



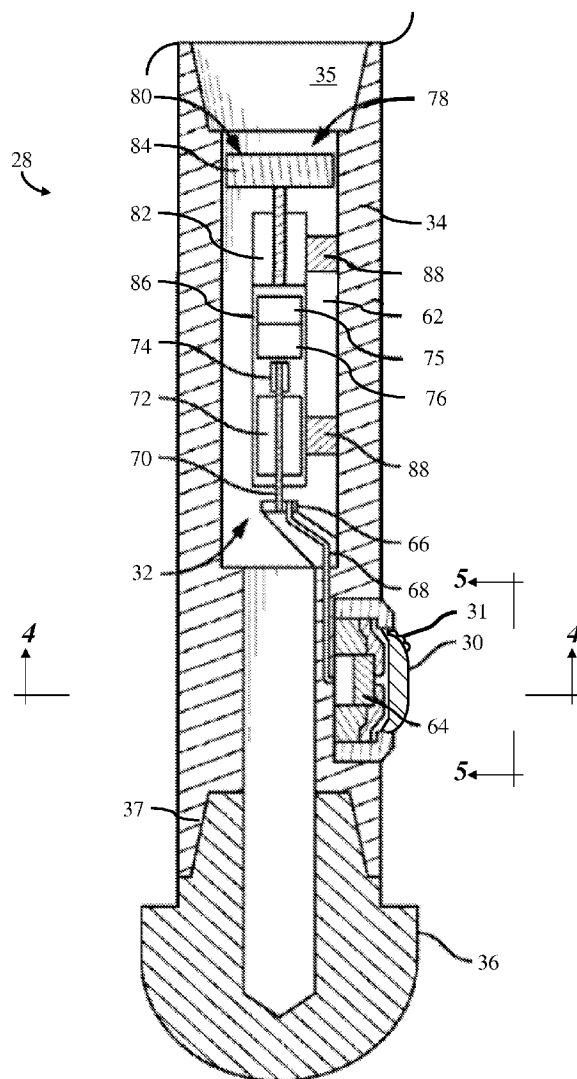
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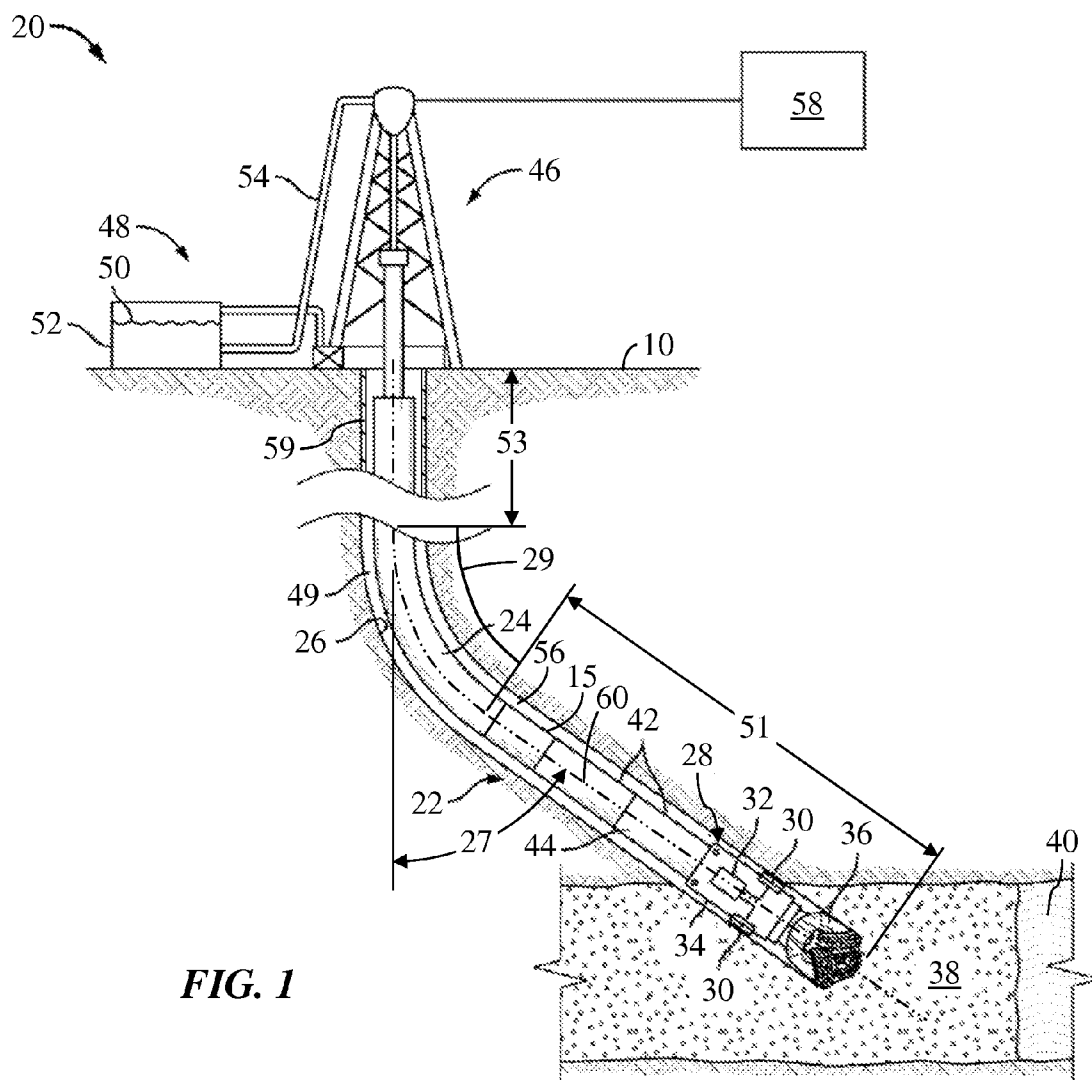
(19) **United States**(12) **Patent Application Publication**
Sugiura(10) **Pub. No.: US 2016/0084007 A1**(43) **Pub. Date: Mar. 24, 2016**(54) **BACK-REAMING ROTARY STEERING**(71) Applicant: **Schlumberger Technology Corporation**, Sugar Land, TX (US)(72) Inventor: **Junichi Sugiura**, Bristol (GB)(21) Appl. No.: **14/495,845**(22) Filed: **Sep. 24, 2014****Publication Classification**(51) **Int. Cl.**
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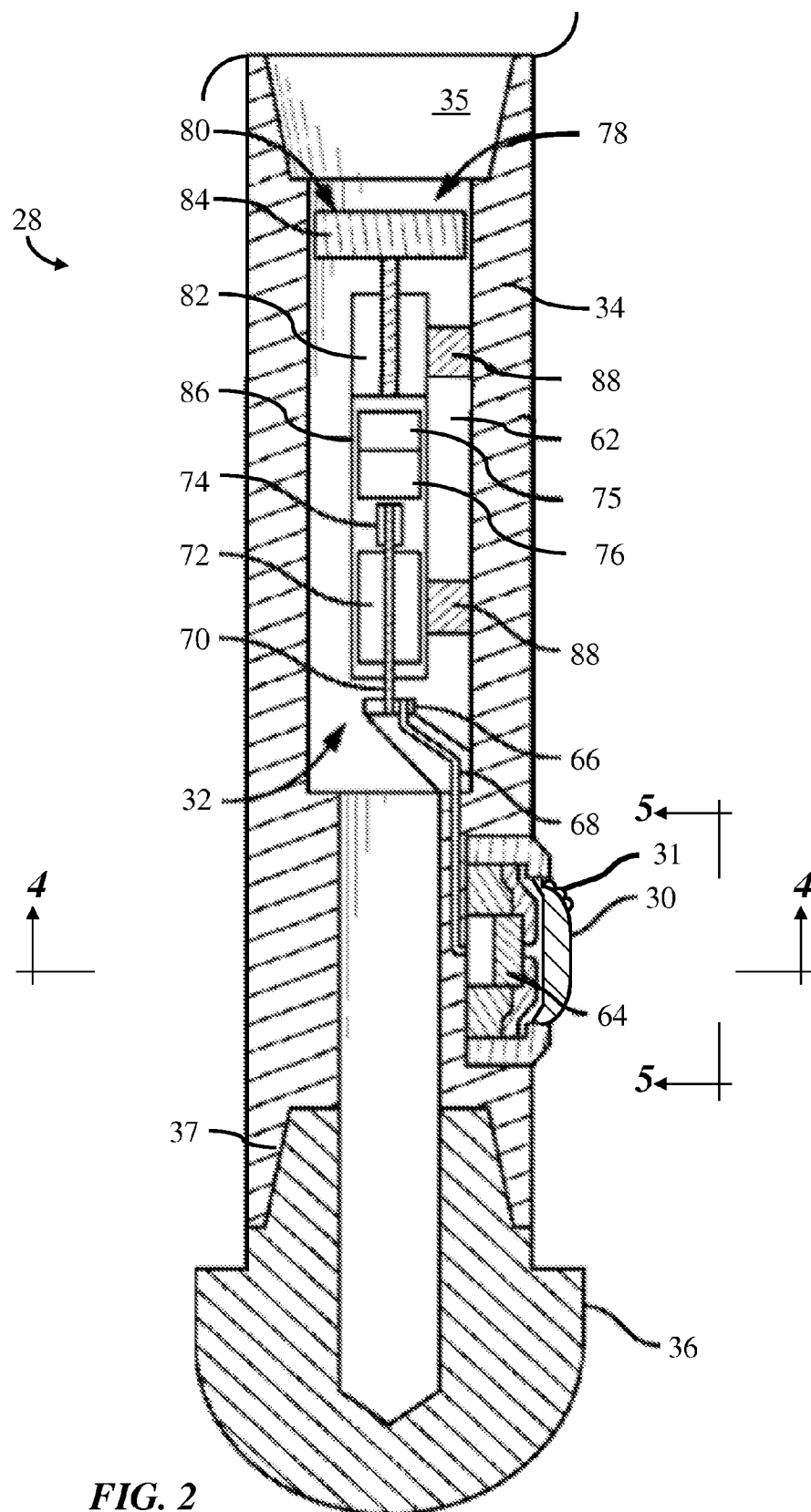
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ABSTRACT

A rotary steerable system (RSS) having multiple steering pads, a valve to sequentially actuate the plurality of steering pads, and a back-reaming bit formed by multiple cutting elements carried by each of the steering pads. While rotating the drill string, the RSS, and the drill bit, the valve and/or the controller are operated to sequentially actuate the steering pads to operatively urge the RSS and the drill bit away from a longitudinal axis of the wellbore, thus steering the wellbore drilling direction. Thereafter, while rotating the drill string, the RSS, and the drill bit, the valve and/or the controller are operated to simultaneously actuate each of the steering pads to operatively urge at least one of the cutting elements on each of the steering pads into contact with a sidewall of the wellbore, thus back-reaming the wellbore.







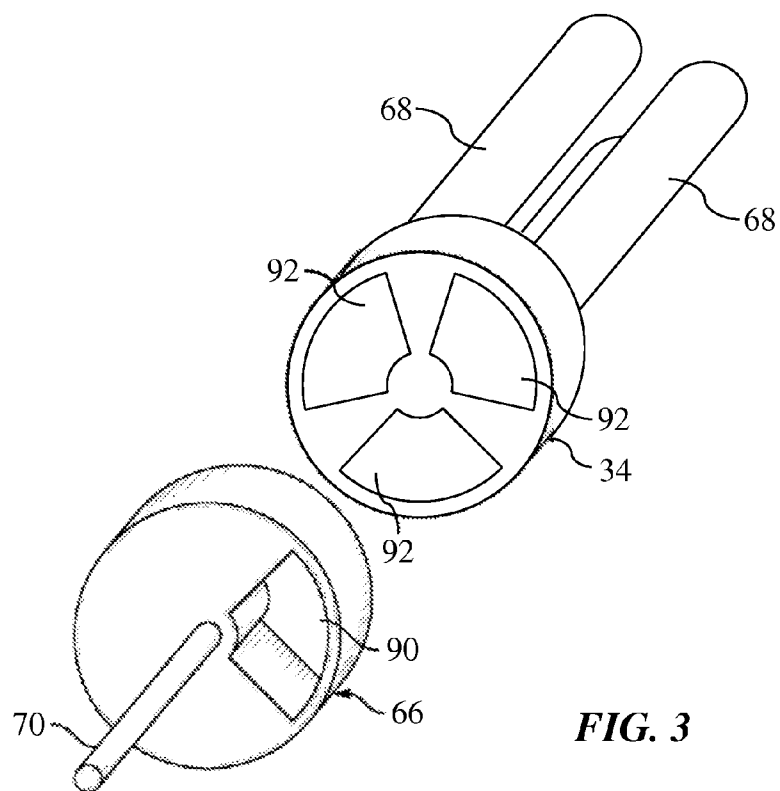


FIG. 3

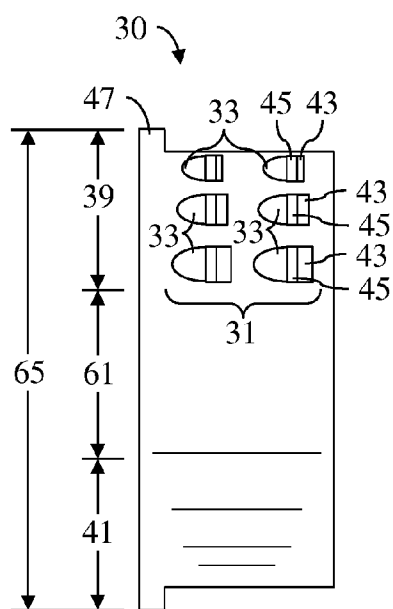


FIG. 5

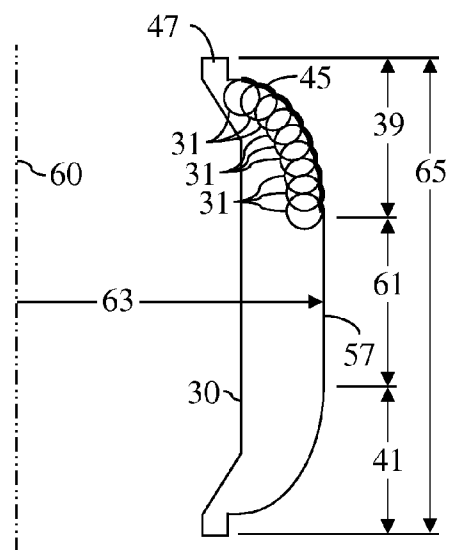


FIG. 6

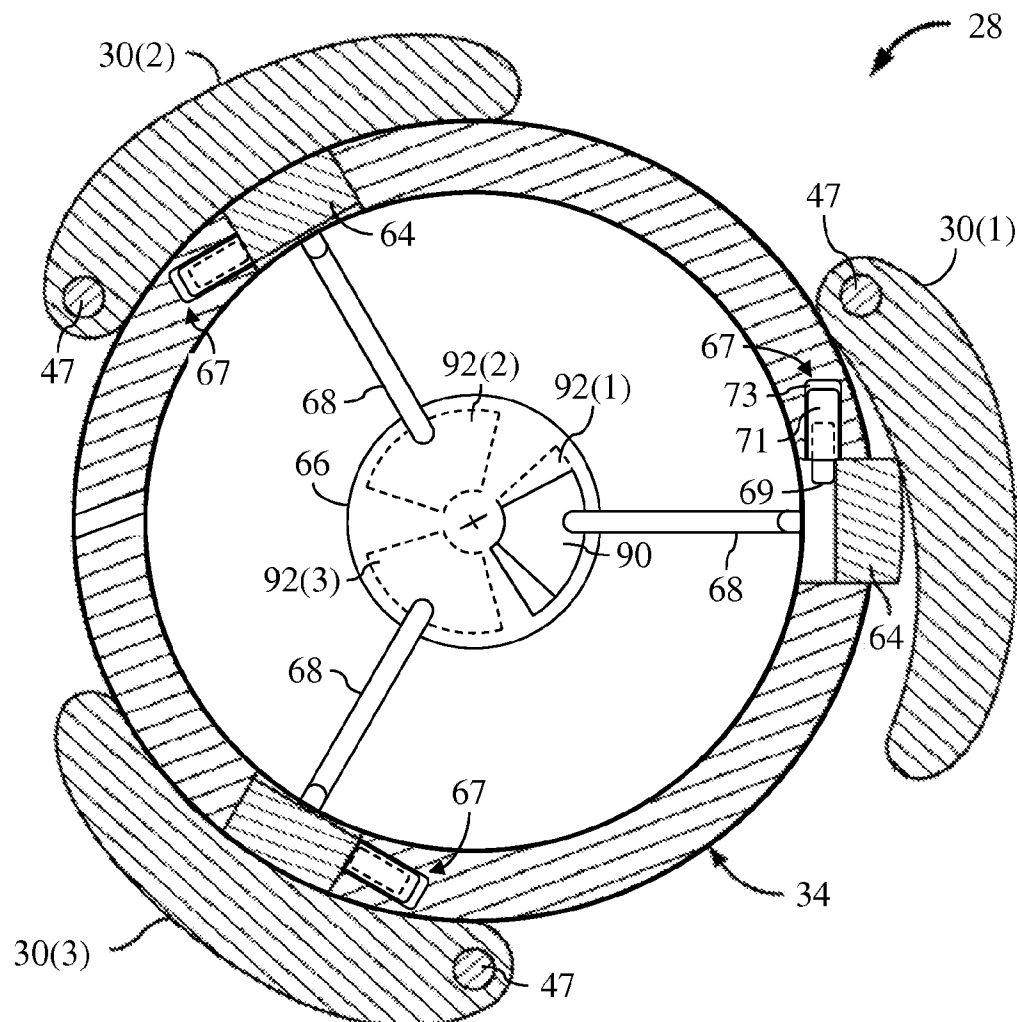


FIG. 4

FIG. 7

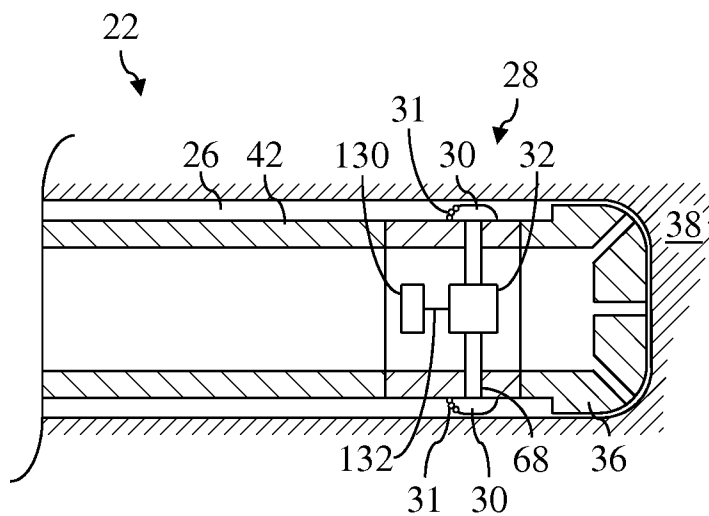


FIG. 8

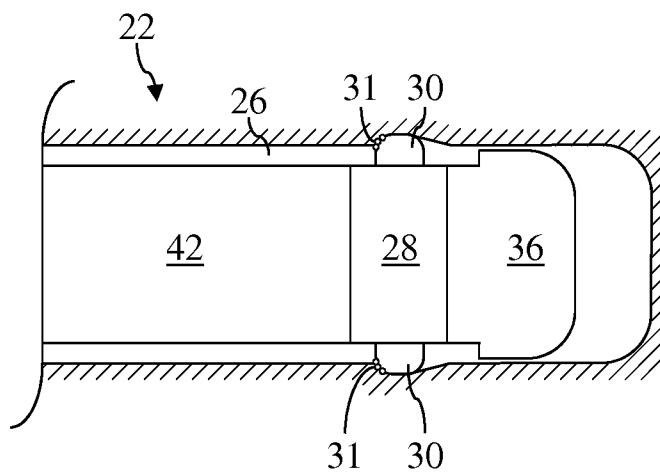
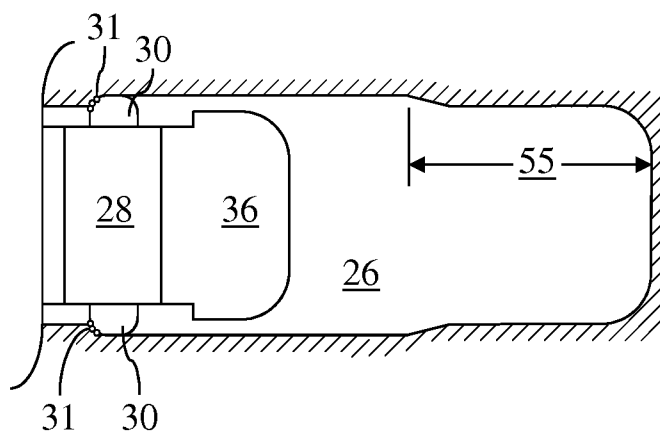
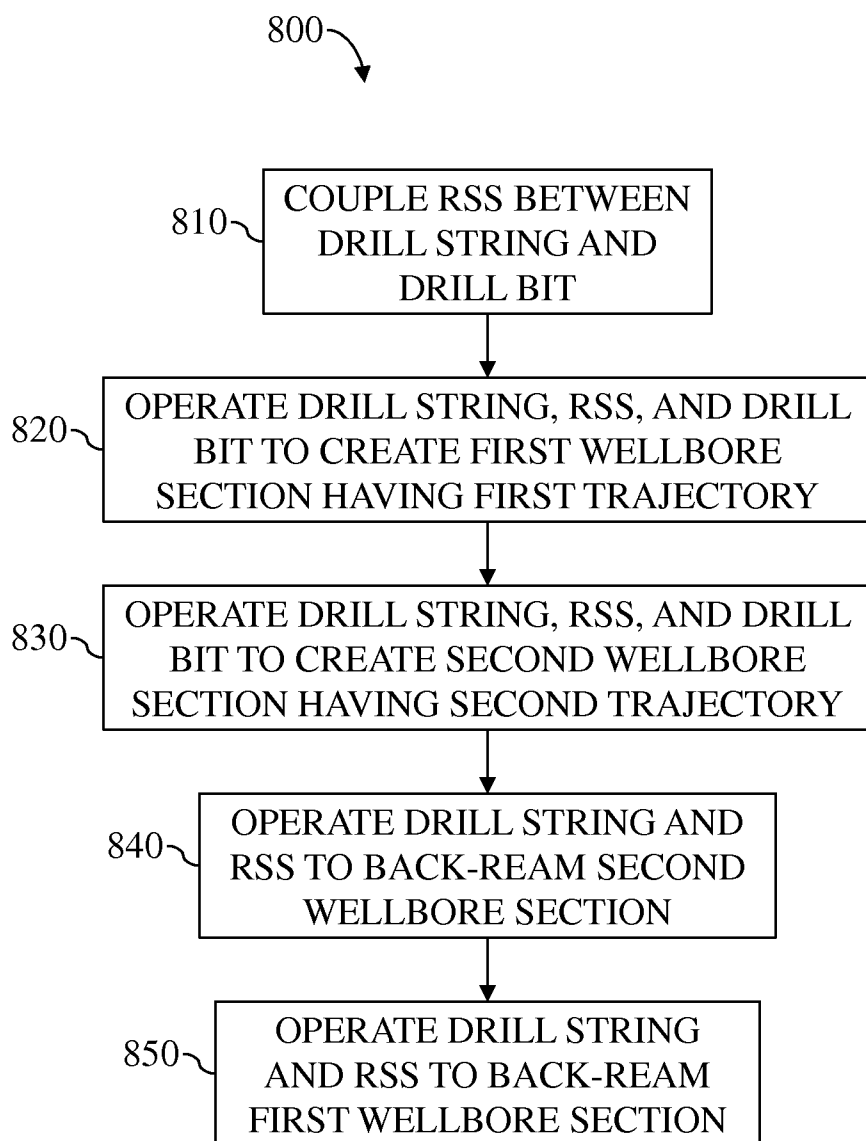
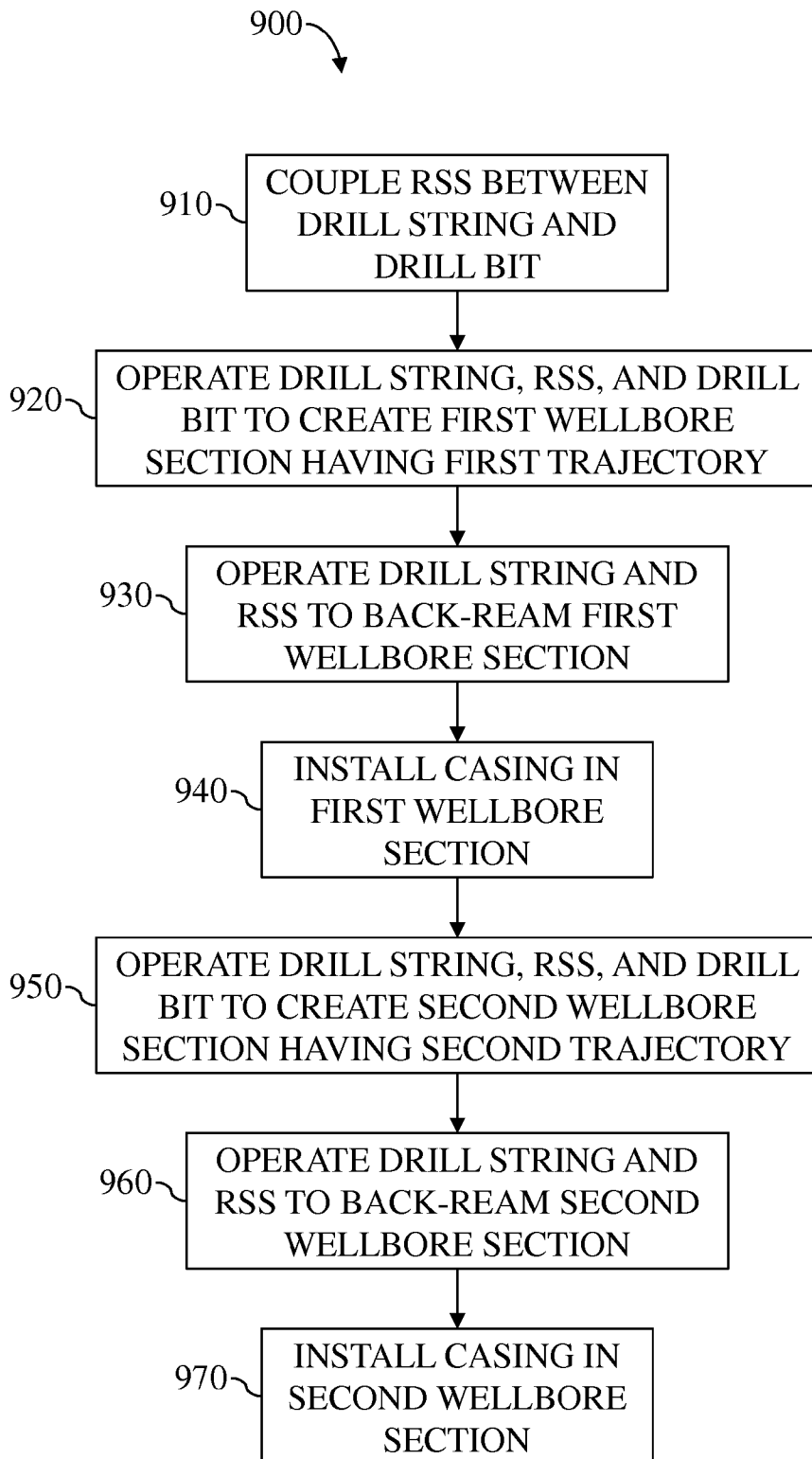


FIG. 9



**FIG. 10**

**FIG. 11**

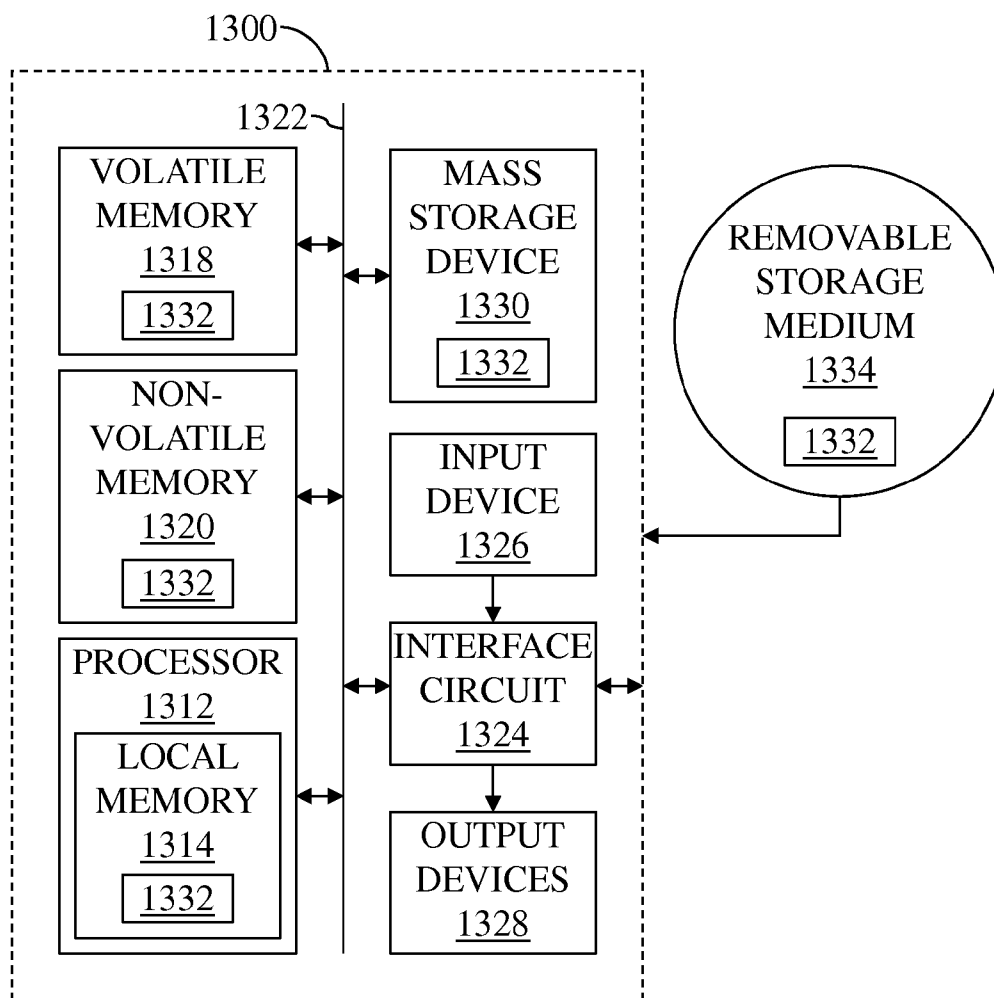


FIG. 12

BACK-REAMING ROTARY STEERING

BACKGROUND OF THE DISCLOSURE

[0001] Oil and gas wellbore drilling applications may utilize a rotary steerable system to control the direction of drilling during formation of the wellbore. A rotary steerable system may utilize a drill bit that is coupled with a drill collar and rotated to drill through the subterranean formation. One or more valves and control systems may control steering pads selectively actuated for radial deflection to control the direction of drilling. The valve(s) may be held at angular orientations with respect to the rotating drill collar to control the flow of fluid to the steering pads.

[0002] Such rotary steerable systems may be utilized in conjunction with a concentric reamer as part of a bottom-hole assembly (BHA). However, due at least in part to operational demands of other BHA components, the concentric reamer is located a considerable distance away from the drill bit. For example, once target depth (TD) is reached, the portion of the wellbore that has not been reamed by the concentric reamer—also known as the “rathole” portion of the wellbore located between the concentric reamer and the drill bit—may far exceed 100-200 feet (or 30-60 meters). Consequently, to open the rathole to an adequate size, the drill string, BHA, and drill bit are removed so that another tool/tool string can be run in-hole to ream the rathole. Of course, this procedure is time-intensive and expensive.

SUMMARY OF THE DISCLOSURE

[0003] The present disclosure introduces a system for drilling a wellbore. The system includes a rotary steerable system (RSS) coupled between a drill string collar and a drill bit. The RSS includes a housing, multiple steering pads, a valve, and a controller. The steering pads are circumferentially spaced around the housing, and are each actuatable to radially extend away from the housing independent of the other steering pads. At least one of the steering pads comprises a back-reaming bit. The valve and the controller are collectively operable to sequentially actuate the steering pads to substantially decentralize the RSS relative to the wellbore, and simultaneously actuate each steering pad to substantially centralize the RSS relative to the wellbore, thus urging the back-reaming bit into contact with a sidewall of the wellbore.

[0004] The present disclosure also introduces an apparatus that includes a drill string disposed within a wellbore that extends from a wellsite surface to a subterranean formation. The apparatus also includes a drill bit and a rotary steerable system (RSS) coupled between the drill string and the drill bit. The RSS includes multiple steering pads spaced circumferentially apart around a perimeter of the RSS, a valve operable to sequentially actuate the steering pads, and a back-reaming bit that includes multiple cutting elements. Each of the steering pads includes at least one of the cutting elements.

[0005] The present disclosure also introduces a method in which an apparatus is conveyed within a wellbore that extends from a wellsite surface to a subterranean formation. The apparatus includes a drill string, a drill bit, and a rotary steerable system (RSS) coupled between the drill string and the drill bit. The RSS includes multiple steering pads spaced circumferentially apart around a perimeter of the RSS. Each of the steering pads carries at least one of a set of cutting elements. The RSS also includes a valve operable for sequentially actuating the steering pads, as well as a controller. The

method also includes rotating the drill string, thereby rotating the RSS and the drill bit, while operating at least one of the valve and the controller to sequentially actuate the steering pads to operatively urge the RSS and the drill bit away from a longitudinal axis of the wellbore. The method also includes rotating the drill string, thereby rotating the RSS and the drill bit, while operating at least one of the valve and the controller to simultaneously actuate the steering pads to operatively urge at least one of the cutting elements on each of the steering pads into contact with a sidewall of the wellbore.

[0006] These and additional aspects of the present disclosure are set forth in the description that follows, and/or may be learned by a person having ordinary skill in the art by reading the materials herein and/or practicing the principles described herein. At least some aspects of the present disclosure may be achieved via means recited in the attached claims

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] The present disclosure is understood from the following detailed description when read with the accompanying figures. It is emphasized that, in accordance with the standard practice in the industry, various features are not drawn to scale. In fact, the dimensions of the various features may be arbitrarily increased or reduced for clarity of discussion.

[0008] FIG. 1 is a schematic view of at least a portion of apparatus according to one or more aspects of the present disclosure.

[0009] FIG. 2 is a sectional view of a portion of the apparatus shown in FIG. 1.

[0010] FIG. 3 is a perspective view of a portion of the apparatus shown in FIG. 2.

[0011] FIG. 4 is a sectional view of a portion of the apparatus shown in FIG. 2.

[0012] FIG. 5 is a side view of a portion of the apparatus shown in FIG. 2.

[0013] FIG. 6 is a schematic view of at least a portion of a bit profile according to one or more aspects of the present disclosure.

[0014] FIG. 7 is a schematic view of at least a portion of apparatus according to one or more aspects of the present disclosure.

[0015] FIG. 8 is a schematic view of at least the apparatus shown in FIG. 7 in a subsequent stage of operation according to one or more aspects of the present disclosure.

[0016] FIG. 9 is a schematic view of at least the apparatus shown in FIG. 8 in a subsequent stage of operation according to one or more aspects of the present disclosure.

[0017] FIG. 10 is a flow-chart diagram of at least a portion of a method according to one or more aspects of the present disclosure.

[0018] FIG. 11 is a flow-chart diagram of at least a portion of a method according to one or more aspects of the present disclosure.

[0019] FIG. 12 is a schematic view of at least a portion of apparatus according to one or more aspects of the present disclosure.

DETAILED DESCRIPTION

[0020] It is to be understood that the following disclosure provides many different embodiments, or examples, for implementing different features of various embodiments. Specific examples of components and arrangements are

described below to simplify the present disclosure. These are, of course, merely examples and are not intended to be limiting. In addition, the present disclosure may repeat reference numerals and/or letters in the various examples. This repetition is for simplicity and clarity, and does not in itself dictate a relationship between the various embodiments and/or configurations discussed. Moreover, the formation of a first feature over or on a second feature in the description that follows may include embodiments in which the first and second features are formed in direct contact, and may also include embodiments in which additional features may be formed interposing the first and second features, such that the first and second features may not be in direct contact.

[0021] FIG. 1 is a schematic view of at least a portion of a drilling system 20 according to one or more aspects of the present disclosure. The drilling system 20 may comprise a BHA 22, which may be coupled to and/or otherwise form a portion of a drill string 24, such as may be utilized to form a wellbore 26 via directional drilling. The drilling system 20 comprises a rotary steerable system (RSS) 28 comprising at least three radially actuated steering pads 30 (two of which being shown in FIG. 2). The steering pads 30 may be at substantially the same axial positions within the RSS 28, as shown in FIG. 1, or one or more of the steering pads 30 may be axially offset in a direction substantially parallel to a longitudinal axis 60 of the wellbore 26, the RSS 28, and/or the BHA 22. The steering pads 30 may be controlled by and/or in conjunction with a corresponding valve system 32. Each steering pad 30 is operable and/or otherwise actuated to act against a sidewall of the wellbore 26, thereby providing directional control. The valve system 32 may be positioned with the steering pads 30 within a drill collar and/or other housing 34 of the RSS 28. The housing 34 is directly or indirectly coupled with a drill bit 36, which is rotated to cut through a surrounding rock formation 38 that may be in or proximate a hydrocarbon bearing reservoir 40.

[0022] Depending on the environment and the operational parameters of the drilling operation, the drilling system 20 may comprise a variety of other features. For example, the drill string 24 may comprise additional drill collars 42 incorporating various drilling modules, such as logging-while-drilling (LWD) and/or measurement-while-drilling (MWD) modules 44, among others. The additional drill collars 42 may also or instead comprise one or more conventional reaming devices, such as a concentric under-reamer device 15 that may be located proximate an uphole end of the BHA 22.

[0023] Various surface systems also may form a part of or otherwise be utilized in conjunction with the drilling system 20. For example, a drilling rig 46 positioned above the wellbore 26 may be utilized in conjunction with a drilling fluid system 48 also positioned at the wellsite. The drilling fluid system 48 is operable to deliver drilling fluid (e.g., "mud") 50 from a drilling fluid tank 52, through tubing 54, and into the drill string 24. The drilling fluid 50 returns to the wellsite surface 10 through an annulus 56 between the drill string 24 and the sidewall of the wellbore 26. The return flow may be utilized to remove drill cuttings resulting from operation of drill bit 36. The drilling fluid 50 may also be utilized in conjunction with control of the RSS 28, such as in conjunction with control of the valve system 32 and/or the steering pads 30. For example, in addition to being conducted by an internal passage of the drill string 24 to the drill bit 36, the drilling fluid 50 may also be directed to or otherwise utilized to actuate the valve system 32 and/or the steering pads 30.

Actuation of the steering pads 30 may be controlled by and/or in conjunction with the valve system 32, thereby controlling the drilling direction.

[0024] The drilling system 20 may also comprise or otherwise be utilized in conjunction with a surface control system 58. The surface control system 58 may be utilized to control communication with the RSS 28 and/or other components of the BHA 22. For example, the surface control system 58 may receive data from downhole sensor systems and communicate commands to the RSS 28 to control actuation of the valve system 32, thereby controlling the drilling direction. Such control electronics and/or other control apparatus may also or instead be located downhole, perhaps integral to the RSS 28 and/or other component of the BHA 22, such as may operate in conjunction with one or more orientation sensors to control the drilling direction. The downhole control electronics may be operable to communicate with the surface control system 58, such as to receive directional commands and/or to relay information related to drilling and/or the formation 38 to the surface control system 58.

[0025] The RSS 28 may be conveyed and operated within the wellbore 26 via the drill string 24, as described above. However, the RSS 28 may also or instead be utilized in conjunction with a mud motor and/or turbine, such as described below and/or otherwise within the scope of the present disclosure. Other means of conveyance and/or fluid delivery, however, may also be utilized in implementations within the scope of the present disclosure, such as coiled tubing, casing, and/or other tubular means.

[0026] In at least one implementation within the scope of the present disclosure, the drilling system 20 does not comprise a reaming component and/or feature other than that which may be incorporated with the steering pads 30. That is, while conventional BHAs, drilling systems, and/or other apparatus utilized for directional drilling may include a concentric reamer and/or other type of reaming component and/or feature disposed at or near an uphole end of the BHA, the drilling system 20, the BHA 22, and the RSS 28 of the present disclosure may include no such reaming component and/or feature because, for example, the steering pads 30 may instead include reaming features and capabilities. Consequently, the drilling system 20, the BHA 22, and the RSS 28 of the present disclosure may be shorter, lighter, less expensive, and/or less complex (whether mechanically, operationally, or otherwise) relative to a conventional drilling system, BHA, and/or RSS.

[0027] FIG. 2 is a schematic view of a portion of the RSS 28 shown in FIG. 1. Referring to FIGS. 1 and 2, collectively, the housing 34 comprises and/or is coupled between the drill bit 36 and an MWD or LWD component 44 and/or other component 42 of the BHA 22. For example, the housing 34 may comprise upper and lower interfaces 35 and 37, respectively, which may couple the RSS 28 between the drill bit 36 and an adjacent drill collar and/or other component of the drill string 24. The interfaces 35 and 37 may be or comprise industry-standard fittings (such as box-pin connections), threads, and/or other coupling means. Such coupling may be in conjunction with one or more flexible and/or other intervening components.

[0028] A variety of RSS components are carried within internal passages 62 of the housing 34, such as may be operable for actuation of the steering pads 30. In the example implementation(s) described below, each steering pad 30 may be moved radially outward from the housing 34 by a corre-

sponding piston 64, which may be hydraulically actuated via drilling fluid 50 metered by the valve system 32. However, hydraulic oil and/or other fluids carried internally with the RSS 28 and/or another component of the BHA 22 or drill string 24 may also or instead be utilized to activate the steering pads 30.

[0029] The valve system 32 may comprise a rotational, spider, barrel, digital, and/or other type of valve 66. The valve 66 may be selectively rotated, digitally actuated, and/or otherwise actuated to direct a portion of the drilling fluid 50 from the corresponding internal passage 62 to selected ones of the steering pads 30. For example, one or more hydraulic lines 68 may communicate drilling fluid 50 from the valve 66 to act against the pistons 64 corresponding to the steering pads 30. The housing 34 and the drill bit 36 rotate during drilling of the wellbore 26, during which time the valve 66 may undergo a controlled, relative rotation to selectively deliver the drilling fluid 50 through the corresponding hydraulic line(s) 68 to the corresponding steering pads 30.

[0030] The valve 66 may be coupled to or otherwise driven by a shaft 70, which may be rotated by a corresponding electric and/or other type of motor 72. One or more encoders and/or other sensors 74 may be operatively engaged with the shaft 70 to monitor the angular orientation of the valve 66 relative to the housing 34. The valve system 32, and/or another component of the RSS 28, may also comprise one or more control devices 75, such as may comprise and/or operate in conjunction with a microprocessor and/or other controller 76. The control devices 75 and/or controllers 76 may each receive data from the sensors 74 and utilize such data and/or other data to control the motor 72. The motor 72 may thus be operable in controlling the angular positioning of the valve 66. One or more of the control devices 75 and/or controllers 76 may also communicate with the surface control system 58, such as to receive commands and/or relay data. One or more of the control devices 75 and/or controllers 76 may also comprise and/or operate in conjunction with one or more additional components, such as a direction and inclination package containing magnetometers and accelerometers (not shown).

[0031] Operational power may be provided to each control device 75, controller 76, motor 72, and/or other components of the RSS 28 via one or more power sources 78, such as may be or comprise batteries (not shown) and/or a turbine 80. Each turbine 80 may comprise and/or operate in conjunction with an alternator 82 driven by rotation of the turbine blades 84, such rotation being in response to the pressurized flow of the drilling fluid 50 through the internal passages 62.

[0032] One or more components of the valve system 32 and/or other component of the RSS 28 may be mounted within a pressure housing 86, such as may provide a level of protection against the relatively high pressure of the drilling fluid 50 and/or the rigors of the downhole environment. For example, the motor 72, sensors 74, control device(s) 75, controller(s) 76, and alternator 82 may be disposed within one or more pressure housings 86. Such pressure housing(s) 86 may be rigidly attached to the housing 34 via one or more centralizers and/or other members 88 disposed within the housing 34. Thus, the pressure housing(s) 86 may rotate with the housing 34.

[0033] Each steering pad 30 may be activated by differential pressure, such as between the inside and outside of the housing 34. When a steering pad 30 is activated, it pivots and/or otherwise moves away from the RSS 28, ultimately

pushing against the sidewall of the wellbore 26, thus deflecting the corresponding RSS 28 in the opposite direction, and thereby providing the RSS 28 with steering capability. As the housing 34 rotates, the valve 66 selectively operates to cause the extension and retraction of the corresponding steering pads 30 by alternately permitting and restricting the flow of drilling fluid 50 through the corresponding hydraulic line 68 to the corresponding piston 64 behind the steering pad 30. The steering pads 30 may thus rotate substantially simultaneously with the rotation/speed of the bit 36. However, in other implementations within the scope of the present disclosure, substantially non-rotating pads may also or instead be utilized.

[0034] FIG. 3 is an exploded view of an example implementation of at least a portion of the valve 66, depicting the valve 66 as being disengaged from the openings 92 leading to the hydraulic lines 68. Referring to FIGS. 1-3, collectively, the valve 66 comprises a valve opening 90 that is rotated via the shaft 70 in response to operation of the motor 72. The valve opening 90 may be selectively aligned with selected ports 92 that are part of and/or rotate with the housing 34. The ports 92 deliver drilling fluid 50 into hydraulic lines 68 for subsequent communication to the corresponding steering pads 30. In the example implementation depicted in FIGS. 1-3, the housing 34 comprises three ports 92 connected to three steering pads 30 via three hydraulic lines 68. However, other implementations within the scope of the present disclosure may include ports 92, steering pads 30, and/or hydraulic lines 68 in other numbers.

[0035] The valve opening 90 may be selectively aligned with individual ports 92 or combinations of adjacent ports 92. Each valve 66 is selectively rotated via the shaft 70 and the motor 72 to bring the valve opening 90 into alignment or out of alignment with a selected one or two ports 92.

[0036] FIG. 4 is a sectional view of the steering pads 30 carried by the housing 34, the valve 66, and related components. To facilitate an understanding of the angular relationship of the valve opening 90 with respect to the ports 92, the ports 92 have been labeled as a first port 92(1), a second port 92(2), and a third port 92(3), corresponding with a first steering pad 30(1), a second steering pad 30(2), and a third steering pad 30(3). The ports 92(1-3) and steering pads 30(1-3) are illustrated as positioned substantially at 0°, 120°, and 240°, respectively, around the housing 34. If the valve 66 and the housing 34 are both positioned at 0°, then the first port 92(1) is activated by the pressure of drilling fluid 50, but the second port 92(2) and third port 92(3) are not activated. If the angle of the housing 34 is substantially 0° while the angle of the valve 66 is substantially 60°, then the first port 92(1) and second port 92(2) are both activated.

[0037] The size of the valve opening 90 and each of the ports 92(1-3) may vary according to a variety of design parameters. For example, the valve opening 90 may have an angular width of about 90° and each of the ports 92(1-3) may have an angular width of about 80°. However, the angular widths and/or other dimensions of the valve opening 90 and the ports 92(1-3) may vary within the scope of the present disclosure. The number of openings 90, ports 92, and hydraulic lines 68 may also vary within the scope of the present disclosure, such as in accord with the number of steering pads 30 of the RSS 28 (which may also vary within the scope of the present disclosure).

[0038] Referring to FIGS. 1-4, collectively, and as described above, the valve system 32 may be operated to

sequentially actuate the steering pads 30 of the RSS 28 to urge the RSS 28 and, hence, the drill bit 36 away from a longitudinal axis 60 of the wellbore 26. Thus, after creating a substantially straight section 53 of the wellbore 26, the steering pads 30 of the RSS 28 may be operated to create a curved section 29 of the wellbore 26.

[0039] That is, a first steering pad 30 of the RSS 28 may be actuated to pivot about a pivot axis, such as may be defined by pivot pins 47, or otherwise extend away from the housing 34 of the RSS 28 and, thus, push against an azimuthal location 49 of the sidewall of the wellbore 26, thereby urging the RSS 28 in the opposite azimuthal direction (toward the right-hand side of the page in FIG. 1). The pivot pins 47 and/or the pivot axis may extend substantially parallel to the longitudinal axis 60 of the housing 34. At substantially the same time, the other steering pads are not actuated, but instead remain substantially retracted against the housing 34, thereby permitting the RSS 28 to be urged away from the longitudinal axis 60 of the wellbore 26. As the RSS 28 continues to rotate in the wellbore 26 (in response to rotation of the BHA 22 and drill string 24), the first actuated steering pad 30 rotates away from the azimuthal location 49 and retracts back toward the housing 34. Consequently, a second steering pad 30 is actuated to extend away from the housing 34 and, thus, push against the azimuthal location 49 of the sidewall of the wellbore 26, thereby continuing to urge the RSS 28 in the opposite azimuthal direction (toward the right-hand side of the page in FIG. 1). At substantially the same time, the other steering pads are not actuated, but instead remain substantially retracted against the housing 34, thereby permitting the RSS 28 to continue to be urged away from the longitudinal axis 60 of the wellbore 26. This process is repeated, with the steering pads 30 being sequentially actuated to push against the azimuthal location 49 of the sidewall of the wellbore 26 until the goal inclination 27 is achieved.

[0040] Thereafter, each of the steering pads 30 may be retracted to drill another, perhaps substantially straight section 51 of the wellbore 26. However, other control schemes by which the steering pads 30 may be controlled to achieve the substantially straight section 51 are also within the scope of the present disclosure, including implementations in which the steering pads 30 are intermittently actuated to account for minor fluctuations in direction, as well as implementations in which the steering pads 30 are actuated to maintain the wellbore 26 on a trajectory that is dependent upon a boundary and/or other feature of the subterranean formation 38 and/or reservoir 40 (e.g., geosteering).

[0041] FIG. 4 also depicts optional locking mechanisms 67 that may each be operable to lock and/or otherwise maintain a corresponding steering pad 30 in the extended position. For example, each locking mechanism 67 may comprise a locking member 69 movable between a locking position, as shown in FIG. 4 with respect to the extended steering pad 30(1), and a retracted position, as shown with respect to the non-extended steering pads 30(2) and 30(3). Each locking mechanism 67 may also comprise one or more solenoids, transducers, and/or other actuators 71 operable to move the corresponding locking member 69 between the locking and retracted positions. Each locking mechanism 67 may be secured within a corresponding recess 73 of the housing 34, whether via threaded engagement, adhesive, press/interference fit, and/or other means. Furthermore, means for locking the steering pads 30 in positions extended away from the housing 34 other than the example locking mechanisms 67

depicted in FIG. 4 are also within the scope of the present disclosure. Such implementations may comprise one or more ramps and/or other features that may be temporarily inserted between the steering pads 30 and the housing 34 to temporarily prevent radially-inward motion of the steering pads 30, and/or one or more features that may be temporarily positioned underneath the piston 64 to temporarily prevent radially-inward motion of the piston 64, among other examples.

[0042] FIG. 5 is a side view of the steering pad 30 shown in FIG. 2. The steering pad 30 shown in FIGS. 2 and 5 (and others) comprises a plurality of cutting elements 31 that, when considered collectively, constructively form a back-reaming bit. Each steering pad 30 of the RSS 28 may carry one or more of the cutting elements 31. In implementations in which more than one of the steering pads 30 each carries more than one of the cutting elements 31, the effective back-reaming bit may be formed by each of the cutting elements 31 carried by each of the steering pads 30, collectively.

[0043] Referring to FIGS. 2 and 5, collectively, each cutting element 31 may be mounted in a corresponding pocket, groove, and/or other recess 33 formed in the corresponding steering pad 30, although other means for assembling the cutting elements 31 to the steering pads 30 are also within the scope of the present disclosure. The recesses 33 may fix the cutting elements 31 in a particular location and orientation. However, one or more of the cutting elements 31 may instead be movable within a recess 33, such as in implementations in which the recess 33 may comprise a bearing and/or other similar element (not shown), such that the cutting element 31 may be coupled to or within the bearing element in a manner permitting the cutting element 31 to rotate relative to the steering pad 30.

[0044] The cutting elements 31 may be arranged, for example, in a regular or irregular grid pattern along or proximate an uphole end or portion 39 of a corresponding one of the steering pads 30. However, other arrangements are also within the scope of the present disclosure. Arranging the cutting elements 31 proximate the uphole end 39 of the corresponding steering pad 30 may reduce or prevent contact between the cutting elements 31 and the sidewall of the wellbore when the steering pad 30 is actuated for steering during directional drilling.

[0045] For example, referring to FIGS. 1-5, collectively, the back-reaming bit formed by the cutting elements 31 may be operable for back-reaming the wellbore 26 by simultaneously extending each of the steering pads 30 away from the housing 34 such that the cutting elements 31 contact the sidewall of the wellbore 26 while the RSS 28 is rotated and the drill string 24 is retracted from the wellbore 26. For example, in implementations in which the valve 66 is a rotary valve, the valve 66 may be disengaged by axial motion away from the openings of the hydraulic lines 68 leading to the steering pads 130 (such as in the disengaged arrangement shown in FIG. 3), and/or otherwise allowing drilling or other working fluid to simultaneously actuate each steering pad 30 substantially simultaneously. For example, one or more solenoids and/or other linear actuators of the RSS 28 may be operable for such disengagement of the valve 66. Similarly, in implementations in which the valve 66 is instead a digital valve, it may be digitally operated to simultaneously actuate each steering pad 30.

[0046] Moreover, by consolidating the cutting elements 31 in or near the uphole ends or portions 39 of the steering pads 30, inadvertent contact between the cutting elements 31 and

the sidewall of the wellbore 26 may be reduced or even eliminated during directional drilling. That is, during directional drilling, the steering pads 30 may not be simultaneously deployed, but are instead sequentially deployed in a manner causing bending of the RSS 28 relative to the wellbore 26. Such bending of the RSS 28 relative to the wellbore 26 induces contact between the downhole ends or portions 41 of the steering pads 30, but not the uphole ends or portions 39 of the steering pads 30, such that excessive material is not inadvertently removed from the sidewall of the wellbore 26 during the directional drilling.

[0047] The cutting elements 31 may each comprise a material having sufficient hardness to cut through the desired formation, cement, scale, and/or other material. For example, the cutting elements 31 may include a substantially cylindrical substrate 43 comprising tungsten carbide and/or other materials, and a cutting layer 45 comprising polycrystalline diamond, polycrystalline cubic boron nitride, other materials, or some combination of the foregoing. The cutting elements 31 may have a diameter ranging between about five millimeters and about 25 millimeters. However, other dimensions are also within the scope of the present disclosure. The cutting elements 31 may have the same or different dimensions relative to each other, including dimensions which may correspond to industry-standard sizes and/or otherwise.

[0048] FIG. 6 is a schematic view of the back-reaming bit as it would appear with the cutting elements 31 rotated into an aggregated profile view, depicting the positions of each cutting element 31 from each steering pad 30 as if each steering pad 30 was positioned at the same azimuth at the same time. Such view also depicts a cutting profile 45 (depicted in FIG. 6 by a heavy dark line) collectively formed by outermost edges of each cutting element 31. As described above, the cutting elements 31 may be located at or near the uphole end or portion 39 of the steering pads 30 and not at or near the downhole end or portion 41 of the steering pads 30. Consequently, when bending of the RSS 28 relative to the wellbore 26 during directional drilling induces contact between the downhole ends or portions 41 of the steering pads 30, but not the uphole ends or portions 39 of the steering pads 30, excessive material is not inadvertently removed from the sidewall of the wellbore 26.

[0049] For example, the uphole end or portion 39 of each steering pad 30 that comprises the cutting elements 31 may be the upper third (33%) of the axial length 65 of the steering pad 30, such that the lower two-thirds (67%) of each steering pad 30 does not comprise cutting elements 31. However, other dimensional ranges are also within the scope of the present disclosure.

[0050] The uphole end or portion 39 of each steering pad 30 that comprises the cutting elements 31 may also be limited to an upper, non-linear portion thereof. For example, as depicted in the example implementation shown in FIG. 6, the uphole end of portion 39 of each steering pad 30 may be curved, arcuate, slanted, tilted, beveled, and/or otherwise non-linear relative to a middle portion 61 of the steering pad 30. As also shown in FIG. 6, the downhole end or portion 41 of each steering pad 30 may also be curved, arcuate, slanted, tilted, beveled, and/or otherwise non-linear relative to the middle portion 61 of the steering pad 30.

[0051] The uphole end or portion 39 of each steering pad 30 that comprises the cutting elements 31 may also be that portion of the steering pad 30 that falls within a maximum radius 63 of the steering pad 30 when actuated. For example, the

middle portion 61 of the steering pad 30 may have the greatest radius 63 (with respect to other features of the steering pad 30) relative to the longitudinal axis 60 of the RSS 28, and the cutting elements 31 may not extend beyond that radius 63. That is, the cutting elements 31 may be flush with or recessed below a gauge surface 57 of the steering pad 30. In other implementations, however, the cutting elements 31 may extend slightly beyond the radius of the middle portion 61, such as to provide clearance for the middle portion 61 during back-reaming, and/or to account for wear of the cutting elements 31 after prolonged use. For example, the outermost edges of the cutting elements 31 may extend beyond the radius 63 of the middle portion 61 by less than about five millimeters.

[0052] Although not shown in the figures, the RSS 28 may comprise mechanical stops and/or other means limiting the maximum extent to which each steering pad 30 may be extended away from the housing 34. Such means may be adjustable and/or otherwise designed to match the effective back-reaming diameter of the back-reaming bit constructively formed by the collective cutting elements 31 with the reaming diameter of another reaming component of the BHA 22, such as the concentric under-reamer 15 shown in FIG. 1.

[0053] FIG. 7 is a simplified view of the RSS 28 shown in FIGS. 1-6, in which the valve system 32 and hydraulic lines 68 are simplified for clarity of the following description. As described above, the RSS 28 is at least indirectly coupled between the drill bit 36 and an MWD or LWD component 44 and/or other component 42 of the BHA 22, and comprises at least three steering pads 30 operable to sequentially actuate to “steer” the drill bit 36 during directional drilling. In the example implementation depicted in FIG. 7, the RSS 28 comprises four circumferentially spaced steering pads 30, comprising two sets each of two diametrically opposed steering pads 30 (although one set is hidden from view in FIG. 7). However, other implementations within the scope of the present disclosure may not comprise diametrically opposed steering pads 30, and may comprise more or less than four steering pads 30.

[0054] The example RSS 28 depicted in FIG. 7 also comprises a controller 130 operable to control the valve system 32 and/or other components of the RSS 28 and/or BHA 22. The controller 130 may comprise one or more instances of the control devices 75 and/or controllers 76 shown in FIG. 2. The controller 130 may be a single, discrete controller operable to control the valve system 32, such as via control/data lines 132 that may extend between the controller 130 and the valve system 32. Other implementations within the scope of the present disclosure, however, may utilize multiple controllers 130 each operable to control the valve system 32 and/or other components of the RSS 28 and/or BHA 22. Where multiple controllers are utilized, two or more (or each) of the controllers may be operably connected to a common communication bus. The common or “main” controller may be located somewhere else in the BHA 22, such as in an MWD, LWD, and/or other component 42/44 of the BHA 22. One or more of the controllers may also be operable to communicate with other tools of the BHA 22, such as the formation testing tools of MWD and/or LWD modules 44, via a common communication bus. For example, for closed-loop geosteering, the steering pad controller 130 may be operable in conjunction with formation data obtained by an LWD and/or MWD module 44 of the BHA 22, such as to reference a boundary and/or other feature of the formation 38 and/or reservoir 40 (FIG. 1) that

may be utilized to guide steering and, thus, the trajectory of the wellbore 26. Thus, among other possible implementations, the LWD and/or MWD module 44 may be utilized to obtain formation/reservoir image and/or other data that may then be utilized with the steering pad controller 130 to maintain the drilling path within a subterranean pay-zone of the formation 38 and/or reservoir 40 while elongating the wellbore 26.

[0055] The steering pad controller and/or other downhole controllers 130 of the RSS 28 and/or other portions of the BHA 22 may also communicate with surface equipment (e.g., the surface control system 58 in FIG. 1) in substantially real-time manner. For example, such communication may be via wired drill pipe, electromagnetic (EM) telemetry, and/or others. However, mud pulse telemetry is also contemplated.

[0056] FIG. 8 is a schematic exterior view of the apparatus shown in FIG. 7 after the controller 130 has operably controlled the valve system 32 to actuate the steering pads 30 of the RSS 28 to operatively urge at least one of the cutting elements 31 on at least one of the steering pads 30 into contact with the sidewall of the wellbore 26, while the drill string 24, BHA 22, RSS 28 and drill bit 36 continue to rotate. For example, such actuation of the steering pads 30 may include actuating each of the steering pads 30 simultaneously such that at least one of the cutting elements 31 on each of the steering pads 30 contacts the sidewall of the wellbore 26.

[0057] Thereafter, the drill string 24 may be retracted from the wellbore 26 while the drill string 24, BHA 22, RSS 28 and drill bit 36 continue to rotate, as shown in FIG. 9. During such rotating retraction, the controller 130 may operably control the valve system 32 to actuate the steering pads 30 to operatively maintain at least one of the cutting elements 31 on at least one of the steering pads 30 in contact with the sidewall of the wellbore 26. For example, such actuation of the steering pads 30 may include actuating each of the steering pads 30 simultaneously such that at least one of the cutting elements 31 on each of the steering pads 30 contacts the sidewall of the wellbore 26. Consequently, the cutting elements 31 contacting the sidewall of the wellbore 26 may be utilized for a back-reaming operation, whereby undulations, bumps, ridges, protrusions, and/or other irregularities of the surface of the wellbore 26 may be reduced, smoothed, and/or partially or substantially removed. Consequently, the length of the remaining rathole section 55 of the wellbore 26 may be substantially limited to axial separation between the end of the drill bit 36 and the cutting elements 31. For example, the rathole section 55 of the wellbore 26 may range between about one meter and about five meters, although other values are also within the scope of the present disclosure.

[0058] The dimensions of various features described above may vary across the myriad implementations within the scope of the present disclosure. One such dimension regards the outer diameter of the effective back-reaming bit constructively formed by the cutting elements 31 collectively carried by one or more of the steering pads 30 relative to the outer diameter of the BHA 22, the RSS 28, and/or the drill bit 36. For example, if the outer diameter of the BHA 22, the RSS 28, and/or the drill bit 36 is about 8.3 inches (or about 21.1 centimeters), then the outer diameter of the back-reaming bit may be about 9.3 inches (or about 23.6 centimeters). If the outer diameter of the BHA 22, the RSS 28, and/or the drill bit 36 is about 6.8 inches (or about 17.3 centimeters), then the outer diameter of the back-reaming bit may be about 7.7 inches (or about 19.6 centimeters). If the outer diameter of the

BHA 22, the RSS 28, and/or the drill bit 36 is about 4.8 inches (or about 12.2 centimeters), then the outer diameter of the back-reaming bit may be about 5.6 inches (or about 14.2 centimeters). The outer diameter of the back-reaming bit may be greater than the outer diameter of the BHA 22, the RSS 28, and/or the drill bit 36 by an amount ranging between about 0.5 inches (or about 1.3 centimeters) and about 1.5 inches (or about 3.8 centimeters). Of course, the dimensions described above are examples, and other dimensions are also within the scope of the present disclosure.

[0059] FIG. 10 is a flow-chart diagram of at least a portion of a method (800) according to one or more aspects of the present disclosure. The method (800) may be executed utilizing at least a portion of the apparatus shown in one or more of FIGS. 1-9, among other apparatus within the scope of the present disclosure. For example, the method (800) may comprise conveying such apparatus within a wellbore that extends from a wellsite surface to a subterranean formation, wherein the wellbore may be substantially similar to the wellbore 26 shown in one or more of FIGS. 1, 7, 8, and 9. Such apparatus may comprise or be utilized in conjunction with a drill string, a drill bit, and an RSS collectively coupled in series between the drill string and the drill bit, such as the drill string 24, the drill bit 36, and the RSS 28 shown in one or more of FIGS. 1-9. The method (800) may comprise coupling (810) the RSS, and perhaps other portions of a BHA (such as the BHA 22 shown in one or more of FIGS. 1-9), between the drill string and the drill bit.

[0060] As described above, the RSS may comprise at least three steering pads spaced circumferentially apart around a perimeter of the RSS, a valve operable to sequentially actuate the steering pads, a controller operable to control the valve, and a plurality of cutting elements carried by one or more of the steering pads. The steering pads may be substantially similar to those shown in one or more of FIGS. 1, 2, and 4-8. The rotational valve may be substantially similar to at least a portion of the valve systems 32 shown in one or more of FIGS. 1-9. The controller may be substantially similar to the surface control system 58 shown in FIG. 1, the controller 75 and/or the processor 76 shown in FIG. 2, and/or the controller 130 shown in FIG. 7. The cutting elements may be substantially similar to those shown in one or more of FIGS. 2 and 5-9.

[0061] The method (800) comprises operating (820) the drill string, the RSS, and the drill bit to create a first wellbore section having a first trajectory. For example, such operation (820) may comprise rotating the drill string, and thereby rotating the RSS and the drill bit, while operating at least one of the valve and the controller to sequentially and/or otherwise actuate the steering pads to operatively urge the RSS and drill bit relative to a longitudinal axis of the wellbore to achieve the intended trajectory of the first wellbore section. The first wellbore section may be substantially similar to the wellbore section 53 or the wellbore section 29 shown in FIG. 1.

[0062] The method (800) also comprises operating (830) the drill string, the RSS, and the drill bit to create a second wellbore section having a second trajectory. For example, such operation (830) may comprise rotating the drill string, and thereby rotating the RSS and the drill bit, while operating at least one of the valve and the controller to sequentially and/or otherwise actuate the steering pads to operatively urge the RSS and drill bit relative to a longitudinal axis of the wellbore to achieve the intended trajectory of the second wellbore section. The second wellbore section may be sub-

stantially similar to the wellbore section 29 or the wellbore section 51 shown in FIG. 1. For example, if the first operation (820) resulted in the substantially straight wellbore section 53 shown in FIG. 1, then the second operation (830) may result in the curved wellbore section 29 shown in FIG. 1. Similarly, if the first operation (820) resulted in the curved wellbore section 29 shown in FIG. 1, then the second operation (830) may result in the substantially straight wellbore section 51 shown in FIG. 1. However, as described above, either or both of the first and second wellbore sections may have trajectories other than as shown in FIG. 1, including trajectories following, paralleling, and/or otherwise corresponding to a boundary and/or other feature of a subterranean formation or reservoir (e.g., geosteering), among other examples within the scope of the present disclosure.

[0063] Rotating the drill string while operating at least one of the valve and the controller to sequentially actuate the steering pads to operatively urge the RSS and the drill bit relative to the longitudinal axis of the wellbore may comprise rotating the drill string while operating at least one of the valve and the controller to sequentially actuate the steering pads to operatively urge the RSS and the drill bit in a first azimuthal direction away from the longitudinal axis of the wellbore. In such implementations, among others, the method (800) may also comprise rotating the drill string while operating at least one of the valve and the controller to sequentially actuate the steering pads to operatively urge the RSS and the drill bit in a second azimuthal direction away from the longitudinal axis of the wellbore. For example, the first and second azimuthal directions may differ by at least about twenty degrees. The first and second azimuthal directions may be substantially opposite each other, such as in implementations in which the first and second azimuthal directions differ by an amount ranging between about 170 degrees and about 190 degrees.

[0064] The method (800) also comprises operating (840) the drill string and the RSS to back-ream the second wellbore section. For example, such operation (840) may comprise rotating the drill string, and thereby rotating the RSS and the drill bit, while operating at least one of the valve and the controller to simultaneously actuate each of the steering pads to operatively urge at least one of the cutting elements on at least one of the steering pads into contact with the sidewall of the wellbore. The operation (840) may comprise operating at least one of the valve and the controller to simultaneously actuate each of the steering pads to operatively urge at least one of the cutting elements on each of the steering pads into substantially simultaneous contact with the sidewall of the wellbore. The operation (840) may also comprise locking one or more of the steering pads in the extended position, such as via operation of the locking mechanisms 67 shown in FIG. 4 and/or other locking means, and may also comprise immediately or otherwise thereafter unlocking the steering pads to permit the steering pads to again retract towards the RSS housing. The resulting, back-reamed wellbore may resemble that shown in FIG. 9, in which the rat-hole section of the wellbore is limited to the distance by which the drill bit and the cutting elements are axially separated.

[0065] The method (800) also comprises operating (850) the drill string and the RSS to back-ream the first wellbore section. For example, such operation (850) may comprise rotating the drill string, and thereby rotating the RSS and the drill bit, while operating at least one of the valve and the controller to simultaneously actuate each of the steering pads

to operatively urge at least one of the cutting elements on each of the steering pads into contact with the sidewall of the wellbore. The operation (850) may also comprise locking one or more of the steering pads in the extended position, such as via operation of the locking mechanisms 67 shown in FIG. 4 and/or other locking means, and may also comprise immediately or otherwise thereafter unlocking the steering pads to permit the steering pads to again retract towards the RSS housing.

[0066] FIG. 11 is a flow-chart diagram of at least a portion of a method (900) according to one or more aspects of the present disclosure. The method (900) may be executed utilizing at least a portion of the apparatus shown in one or more of FIGS. 1-9, among other apparatus within the scope of the present disclosure. For example, the method (900) may comprise conveying such apparatus within a wellbore that extends from a wellsite surface to a subterranean formation, wherein the wellbore may be substantially similar to the wellbore 26 shown in one or more of FIGS. 1, 7, 8, and 9. Such apparatus may comprise or be utilized in conjunction with a drill string, a drill bit, and an RSS collectively coupled in series between the drill string and the drill bit, such as the drill string 24, the drill bit 36, and the RSS 28 shown in one or more of FIGS. 1-9. The method (900) may comprise coupling (910) the RSS, and perhaps other portions of a BHA (such as the BHA shown in one or more of FIGS. 1-9), between the drill string and the drill bit.

[0067] As described above, the RSS may comprise at least three steering pads spaced circumferentially apart around a perimeter of the RSS, a valve operable to sequentially actuate the steering pads, a controller operable to control the valve, and a plurality of cutting elements carried by one or more of the steering pads. The steering pads may be substantially similar to those shown in one or more of FIGS. 1, 2, and 4-9. The rotational valve may be substantially similar to at least a portion of the valve systems 32 shown in one or more of FIGS. 1-9. The controller may be substantially similar to the surface control system 58 shown in FIG. 1, the controller 75 and/or the processor 76 shown in FIG. 2, and/or the controller 130 shown in FIG. 7. The cutting elements may be substantially similar to those shown in one or more of FIGS. 2 and 5-9.

[0068] The method (900) comprises operating (920) the drill string, the RSS, and the drill bit to create a first wellbore section having a first trajectory. For example, such operation (920) may comprise rotating the drill string, and thereby rotating the RSS and the drill bit, while operating at least one of the valve and the controller to sequentially and/or otherwise actuate the steering pads to operatively urge the RSS and drill bit relative to a longitudinal axis of the wellbore to achieve the intended trajectory of the first wellbore section. The first wellbore section may be substantially similar to the wellbore section 53 or the wellbore section 29 shown in FIG. 1.

[0069] The method (900) also comprises operating (930) the drill string and the RSS to back-ream the first wellbore section. For example, such operation (930) may comprise rotating the drill string, and thereby rotating the RSS and the drill bit, while operating at least one of the valve and the controller to simultaneously actuate each of the steering pads to operatively urge at least one of the cutting elements on at least one of the steering pads into contact with the sidewall of the wellbore. The operation (930) may comprise operating at least one of the valve and the controller to simultaneously actuate each of the steering pads to operatively urge at least

one of the cutting elements on each of the steering pads into substantially simultaneous contact with the sidewall of the wellbore. The operation (930) may also comprise locking one or more of the steering pads in the extended position, such as via operation of the locking mechanisms 67 shown in FIG. 4 and/or other locking means, and may also comprise immediately or otherwise thereafter unlocking the steering pads to permit the steering pads to again retract towards the RSS housing.

[0070] The method (900) may also comprise installing (940) a casing in the first wellbore section after the back-reaming operation (930). For example, the operation (920) performed to create the first wellbore section may result in the wellbore section 53 shown in FIG. 1, and the installed (940) casing may be substantially similar to the casing 59 shown in FIG. 1. Installing (940) the casing may comprise positioning casing in the back-reamed first wellbore section, and then securing the positioned casing in place by cement and/or coupling the casing to previously installed casing, among other installation methods within the scope of the present disclosure. Installing (940) the casing in the back-reamed first wellbore section may be performed with or without removing the drill string from the wellbore.

[0071] The method (900) also comprises operating (950) the drill string, the RSS, and the drill bit to create a second wellbore section having a second trajectory. For example, such operation (950) may comprise rotating the drill string, and thereby rotating the RSS and the drill bit, while operating at least one of the valve and the controller to sequentially and/or otherwise actuate the steering pads to operatively urge the RSS and drill bit relative to a longitudinal axis of the wellbore to achieve the intended trajectory of the second wellbore section. The second wellbore section may be substantially similar to the wellbore section 29 or the wellbore section 51 shown in FIG. 1. For example, if the first operation (920) resulted in the substantially straight wellbore section 53 shown in FIG. 1, then the second operation (950) may result in the curved wellbore section 29 shown in FIG. 1. Similarly, if the first operation (920) resulted in the curved wellbore section 29 shown in FIG. 1, then the second operation (950) may result in the substantially straight wellbore section 51 shown in FIG. 1. However, as described above, either or both of the first and second wellbore sections may have trajectories other than as shown in FIG. 1, including trajectories following, paralleling, and/or otherwise corresponding to a boundary and/or other feature of a subterranean formation or reservoir (e.g., geosteering), among other examples within the scope of the present disclosure.

[0072] The method (900) also comprises operating (960) the drill string and the RSS to back-ream the second wellbore section. For example, such operation (960) may comprise rotating the drill string, and thereby rotating the RSS and the drill bit, while operating at least one of the valve and the controller to simultaneously actuate each of the steering pads to operatively urge at least one of the cutting elements on at least one of the steering pads into contact with the sidewall of the wellbore. The operation (960) may comprise operating at least one of the valve and the controller to simultaneously actuate each of the steering pads to operatively urge at least one of the cutting elements on each of the steering pads into substantially simultaneous contact with the sidewall of the wellbore. The operation (960) may also comprise locking one or more of the steering pads in the extended position, such as via operation of the locking mechanisms 67 shown in FIG. 4

and/or other locking means, and may also comprise immediately or otherwise thereafter unlocking the steering pads to permit the steering pads to again retract towards the RSS housing. The resulting, back-reamed wellbore may resemble that shown in FIG. 9, in which the rathole section of the wellbore is limited to the distance by which the drill bit and the cutting elements are axially separated.

[0073] The method (900) may also comprise installing (970) a casing in the second wellbore section after the back-reaming operation (960). Installing (970) the casing may comprise positioning casing in the back-reamed second wellbore section, and then securing the positioned casing in place by cement and/or coupling the casing to previously installed (940) casing, among other installation methods within the scope of the present disclosure. Installing (970) the casing in the back-reamed second wellbore section may be performed with or without removing the drill string from the wellbore.

[0074] Methods within the scope of the present disclosure may also comprise conventional back-reaming that is performed in addition to the back-reaming described above. For example, such conventional back-reaming may utilize the drill bit to clean the borehole, including implementations in which the conventional back-reaming does not substantially enlarge the borehole diameter. Such implementations may entail maintaining each of the steering pads retracted against the housing of the RSS via corresponding actuation (or lack thereof) of the digital or rotary valves.

[0075] FIG. 12 is a schematic view of at least a portion of apparatus according to one or more aspects of the present disclosure. The apparatus is or comprises a processing system 1300 that may execute example machine-readable instructions to implement at least a portion of one or more of the methods and/or processes described herein, and/or to implement a portion of one or more of the example RSS and/or other downhole tools described herein. The processing system 1300 may be or comprise, for example, one or more processors, controllers, special-purpose computing devices, servers, personal computers, personal digital assistant (“PDA”) devices, smartphones, internet appliances, and/or other types of computing devices. Moreover, while it is possible that the entirety of the processing system 1300 shown in FIG. 12 is implemented within downhole apparatus, perhaps as at least a portion of the control devices 75, controllers 76, controller 130, other downhole apparatus shown in one or more of FIGS. 1-9, and/or other downhole apparatus, it is also contemplated that one or more components or functions of the processing system 1300 may be implemented in wellsite surface equipment, perhaps including the surface control system 58 depicted in FIG. 1 and/or other surface equipment.

[0076] The processing system 1300 may comprise a processor 1312 such as, for example, a general-purpose programmable processor. The processor 1312 may comprise a local memory 1314, and may execute coded instructions 1332 present in the local memory 1314 and/or another memory device. The processor 1312 may execute, among other things, machine-readable instructions or programs to implement the methods and/or processes described herein. The programs stored in the local memory 1314 may include program instructions or computer program code that, when executed by an associated processor, enable surface equipment and/or downhole controller and/or control system to perform tasks as described herein. The processor 1312 may be, comprise, or be implemented by one or a plurality of processors of various types suitable to the local application environment, and may

include one or more of general-purpose computers, special-purpose computers, microprocessors, digital signal processors (“DSPs”), field-programmable gate arrays (“FPGAs”), application-specific integrated circuits (“ASICs”), and processors based on a multi-core processor architecture, as non-limiting examples. Of course, other processors from other families are also appropriate.

[0077] The processor **1312** may be in communication with a main memory, such as may include a volatile memory **1318** and a non-volatile memory **1320**, perhaps via a bus **1322** and/or other communication means. The volatile memory **1318** may be, comprise, or be implemented by random access memory (RAM), static random access memory (SRAM), synchronous dynamic random access memory (SDRAM), dynamic random access memory (DRAM), RAMBUS dynamic random access memory (RDRAM) and/or other types of random access memory devices. The non-volatile memory **1320** may be, comprise, or be implemented by read-only memory, flash memory and/or other types of memory devices. One or more memory controllers (not shown) may control access to the volatile memory **1318** and/or the non-volatile memory **1320**.

[0078] The processing system **1300** may also comprise an interface circuit **1324**. The interface circuit **1324** may be, comprise, or be implemented by various types of standard interfaces, such as an Ethernet interface, a universal serial bus (USB), a third generation input/output (3GIO) interface, a wireless interface, and/or a cellular interface, among others. The interface circuit **1324** may also comprise a graphics driver card. The interface circuit **1324** may also comprise a communication device such as a modem or network interface card to facilitate exchange of data with external computing devices via a network (e.g., Ethernet connection, digital subscriber line (“DSL”), telephone line, coaxial cable, cellular telephone system, satellite, etc.).

[0079] One or more input devices **1326** may be connected to the interface circuit **1324**. The input device(s) **1326** may permit a user to enter data and commands into the processor **1312**. The input device(s) **1326** may be, comprise, or be implemented by, for example, a keyboard, a mouse, a touchscreen, a track-pad, a trackball, an isopoint, and/or a voice recognition system, among others.

[0080] One or more output devices **1328** may also be connected to the interface circuit **1324**. The output devices **1328** may be, comprise, or be implemented by, for example, display devices (e.g., a liquid crystal display or cathode ray tube display (CRT), among others), printers, and/or speakers, among others.

[0081] The processing system **1300** may also comprise one or more mass storage devices **1330** for storing machine-readable instructions and data. Examples of such mass storage devices **1330** include floppy disk drives, hard drive disks, compact disk (CD) drives, and digital versatile disk (DVD) drives, among others. The coded instructions **1332** may be stored in the mass storage device **1330**, the volatile memory **1318**, the non-volatile memory **1320**, the local memory **1314**, and/or on a removable storage medium **1334**, such as a CD or DVD. Thus, the modules and/or other components of the processing system **1300** may be implemented in accordance with hardware (embodied in one or more chips including an integrated circuit such as an application specific integrated circuit), or may be implemented as software or firmware for execution by a processor. In particular, in the case of firmware or software, the embodiment can be provided as a computer

program product including a computer readable medium or storage structure embodying computer program code (i.e., software or firmware) thereon for execution by the processor.

[0082] In view of the entirety of the present disclosure, including the figures and the claims that follow, a person having ordinary skill in the art will readily recognize that the present disclosure introduces a system for drilling a wellbore, wherein the system comprises: a rotary steerable system (RSS) at least indirectly coupled between a drill string collar and a drill bit, wherein the RSS comprises: a housing; a plurality of steering pads circumferentially spaced around the housing, wherein each of the plurality of steering pads is actuatable to radially extend away from the housing independent of the other ones of the plurality of steering pads, and wherein at least one of the plurality of steering pads comprises a back-reaming bit; a valve; and a controller, wherein the valve and the controller are collectively operable to: sequentially actuate ones of the plurality of steering pads to substantially decentralize the RSS relative to the wellbore; and simultaneously actuate each of the plurality of steering pads to substantially centralize the RSS relative to the wellbore, thus urging the back-reaming bit into contact with a sidewall of the wellbore.

[0083] Each of the plurality of steering pads may be actuatable to radially extend away from the housing by rotating about an axis that is substantially parallel to a longitudinal axis of the housing.

[0084] The valve may be a digital valve.

[0085] The valve may be a rotational valve. The valve and the controller may be collectively operable to simultaneously actuate each of the plurality of steering pads by disengaging the valve.

[0086] The back-reaming bit may comprise a plurality of cutting elements. Each of the plurality of cutting elements may comprise: a substrate coupled to the corresponding steering pad; and a cutting layer coupled to the substrate. The substrate may substantially comprise tungsten carbide. The cutting layer may substantially comprise polycrystalline diamond. Each of the plurality of steering pads may comprise at least one of the plurality of cutting elements. Simultaneously actuating each of the plurality of steering pads to substantially centralize the RSS relative to the wellbore may urge at least one of the plurality of cutting elements on each of the plurality of steering pads into contact with the sidewall of the wellbore.

[0087] Each of the plurality of steering pads may be actuatable to radially extend away from a retracted position toward an extended position. Each of the plurality of steering pads may be lockable in the extended position.

[0088] The cutting elements may be disposed in an uphole portion of each of the plurality of steering pads and not in a downhole portion of each of the plurality of steering pads.

[0089] The present disclosure also introduces an apparatus comprising: a drill string disposed within a wellbore that extends from a wellsite surface to a subterranean formation; a drill bit; and a rotary steerable system (RSS) coupled between the drill string and the drill bit, wherein the RSS comprises: a plurality of steering pads spaced circumferentially apart around a perimeter of the RSS; a valve operable to sequentially actuate the plurality of steering pads; and a back-reaming bit comprising a plurality of cutting elements, wherein each of the plurality of steering pads comprises at least one of the plurality of cutting elements.

[0090] Each of the plurality of cutting elements may comprise: a substrate coupled to a corresponding one of the plu-

ality of steering pads; and a cutting layer coupled to the substrate. The substrate may substantially comprise tungsten carbide. The cutting layer may substantially comprise polycrystalline diamond.

[0091] The apparatus may further comprise a controller, wherein the valve and the controller may be collectively operable to sequentially actuate the plurality of steering pads to operatively urge the RSS away from a longitudinal axis of the wellbore. The valve and the controller may be collectively further operable to simultaneously actuate each of the plurality of steering pads to operatively urge at least one of the plurality of cutting elements on each of the plurality of steering pads into contact with a sidewall of the wellbore.

[0092] The apparatus may not comprise a reaming tool, component, or feature disposed between the drill string and the RSS.

[0093] The apparatus may not comprise a reaming tool, component, or feature disposed between the drill string and the drill bit, other than the back-reaming bit formed by the plurality of cutting elements comprised by corresponding ones of the plurality of steering pads.

[0094] The present disclosure also introduces a method comprising: conveying apparatus within a wellbore that extends from a wellsite surface to a subterranean formation, wherein the apparatus comprises a drill string, a drill bit, and a rotary steerable system (RSS) coupled between the drill string and the drill bit, and wherein the RSS comprises: a plurality of steering pads spaced circumferentially apart around a perimeter of the RSS, wherein each of the plurality of steering pads carries at least one of a plurality of cutting elements; a valve operable for sequentially actuating the steering pads; and a controller; rotating the drill string, thereby rotating the RSS and the drill bit, while operating at least one of the valve and the controller to sequentially actuate the plurality of steering pads to operatively urge the RSS and the drill bit away from a longitudinal axis of the wellbore; and rotating the drill string, thereby rotating the RSS and the drill bit, while operating at least one of the valve and the controller to simultaneously actuate each of the plurality of steering pads to operatively urge at least one of the plurality of the cutting elements on each of the plurality of steering pads into contact with a sidewall of the wellbore.

[0095] The method may further comprise, prior to conveying at least a portion of the apparatus within the wellbore, coupling the RSS between the drill string and the drill bit.

[0096] Rotating the drill string while operating at least one of the valve and the controller to sequentially actuate the plurality of steering pads to operatively urge the RSS and the drill bit away from a longitudinal axis of the wellbore may comprise rotating the drill string while operating at least one of the valve and the controller to sequentially actuate the plurality of steering pads to operatively urge the RSS and the drill bit in a first azimuthal direction away from the longitudinal axis of the wellbore. In such implementations, the method may further comprise: rotating the drill string while operating at least one of the valve and the controller to sequentially actuate the plurality of steering pads to operatively urge the RSS and the drill bit in a second azimuthal direction away from the longitudinal axis of the wellbore. The first and second azimuthal directions may differ by at least about twenty degrees. The first and second azimuthal directions may be substantially opposite each other. The first and second azimuthal directions may differ by an amount ranging between about 170 degrees and about 190 degrees. Rotating

the drill string while operating at least one of the valve and the controller to sequentially actuate the plurality of steering pads to operatively urge the RSS and the drill bit in the first azimuthal direction away from the longitudinal axis of the wellbore may create a first wellbore section extending in a first wellbore direction. Rotating the drill string while operating at least one of the valve and the controller to sequentially actuate the plurality of steering pads to operatively urge the RSS and the drill bit in the second azimuthal direction away from the longitudinal axis of the wellbore may create a second wellbore section extending in a second wellbore direction. Rotating the drill string while operating at least one of the valve and the controller to simultaneously actuate each of the plurality of steering pads to operatively urge at least one of the plurality of the cutting elements on each of the plurality of steering pads into contact with the sidewall of the wellbore may include back-reaming the first and second wellbore sections. The second wellbore section may be created after the first wellbore section is created. The second wellbore section may be back-reamed before the first wellbore section is back-reamed.

[0097] The foregoing outlines features of several embodiments so that a person having ordinary skill in the art may better understand the aspects of the present disclosure. A person having ordinary skill in the art should appreciate that they may readily use the present disclosure as a basis for designing or modifying other processes and structures for carrying out the same goals and/or achieving the same aspects of the implementations introduced herein. A person having ordinary skill in the art should also realize that such equivalent constructions do not depart from the scope of the present disclosure, and that they may make various changes, substitutions and alterations herein without departing from the spirit and scope of the present disclosure.

[0098] The Abstract at the end of this disclosure is provided to comply with 37 C.F.R. §1.72(b) to allow the reader to quickly ascertain the nature of the technical disclosure. It is submitted with the understanding that it will not be used to interpret or limit the scope or meaning of the claims.

What is claimed is:

1. A system for drilling a wellbore, comprising:

a rotary steerable system (RSS) at least indirectly coupled between a drill string collar and a drill bit, wherein the RSS comprises:

a housing;

a plurality of steering pads circumferentially spaced around the housing, wherein each of the plurality of steering pads is actuatable to radially extend away from the housing independent of the other ones of the plurality of steering pads, and wherein at least one of the plurality of steering pads comprises a back-reaming bit;

a valve; and

a controller, wherein the valve and the controller are collectively operable to:

sequentially actuate ones of the plurality of steering pads to substantially decentralize the RSS relative to the wellbore; and

simultaneously actuate each of the plurality of steering pads to substantially centralize the RSS relative to the wellbore, thus urging the back-reaming bit into contact with a sidewall of the wellbore.

2. The system of claim 1 wherein each of the plurality of steering pads is actuatable to radially extend away from the

housing by rotating about an axis that is substantially parallel to a longitudinal axis of the housing.

3. The system of claim 1 wherein the valve and the controller are collectively operable to simultaneously actuate each of the plurality of steering pads by disengaging the valve.

4. The system of claim 1 wherein the back-reaming bit comprises a plurality of cutting elements.

5. The system of claim 4 wherein each of the plurality of cutting elements comprises:

- a substrate coupled to the corresponding steering pad; and
- a cutting layer coupled to the substrate.

6. The system of claim 4 wherein each of the plurality of steering pads comprises at least one of the plurality of cutting elements.

7. The system of claim 6 wherein simultaneously actuating each of the plurality of steering pads to substantially centralize the RSS relative to the wellbore urges at least one of the plurality of cutting elements on each of the plurality of steering pads into contact with the sidewall of the wellbore.

8. The system of claim 1 wherein each of the plurality of steering pads is actuatable to radially extend away from a retracted position toward an extended position.

9. The system of claim 8 wherein each of the plurality of steering pads is lockable in the extended position.

10. The system of claim 1 wherein the cutting elements are disposed in an uphole portion of each of the plurality of steering pads and not in a downhole portion of each of the plurality of steering pads.

11. An apparatus, comprising:

- a drill string disposed within a wellbore that extends from a wellsite surface to a subterranean formation;
- a drill bit; and

- a rotary steerable system (RSS) coupled between the drill string and the drill bit, wherein the RSS comprises:

- a plurality of steering pads spaced circumferentially apart around a perimeter of the RSS;

- a valve operable to sequentially actuate the plurality of steering pads; and

- a back-reaming bit comprising a plurality of cutting elements, wherein each of the plurality of steering pads comprises at least one of the plurality of cutting elements.

12. The apparatus of claim 11 wherein each of the plurality of cutting elements comprises:

- a substrate coupled to a corresponding one of the plurality of steering pads; and

- a cutting layer coupled to the substrate.

13. The apparatus of claim 12 wherein:

- the substrate substantially comprises tungsten carbide; and
- the cutting layer substantially comprises polycrystalline diamond.

14. The apparatus of claim 11 further comprising a controller, wherein the valve and the controller are collectively operable to sequentially actuate the plurality of steering pads to operatively urge the RSS away from a longitudinal axis of the wellbore.

15. The apparatus of claim 14 wherein the valve and the controller are collectively further operable to simultaneously actuate each of the plurality of steering pads to operatively urge at least one of the plurality of cutting elements on each of the plurality of steering pads into contact with a sidewall of the wellbore.

16. The apparatus of claim 11 not comprising a reaming tool, component, or feature disposed between the drill string and the RSS.

17. The apparatus of claim 11 not comprising a reaming tool, component, or feature disposed between the drill string and the drill bit, other than the back-reaming bit formed by the plurality of cutting elements comprised by corresponding ones of the plurality of steering pads.

18. A method, comprising:

- conveying apparatus within a wellbore that extends from a wellsite surface to a subterranean formation, wherein the apparatus comprises a drill string, a drill bit, and at a rotary steerable system (RSS) coupled between the drill string and the drill bit, and wherein the RSS comprises:
- a plurality of steering pads spaced circumferentially apart around a perimeter of the RSS, wherein each of the plurality of steering pads carries at least one of a plurality of cutting elements;

- a valve operable for sequentially actuating the steering pads; and

- a controller;

- rotating the drill string, thereby rotating the RSS and the drill bit, while operating at least one of the valve and the controller to sequentially actuate the plurality of steering pads to operatively urge the RSS and the drill bit away from a longitudinal axis of the wellbore; and

- rotating the drill string, thereby rotating the RSS and the drill bit, while operating at least one of the valve and the controller to simultaneously actuate each of the plurality of steering pads to operatively urge at least one of the plurality of the cutting elements on each of the plurality of steering pads into contact with a sidewall of the wellbore.

19. The method of claim 18 wherein:

- rotating the drill string while operating at least one of the valve and the controller to sequentially actuate the plurality of steering pads to operatively urge the RSS and the drill bit away from a longitudinal axis of the wellbore comprises:

- rotating the drill string while operating at least one of the valve and the controller to sequentially actuate the plurality of steering pads to operatively urge the RSS and the drill bit in a first azimuthal direction away from the longitudinal axis of the wellbore; and

- the method further comprises:

- rotating the drill string while operating at least one of the valve and the controller to sequentially actuate the plurality of steering pads to operatively urge the RSS and the drill bit in a second azimuthal direction away from the longitudinal axis of the wellbore, wherein the first and second azimuthal directions differ by at least about twenty degrees.

20. The method of claim 19 wherein:

- rotating the drill string while operating at least one of the valve and the controller to sequentially actuate the plurality of steering pads to operatively urge the RSS and the drill bit in the first azimuthal direction away from the longitudinal axis of the wellbore creates a first wellbore section extending in a first wellbore direction;

- rotating the drill string while operating at least one of the valve and the controller to sequentially actuate the plurality of steering pads to operatively urge the RSS and the drill bit in the second azimuthal direction away from

the longitudinal axis of the wellbore creates a second wellbore section extending in a second wellbore direction; and
rotating the drill string while operating at least one of the valve and the controller to simultaneously actuate each of the plurality of steering pads to operatively urge at least one of the plurality of the cutting elements on each of the plurality of steering pads into contact with the sidewall of the wellbore includes back-reaming the first and second wellbore sections.

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