm 805 positions it proximate wellbore wall 302. When cleaning is completed, retractable arm 805 pulls vibrational wave source into recess 806 of tool body 811.

The apparatus may further include a means for detecting accretions of particles between the vibrational wave source and the wellbore wall. If this detecting means detects a threshold level of accreted particles, the vibrational wave source may be moved away from

the wellbore wall. The vibrational wave source may then radiate vibrational waves to break up the accretions and reposition proximate the wellbore wall to continue the cleaning process. In the example apparatus shown in Figure 8, the detecting means includes an accelerometer 807 connected to a vibrational wave source pad 801. Accelerometer 807, which may be a conventional prior-art accelerometer, may produce an electrical signal for a signature vibration pattern indicating that particles have accreted between vibrational wave source 803 and wellbore wall 302. The signature vibration pattern will be determined empirically by comparing the vibrations that vibrational wave source 803 experiences when no particles have accreted to vibrations that vibrational wave source 803 experiences when particles have accreted. Other suitable means of detecting accretions of particles will be apparent to persons of ordinary skill in the art having the benefit of this disclosure.

The apparatus may also comprise a means for monitoring energy transfer from the vibrational wave source to the wellbore wall. If the amount of energy transferred is insufficient or excessive, the vibrational wave source can be repositioned, or the cleaning process repeated, to optimally reduce the skin effect. The vibrational waves radiated by vibrational wave source 803 may also be altered to optimally reduce the skin effect at that wellbore wall 302 if necessary. In an example apparatus shown in Figure 8, the monitoring means includes a hydrophone 810 suitable for use in a downhole environment inside tool body 811. Hydrophone 810, which may be a conventional prior-art hydrophone, may translate vibrational waves traveling through fluid present near wellbore wall 302 into an electrical signal proportional to the amount of energy transferred by the vibrational waves. The vibrational waves may contact hydrophone 810 through port 812. A processing unit 813 then measures the electrical signal to monitor the energy transferred from vibrational wave source 803 to wellbore wall 302. Processing unit 813 may be in tool body 811, elsewhere downhole, or even uphole.

In an alternate example shown in Figure 9, the monitoring means may include an accelerometer 901 connected to vibrational wave source pad 801 and a processing unit 902. Accelerometer 901 may also be a conventional prior-art accelerometer. Accelerometer 901 should be acoustically isolated with an insulator 903 from vibrational wave source pad 801, however, and produce an electrical signal proportional to the vibrations experienced by wellbore wall 302 in response to the vibrational waves radiated by vibrational wave source 803. In certain example apparatuses, accelerometer 901 will directly contact wellbore wall

302. Processing unit 902 then measures the electrical signal produced by accelerometer 901 to monitor the energy received by wellbore wall 302 from vibrational wave source 901. Accelerometer 901 may comprise a spring-loaded membrane having a wearface that contacts wall 302, at least one piezoelectric element attached to this spring-loaded membrane, and a backing mass attached to the at least one piezoelectric element. Accelerometer 901 may further comprise a housing to protect the at least one piezoelectric element. Other suitably designed accelerometers may be used, however, as will be apparent to persons of ordinary skill in the art having the benefit of this disclosure. Further, other means for monitoring energy transfer from the vibrational wave source to the wellbore wall will be apparent to persons of ordinary skill in the art having the benefit of this disclosure. For example, standard formation receivers may be used, inside or outside the tool body. The vibrational wave source 100 could then be used as a transmitter between cleaning pulses. Example apparatuses may also include conventional receivers used in sonic logging tools. While the hydrophone described herein may be a broad band receiver, other receivers may be tuned to specific cleaning frequencies.

Example apparatuses include at least one vibrational wave source. In certain examples, however, the apparatus may include a plurality of vibrational wave sources displaced axially at the same circumferential orientation, displaced radially at the same axial location, or displaced in some combination of the two configurations. The number of vibrational wave sources chosen can depend on the power available to the apparatus as well as its mechanical complexity. Figure 10 displays an example apparatus 1010 that uses vibrational wave source pads and retractable arms to position the vibrational wave sources in the borehole. Any positioning means, however, may be used. Here, the plurality of vibrational wave sources includes three vibrational wave source pads, 1020, 1030 and 1040, each containing one vibrational wave source 1020', 1030' and 1040', but any number of vibrational wave sources may be used, as will be apparent to persons of ordinary skill in the art having the benefit of this disclosure. Each vibrational wave source pad 1020, 1030 and 1040 is aligned axially with the others. In this example, gaps "g" separate vibrational wave source pads 1020, 1030 and 1040. In certain example apparatuses, gap g will be about 3 feet to about 5 feet. Gap g, however, may be of any suitable size chosen for a particular application, as a person of ordinary skill in the art having the benefit of this disclosure will realize.

The vibrational wave sources that form the plurality vibrational wave sources of the apparatus may be activated continuously, or in succession, with or without intervening periods of inactivation. For example, the vibrational wave source 1020' may first radiate vibrational waves at portion 1021 of the wellbore wall for a period of time. Vibrational wave source 1020' then stops to allow fluid flow to flush away any particles from portion 1021 and from any structures or materials present at portion 1021. Once vibrational wave source 1020' stops, vibrational wave source 1030' will radiate vibrational waves for another period of time at portion 1031 of the wellbore wall and then stop to allow fluid flow to flush away any particles from portion 1031 and from any structures or materials present at portion 1031. Once vibrational wave source 1030' stops, vibrational wave source 1040' will radiate vibrational waves for another period of time at portion 1041 of the wellbore wall and then stop to allow fluid flow to flush away any particles from portion 1041 and from any structures or materials present at portion 1041. If necessary, vibrational wave source 1020' may radiate vibrational waves again, and the process may be repeated with vibrational wave sources 1030' and 1040'. Moreover, vibrational wave sources 1020', 1030', and 1040' may radiate vibrational waves at different frequencies to optimally reduce the skin effect.

Although this example method activates vibrational wave sources in succession from left to right in Figure 10, any order of activation may be used. In alternative methods of the present invention, the plurality of vibrational wave sources may be activated simultaneously, either for defined periods of time or continuously. The periods of time during which vibrational wave sources radiate vibrational waves may vary as needed for different skin effects and downhole environments, or to optimize use of the available power, as a person of ordinary skill in the art having the benefit of this disclosure will realize. A typical activation period will be longer than approximately 2,000 cycles. The optimal duration of the activation period depends on the rate at which the apparatus traverses in the well. If the rate of axial traverse is zero, and thus the apparatus is still, the activation should typically be no longer than approximately 5 seconds at any given location on the wellbore wall. If the apparatus axially traverses the wellbore at a rate such that it moves to an entirely new location in less than approximately 5 seconds, as in slow, continuous motion, the apparatus may be continually activated. An intervening period of inactivation may occur between multiple periods of activation, if desired. During these intervening periods, formation fluid flow will

further flush loosened fines. However, formation fluid flow may flush fines even during activation.

The multiple vibrational wave sources may assume different configurations to offer wider coverage, if desired. In an alternative example shown in Figures 11A, 11B, and 11C, the apparatus may include a plurality of vibrational wave sources on vibrational wave source pads displaced both circumferentially and axially. Each vibrational wave source pad 1120, 1130, and 1140 may be displaced circumferentially by 60 degrees from the nearest vibrational wave source pad, as shown in the cross-sectional view of Figure 11A. Vibrational wave source pads 1120, 1130, and 1140 may also be displaced circumferentially by about 120 degrees from the nearest vibrational wave source pad, as shown in the cross-sectional view of Figure 11B. In addition to their circumferential displacement, vibrational wave sources 1120, 1130, and 1140 may be displaced axially by a gap g , as shown in the longitudinal view of Figure 11C. The number and orientation of vibrational wave sources may vary to best suit the particular well, to optimize power utilization, and to utilize different frequencies to more effectively clean, as persons of ordinary skill in the art having the benefit of this disclosure will realize. The apparatuses shown in Figures 11A, 11B, and 11C may be activated using the methods described earlier in this disclosure; that is, the vibrational wave sources may be activated in succession, simultaneously for defined time periods, or simultaneously and continuously. As with the apparatus shown in Figure 10, other methods may be used to produce the desired cleaning effect.

The apparatus may also include a means for determining how much the skin effect in the downhole environment has been reduced. This determining means may measure a speed of sound or propagation speed for the vibrational waves in a wellbore wall that has already been cleaned. The speed of sound after cleaning can be compared with a measured control speed at which vibrational waves traveled in the same wellbore wall prior to cleaning. The control speed can be determined empirically by measuring the speed of sound for vibrational waves at low acoustic intensities propagating in the wellbore wall. For example, production improvement observed in a test well in a particular reservoir could be correlated with the change in the speed of sound. Empirical data from other cleanings may be useful to supplement this comparison.

Any apparatus for reducing a skin effect in a downhole environment may incorporate a means for determining how much the skin effect has been reduced. For example, the

vibrational wave source pads 1201 and 1202 shown in Figure 12 connect to accelerometers 1203 and 1204. Accelerometers 1203 and 1204 contact the wellbore wall but are acoustically isolated via insulators 1206 from the vibrational wave sources 1201' and 1202' contained in vibrational wave source pads 1201 and 1202, respectively. To determine how much the skin effect in the downhole environment has been reduced, vibrational wave source 1201' first radiates vibrational waves at the wellbore wall. Accelerometer 1203 will detect vibrations in the wellbore wall as a result of the radiated vibrational waves and create an electrical signal in response to the detected vibrations. This electrical signal is transmitted to processing unit 1205, which calculates the speed at which the vibrational waves traveled based on the time difference between the radiation and detection of the vibrational waves in the wellbore wall. Because the time at which the radiation began, the time at which the accelerometer detected the vibration, and the distance between vibrational wave source 1201' and accelerometer 1203 are known quantities, the speed at which the vibrational waves travel can be easily calculated by dividing the distance by the time difference. A suitable method of tracking the times of radiation and subsequent detection of the vibrational waves will be apparent to persons of ordinary skill in the art having the benefit of this disclosure. This process of measuring the speed at which the vibrational waves travel may be repeated as vibrational wave sources 1201' and 1202' are fired. Alternatively, two transmitters with two intervening accelerometers or hydrophones may be used to determine how much cleaning has been achieved. Standard methods for measuring borehole compensated speed or acoustic attenuation may be used to measure the cleaning effect. Empirical data can be used to correlate the acoustic attenuation of the vibrational waves with the effectiveness of the cleaning.

Therefore, the present invention is well adapted to carry out the objects and attain the ends and advantages mentioned, as well as those that are inherent therein. While the invention has been depicted and described, and is defined by reference to the exemplary embodiments of the invention, such a reference does not imply a limitation on the invention, and no such limitation is to be inferred. The invention is capable of considerable modification, alteration and equivalents in form and function, as will occur to those ordinarily skilled in the pertinent arts and having the benefit of this disclosure. The depicted and described embodiments of the invention are exemplary only and are not exhaustive of the

invention. Consequently, the invention is intended to be limited only by the spirit and scope of the appended claims, giving full cognizance to equivalents in all respects.

What is claimed is:

1. A method of reducing a skin effect in a downhole environment, comprising the step of radiating vibrational waves at a wellbore wall such that the vibrational waves have at least one direction of greatest vibrational energy transfer directed toward the wellbore wall, thereby reducing the skin effect.
2. The method of claim 1 wherein the radiating step comprises the step of positioning at least one vibrational wave source proximate the wellbore wall, wherein the at least one vibrational wave source has at least one direction of greatest energy transfer.
3. The method of claim 2 wherein the radiating step further comprises the steps of:
radiating vibrational waves from at least one vibrational wave source at the wellbore wall; and
flushing away any particles from the wellbore wall and from any structures or materials present at the wellbore wall with fluid flow.
4. The method of claim 3 wherein the step of radiating vibrational waves from at least one vibrational wave source and the step of flushing away any particles occur simultaneously.
5. The method of claim 2 wherein the radiating step further comprises the steps of:
radiating vibrational waves from a plurality of vibrational wave sources at the wellbore wall; and
flushing away any particles from the wellbore wall and from any structures or materials present at the wellbore wall with fluid flow.
6. The method of claim 5 wherein the step of radiating vibrational waves from a plurality of vibrational wave sources comprises the step of radiating vibrational waves in succession from each vibrational wave source.
7. The method of claim 5 wherein the step of radiating vibrational waves from a plurality of vibrational wave sources comprises the step of radiating vibrational waves simultaneously.
8. The method of claim 5 wherein the step of radiating vibrational waves from a plurality of vibrational wave sources comprises the step of radiating vibrational waves simultaneously and substantially continuously.
9. The method of claim 5 wherein the step of radiating vibrational waves from a plurality of vibrational wave sources comprises the step of radiating vibrational waves

- having at least two different frequencies from the plurality of vibrational wave sources.
10. The method of claim 5 wherein the step of radiating vibrational waves from a plurality of vibrational wave sources comprises selecting an order of activation and one or more periods of activation time for the plurality of vibrational wave sources to optimize usage of available power.
 11. The method of claim 2 wherein the at least one vibrational wave source is an acoustic wave source having at least one direction of greatest energy transfer.
 12. The method of claim 11 wherein the acoustic wave source is an oval-mode acoustic wave source having a plurality of directions of greatest energy transfer.
 13. The method of claim 2 further comprising the step of placing the at least one vibrational wave source in the well.
 14. The method of claim 2 further comprising the step of orienting the at least one vibrational wave source such that at least one direction of greatest vibrational energy transfer is directed toward the wellbore wall.
 15. The method of claim 2 further comprising the step of maintaining a standoff distance between the vibrational wave source and the wellbore wall.
 16. The method of claim 2 further comprising the step of optimizing reduction of the skin effect by creating a standing wave pattern between the vibrational wave source and the wellbore wall.
 17. The method of claim 2 further comprising the steps of:
 - detecting accretions of particles between the wellbore wall and the at least one vibrational wave source;
 - moving the at least one vibrational wave source away from the wellbore wall when a threshold level of accreted particles between the wellbore wall and the at least one vibrational wave source is detected;
 - radiating vibrational waves at the accreted particles; and
 - repositioning the at least one vibrational wave source proximate the wellbore wall.

18. The method of claim 2 further comprising the steps of:
 - monitoring whether the vibrational wave source transfers sufficient vibrational energy to the wellbore wall to reduce the skin effect; and
 - repositioning the vibrational wave source to optimally decrease the skin effect.
19. The method of claim 2 further comprising the steps of:
 - monitoring whether the vibrational wave source transfers sufficient vibrational energy to the wellbore wall to reduce the skin effect; and
 - altering the vibrational waves radiated by the vibrational wave source to optimally decrease the skin effect.
20. The method of claim 2 further comprising the step of determining how much the skin effect in the downhole environment has been reduced.
21. The method of claim 20 wherein the determining step comprises the steps of:
 - measuring a speed of sound for the downhole environment; and
 - comparing the measured speed of sound to a control speed of sound for a previously-cleaned wellbore wall.
22. The method of claim 20 wherein the determining step comprises the steps of:
 - measuring a speed of sound for the downhole environment; and
 - comparing the measured speed of sound to a control speed of sound measured before the vibrational waves were radiated at the wellbore wall.
23. The method of claim 20 wherein the determining step comprises the steps of:
 - measuring an acoustic attenuation value for the downhole environment; and
 - comparing the acoustic attenuation value to a control acoustic attenuation value for a previously-cleaned wellbore wall.
24. An apparatus for reducing a skin effect in a downhole environment, comprising:
 - at least one vibrational wave source having at least one direction of greatest vibrational energy transfer; and
 - a means for positioning the vibrational wave source proximate a wellbore wall.
25. The apparatus of claim 24 wherein the vibrational wave source comprises an oval-mode acoustic wave source

26. The apparatus of claim 24 further comprising a tool body, wherein the tool body houses a control for the vibrational wave source.
27. The apparatus of claim 24 further comprising a means for placing the vibrational wave source in a well.
28. The apparatus of claim 27 wherein the means for placing the vibrational wave source in the well comprises a wireline.
29. The apparatus of claim 27 wherein the means for placing the vibrational wave source in the well comprises coiled tubing.
30. The apparatus of claim 27 wherein the means for placing the vibrational wave source in the well comprises a well tractor.
31. The apparatus of claim 24 wherein the means for positioning the vibrational wave source proximate the wellbore wall is a decentralizer.
32. The apparatus of claim 31 wherein the decentralizer comprises a bowed spring member that pushes against a first side of the wellbore wall to position the vibrational wave source proximate a second, opposing side of the wellbore wall.
33. The apparatus of claim 31 further comprising a means for orienting the vibrational wave source such that at least one direction of greatest vibrational energy transfer is directed toward the wellbore wall.
34. The apparatus of claim 33 wherein the means for orienting the vibrational wave source comprises a rotator-resolver, wherein the rotator-resolver orients the vibrational wave source such that the at least one direction of greatest energy transfer is directed toward the wellbore wall.
35. The apparatus of claim 34 wherein the decentralizer comprises:
 - at least two articulated joints connecting the vibrational wave source to the rotator-resolver; and
 - at least one retractable arm, wherein the at least one retractable arm positions the vibrational wave source proximate the wellbore wall.
36. The apparatus of claim 34 wherein the decentralizer comprises:
 - a vibrational wave source pad attached to the rotator-resolver; and
 - at least one retractable arm, wherein the at least one retractable arm positions the vibrational wave source proximate the wellbore wall.

37. The apparatus of claim 24 further comprising at least one standoff contactor, wherein the at least one standoff contactor maintains a standoff distance between the vibrational wave source and the wellbore wall.
38. The apparatus of claim 37 wherein the at least one standoff contactor maintains a standoff distance chosen to enable creation of a standing wave pattern between the vibrational wave source and the wellbore wall.
39. The apparatus of claim 37 wherein the at least one standoff contactor includes contact points that contact the wellbore wall.
40. The apparatus of claim 39 further comprising an actuator that moves the vibrational wave source relative to the contact points to adjust the standoff distance.
41. The apparatus of claim 24 further comprising a means for detecting accretions of particles between the vibrational wave source and the wellbore wall.
42. The apparatus of claim 41 wherein the means for detecting accretions of particles comprises:
 - an accelerometer coupled to the vibrational wave source, wherein the accelerometer produces an electrical signal proportional to vibrations experienced by the vibrational wave source; and
 - a processing unit that monitors the electrical signal, wherein the processing unit can detect a signature vibration pattern indicating that particles have accreted.
43. The apparatus of claim 24 further comprising a means for monitoring energy transfer from the vibrational wave source to the wellbore wall.
44. The apparatus of claim 43 wherein the means for monitoring energy transfer comprises:
 - a hydrophone suitable for use in downhole environments, wherein the hydrophone converts vibrational energy traveling through a fluid present near the wellbore wall into an electrical signal; and
 - a processing unit, which monitors the electrical signal.
45. The apparatus of claim 43 wherein the means for monitoring energy transfer comprises:

an accelerometer connected to the vibrational wave source, wherein the accelerometer produces an electrical signal proportional to vibrations experienced by the vibrational wave source; and

a processing unit, which monitors the electrical signal.

46. The apparatus of claim 43 wherein the means for monitoring energy transfer from the vibrational wave source to the wellbore wall comprises:

an accelerometer that produces an electrical signal proportional to vibrations experienced by the wellbore wall, wherein the accelerometer is acoustically isolated from the vibrational wave source; and

a processing unit that measures the electrical signal.

47. The apparatus of claim 24 wherein the apparatus for reducing a skin effect in a downhole environment comprises a plurality of vibrational wave sources.

48. The apparatus of claim 47 wherein the plurality of vibrational wave sources are displaced axially with an axial gap between each vibrational wave source.

49. The apparatus of claim 47 wherein the plurality of vibrational wave sources are displaced circumferentially with a circumferential gap between each vibrational wave source.

50. The apparatus of claim 24 further comprising a means for determining how much the skin effect in the downhole environment has been reduced.

51. The apparatus of claim 50 wherein the means for determining how much the skin effect in the downhole environment has been reduced comprises:

an accelerometer contacting the wellbore wall, wherein the accelerometer is acoustically isolated from the vibrational wave source; and
a processing unit coupled to the accelerometer.

52. An apparatus for reducing a skin effect in a downhole environment, comprising:

a vibrational wave source having at least one direction of greatest vibrational energy transfer;

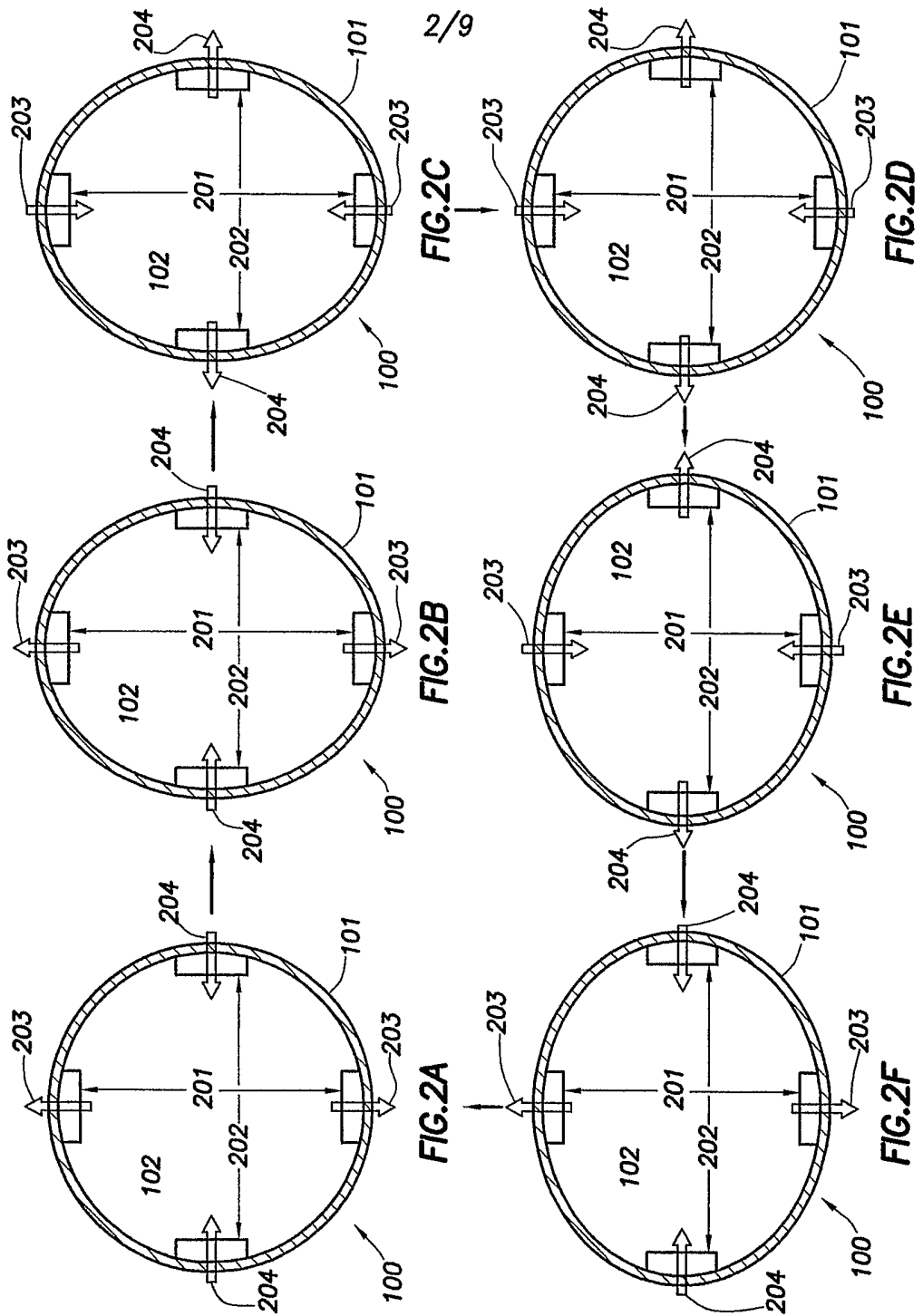
at least one standoff contactor, wherein the at least one standoff contactor maintains a standoff distance between the vibrational wave source and a wellbore wall;

a decentralizer, wherein the decentralizer positions the vibrational wave source proximate a wellbore wall; and

a wireline, wherein the wireline may be used to place the vibrational wave source in the well.

53. The apparatus of claim 52 further comprising a hydrophone.
54. The apparatus of claim 52 further comprising an accelerometer.
55. An apparatus for reducing a skin effect in a downhole environment, comprising:
 - a vibrational wave source having at least one direction of greatest vibrational energy transfer;
 - at least one standoff contactor, wherein the at least one standoff contactor maintains a standoff distance between the vibrational wave source and a wellbore wall;
 - a rotator-resolver, wherein the rotator-resolver orients the vibrational wave source such that the at least one direction of greatest vibrational energy transfer is directed toward the wellbore wall;
 - at least two articulated joints connecting the vibrational wave source to the rotator-resolver; and
 - at least one retractable arm, wherein the at least one retractable arm positions the vibrational wave source proximate the wellbore wall.
56. The apparatus of claim 55 further comprising a hydrophone.
57. The apparatus of claim 55 further comprising an accelerometer.
58. An apparatus for reducing a skin effect in a downhole environment, comprising:
 - a vibrational wave source having at least one direction of greatest vibrational energy transfer;
 - at least one standoff contactor, wherein the at least one standoff contactor maintains a standoff distance between the vibrational wave source and a wellbore wall;
 - a rotator-resolver, wherein the rotator-resolver orients the vibrational wave source such that the at least one direction of greatest vibrational energy transfer is directed toward the wellbore wall;
 - a vibrational wave source pad attached to the rotator-resolver; and
 - at least one retractable arm, wherein the at least one retractable arm positions the vibrational wave source proximate the wellbore wall.
59. The apparatus of claim 58 further comprising a hydrophone.

60. The apparatus of claim 58 further comprising an accelerometer.
61. An apparatus for reducing a skin effect in a downhole environment, comprising:
- a plurality of vibrational wave sources wherein each vibrational wave source has at least one direction of greatest vibrational energy transfer;
 - at least one standoff contactor, wherein the at least one standoff contactor maintains a standoff distance between the plurality of vibrational wave sources and a wellbore wall;
 - a rotator-resolver, wherein the rotator-resolver orients the plurality of vibrational wave sources such that the at least one direction of greatest vibrational energy transfer is directed toward the wellbore wall;
 - a vibrational wave source pad attached to the rotator-resolver; and
 - at least one retractable arm, wherein the at least one retractable arm positions the plurality of vibrational wave sources proximate the wellbore wall.
62. The apparatus of claim 61 further comprising a hydrophone.
63. The apparatus of claim 61 further comprising an accelerometer.



3/9

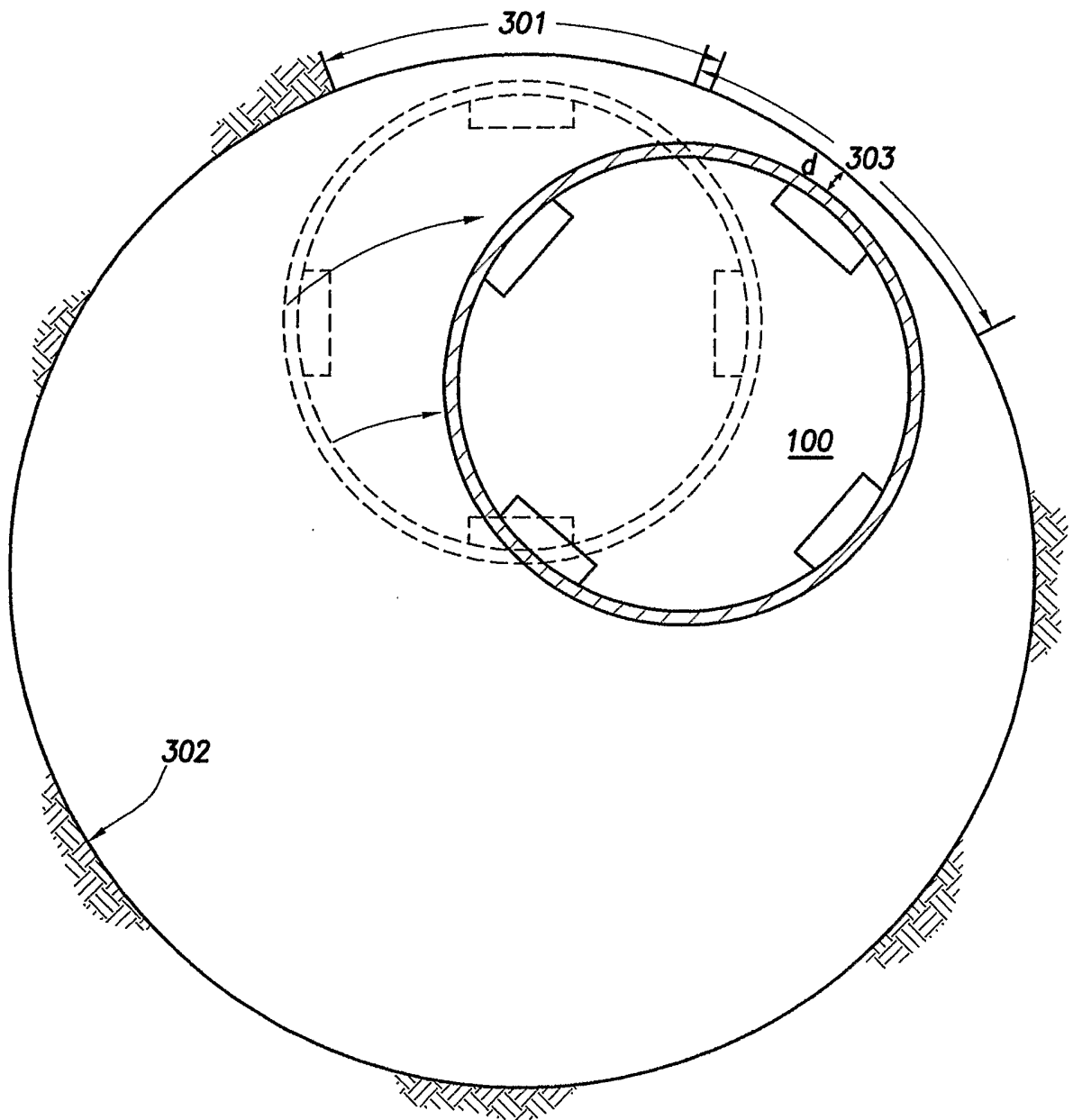


FIG. 3

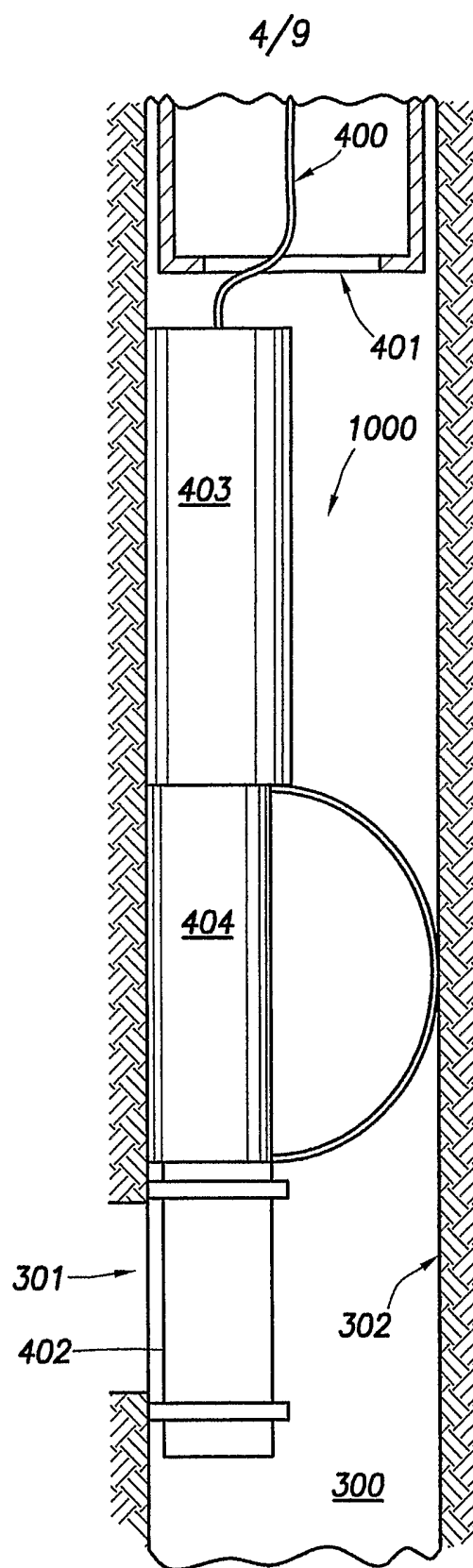


FIG.4

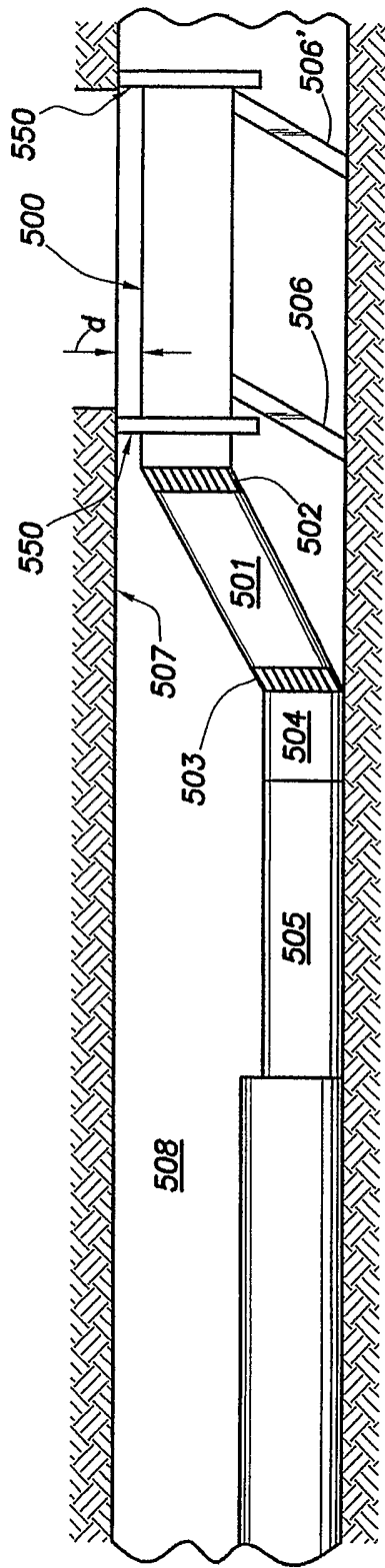


FIG. 5

5/9

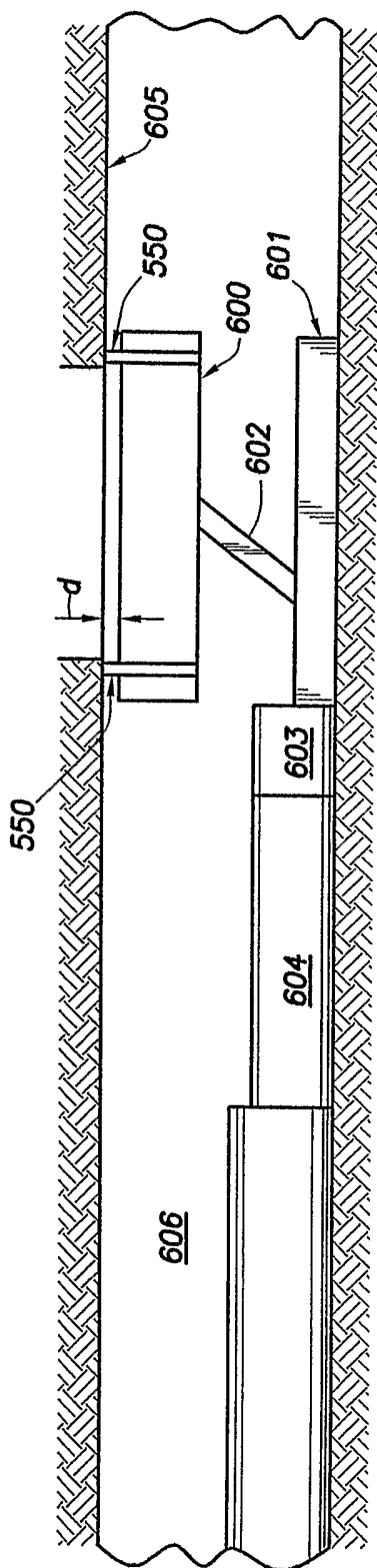


FIG. 6

6/9

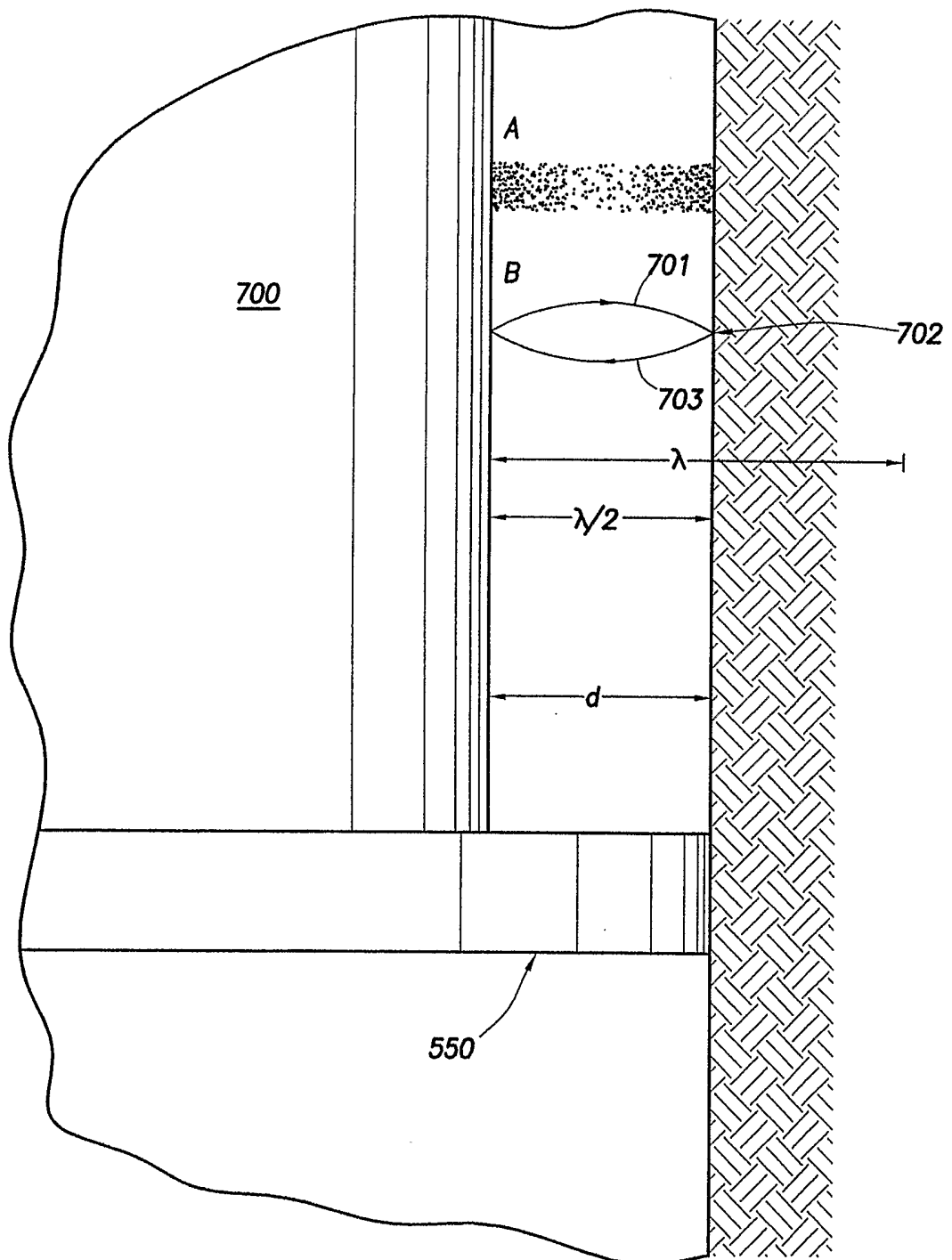


FIG.7

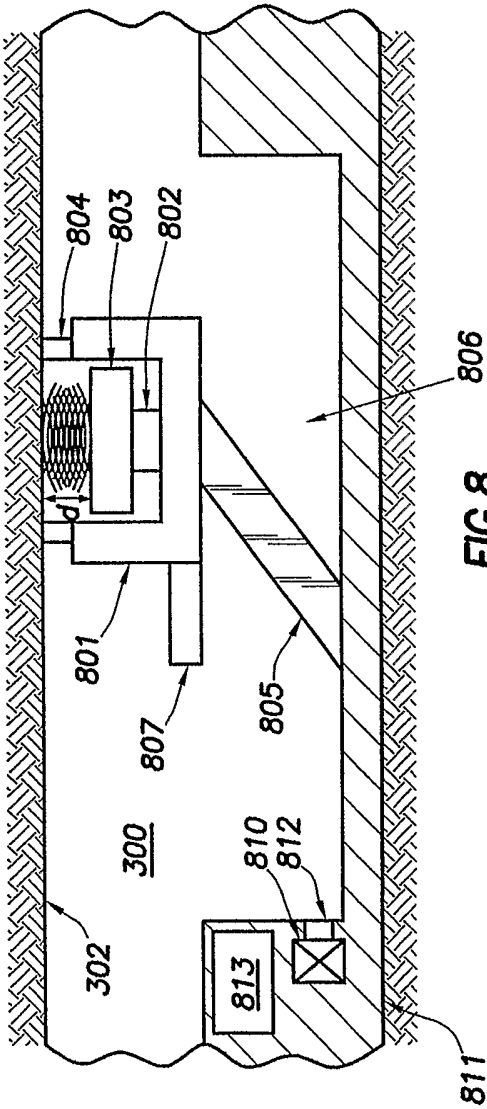


FIG. 8

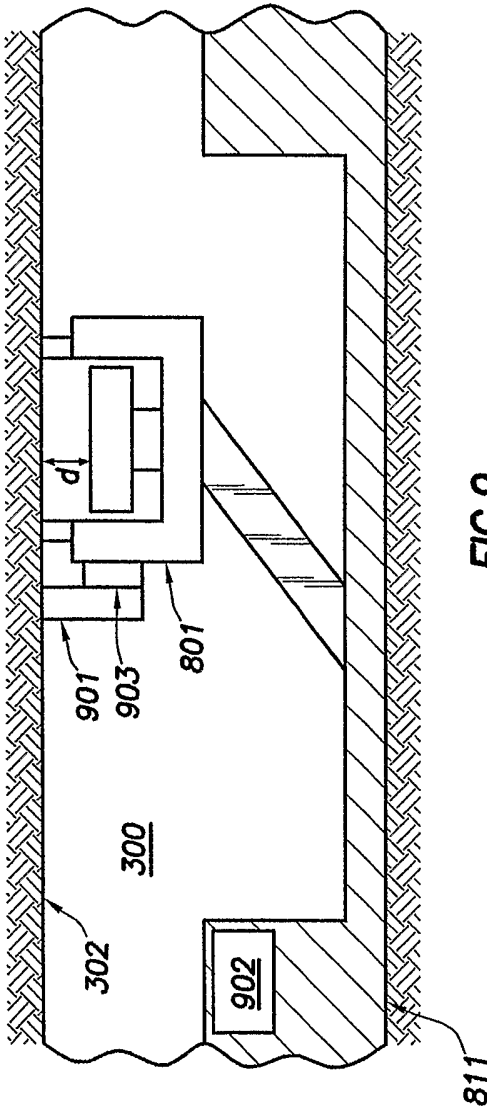


FIG. 9

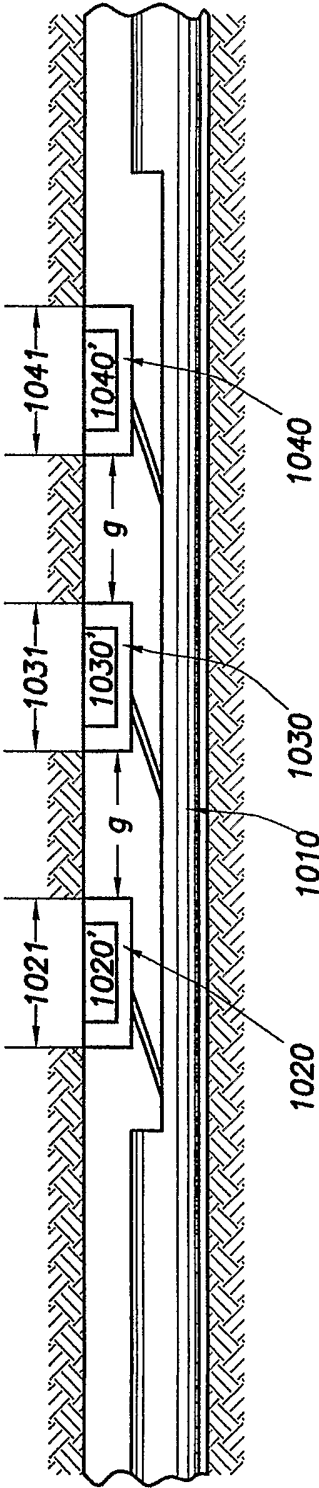


FIG. 10

8/9

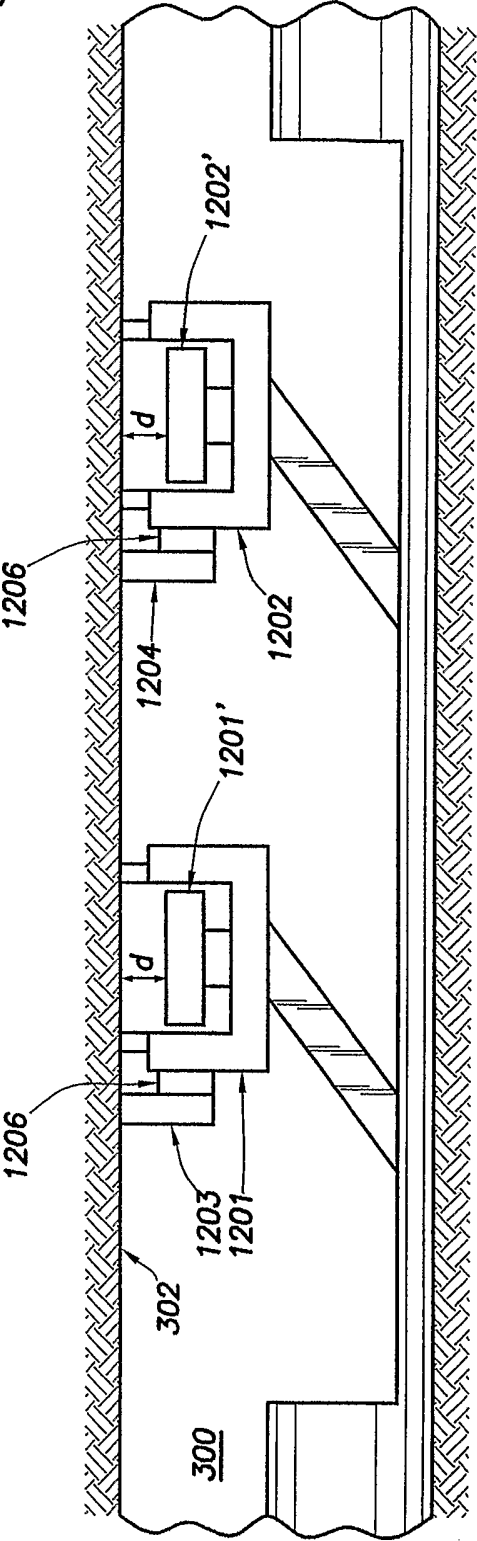


FIG. 12

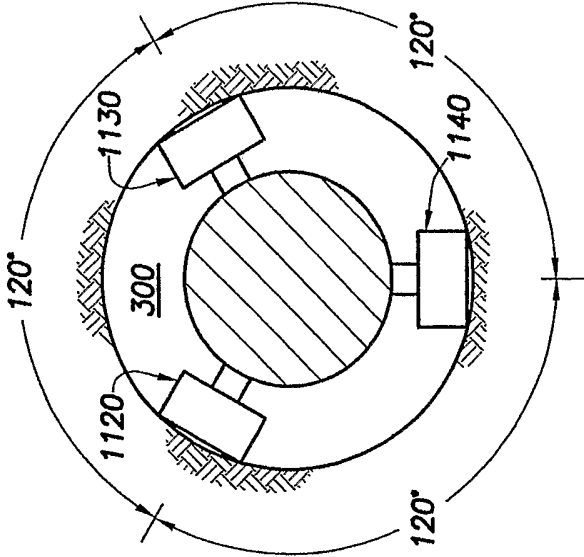


FIG. 11B

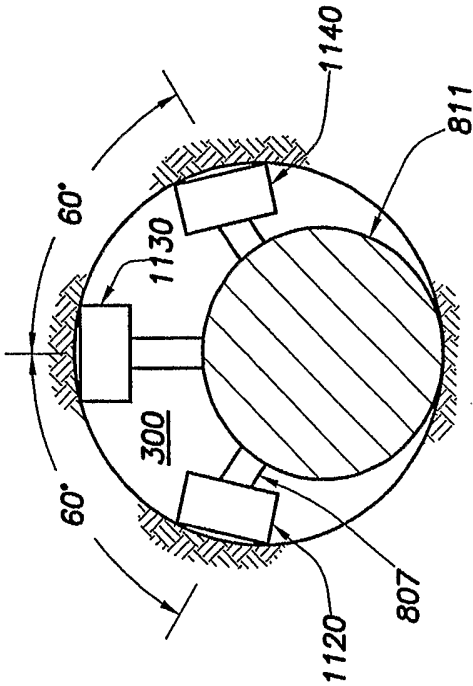


FIG. 11A

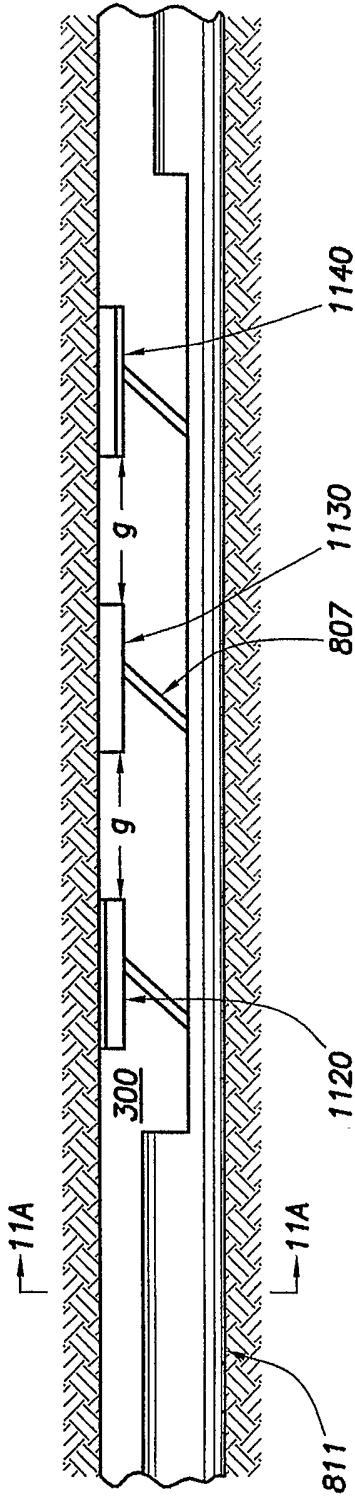


FIG. 11C

INTERNATIONAL SEARCH REPORT

International Application No

CT/GB2005/003579

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 E21B43/00 E21B28/00

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)
IPC 7 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 practical, search terms used)

EPO-Internal, WPI Data, TULSA

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 228 508 A (FACTEAU ET AL) 20 July 1993 (1993-07-20) column 1, lines 5-12 column 3, lines 24-34 column 3, line 62 - column 4, line 8 column 6, lines 3-34 column 6, lines 47-57 figures 1,3	1-11,13, 14, 18-20, 24,27, 29,47,49
Y	US 5 595 243 A (MAKI, JR. ET AL) 21 January 1997 (1997-01-21) the whole document	1-15, 24-29, 37,39, 47-49

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

1 November 2005

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INTERNATIONAL SEARCH REPORT

International Application No

T/GB2005/003579

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
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Y	WO 02/46572 A (HALLIBURTON ENERGY SERVICES, INC) 13 June 2002 (2002-06-13) the whole document	1-15, 24-29, 37,39, 47-49
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A	SUSAN JACKSON ET AL: "Advances in Seismic Stimulation Technologies" NETWORK NEWS (PETROLEUM TECHNOLOGY TRANSFER COUNCIL), 'Online! vol. 7, no. 2, June 2001 (2001-06), pages 1-16, XP002351809 Retrieved from the Internet: URL:http://www.pttc.org/news/vol7no2.pdf> 'retrieved on 2005-10-28! page 7 - page 9	1,24,52, 55,58,61
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