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(54) **AUTOMATIC DRILL PIPE ADD AND REMOVE SYSTEM**

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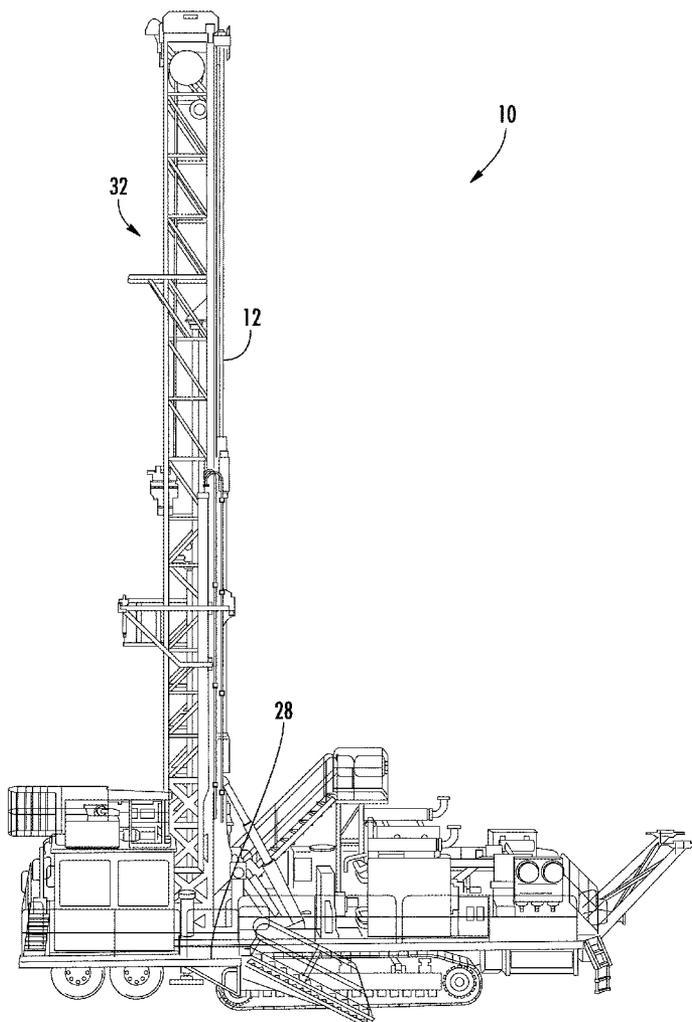
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(57) **ABSTRACT**

A drilling rig carousel assembly includes a drilling rig carousel comprising a plurality of slots for holding drill components, a first actuator coupled to the drilling rig carousel and configured to axially rotate the drilling rig carousel, a second actuator coupled to the drilling rig carousel and configured to move the drilling rig carousel between a first position and a second position, and a sensor assembly. The sensor assembly includes a rotation sensor configured to monitor an axial rotation of the drilling rig carousel, and a position sensor configured to provide a signal representative of whether the drilling rig carousel is in the first position or the second position.



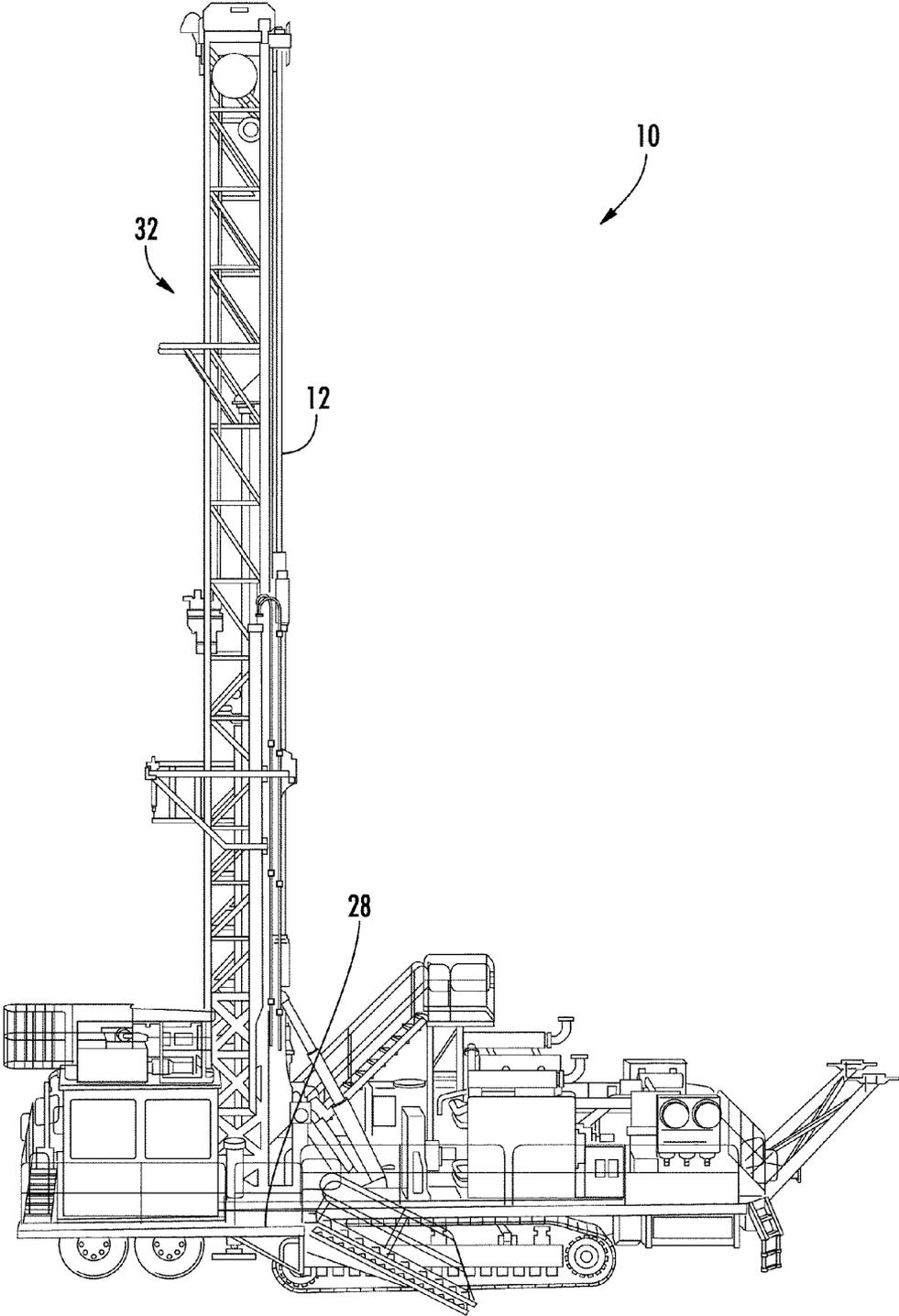


FIG. 1

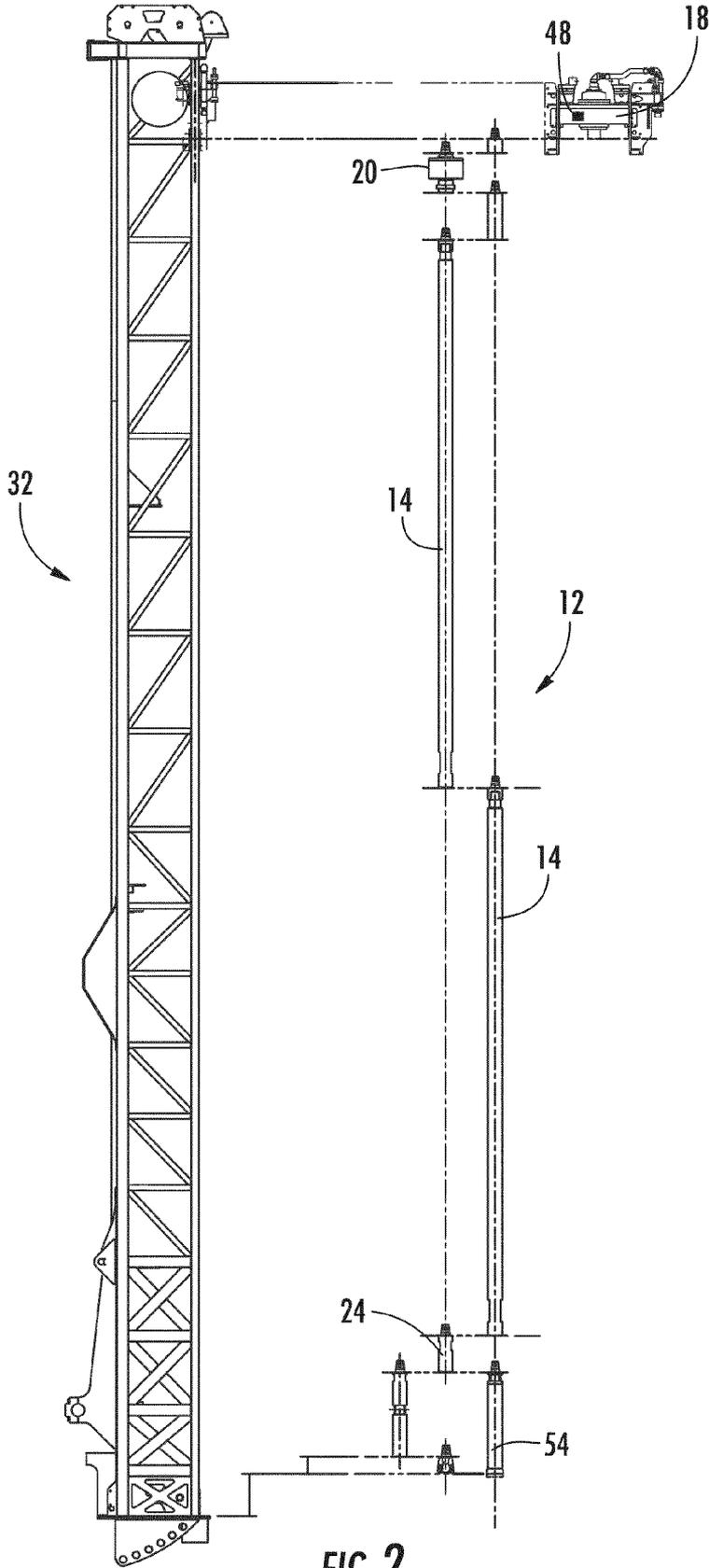
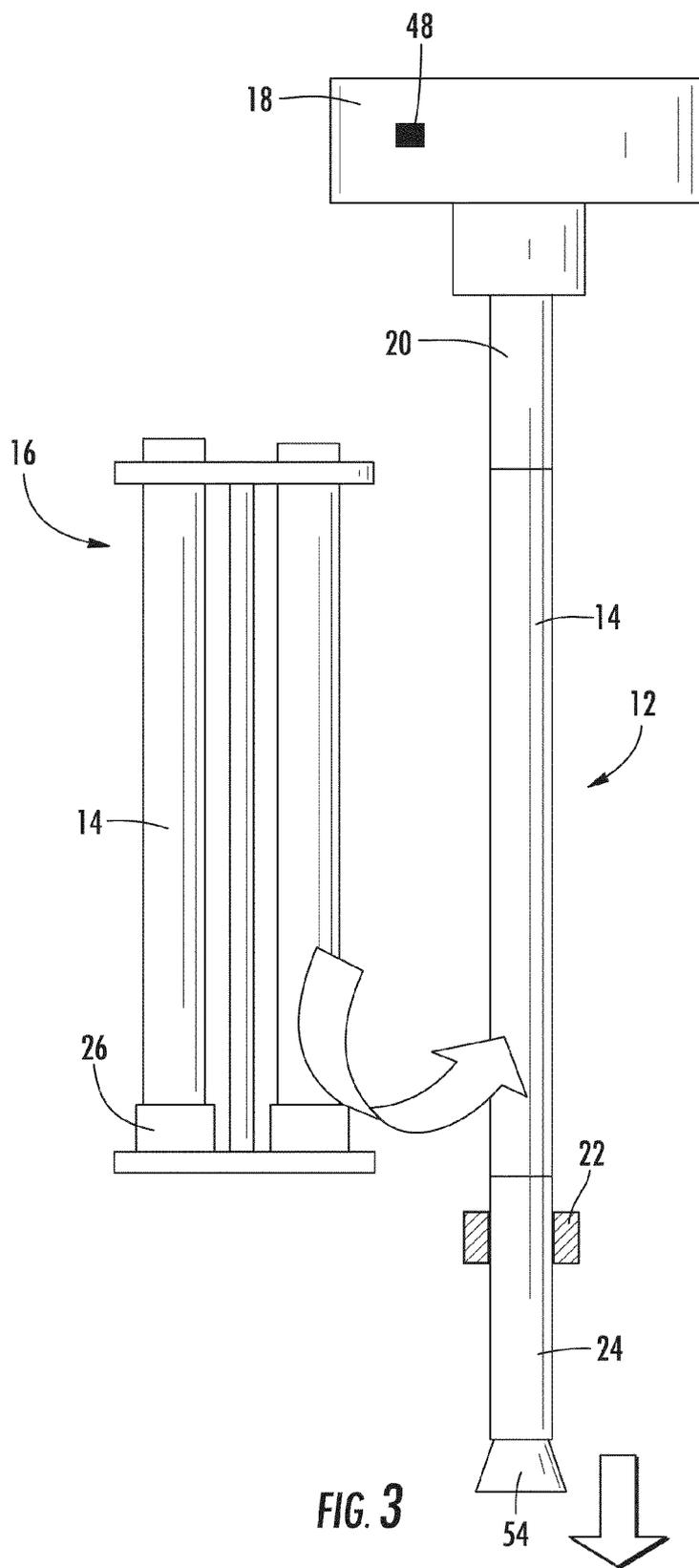


FIG. 2



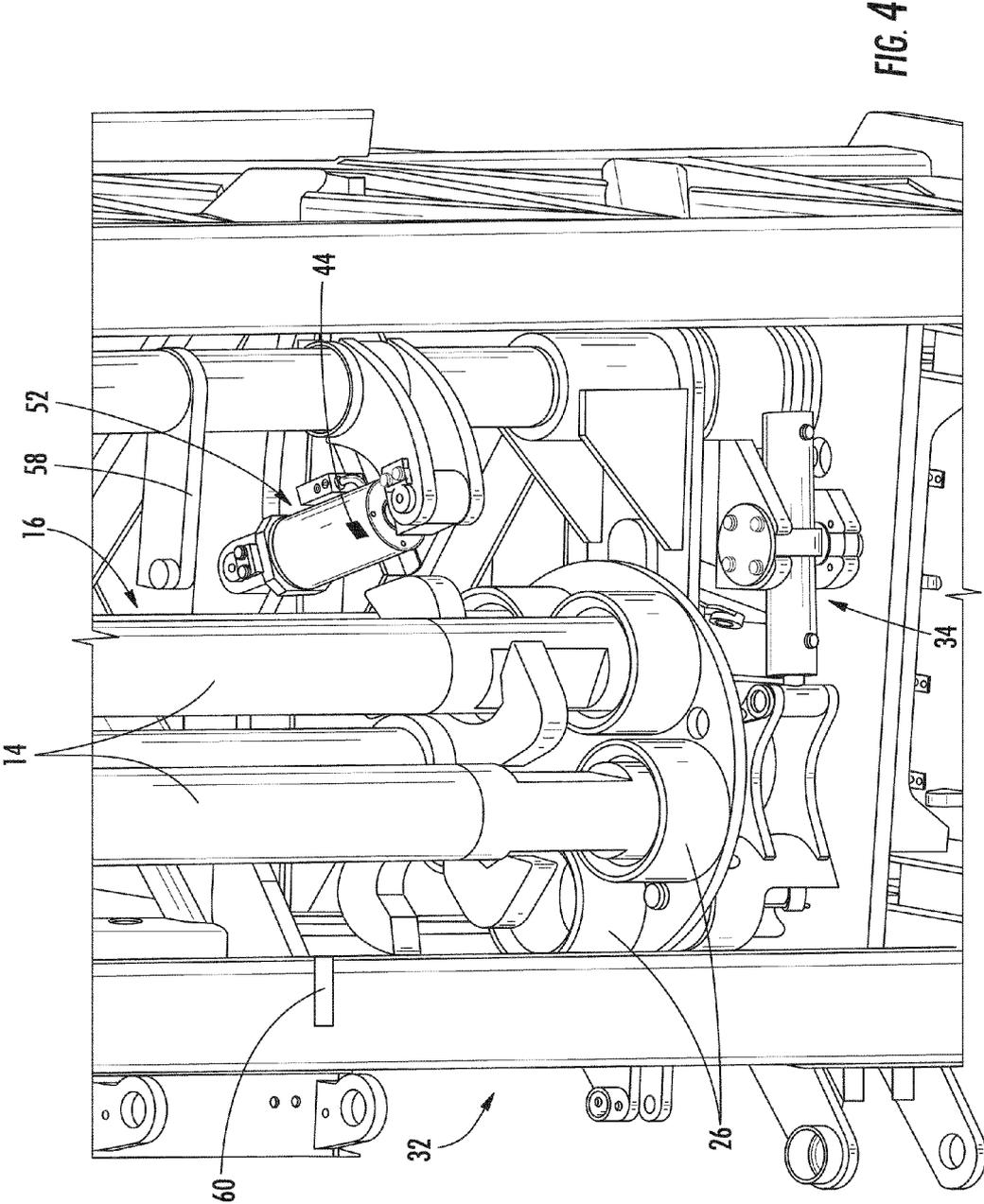


FIG. 4

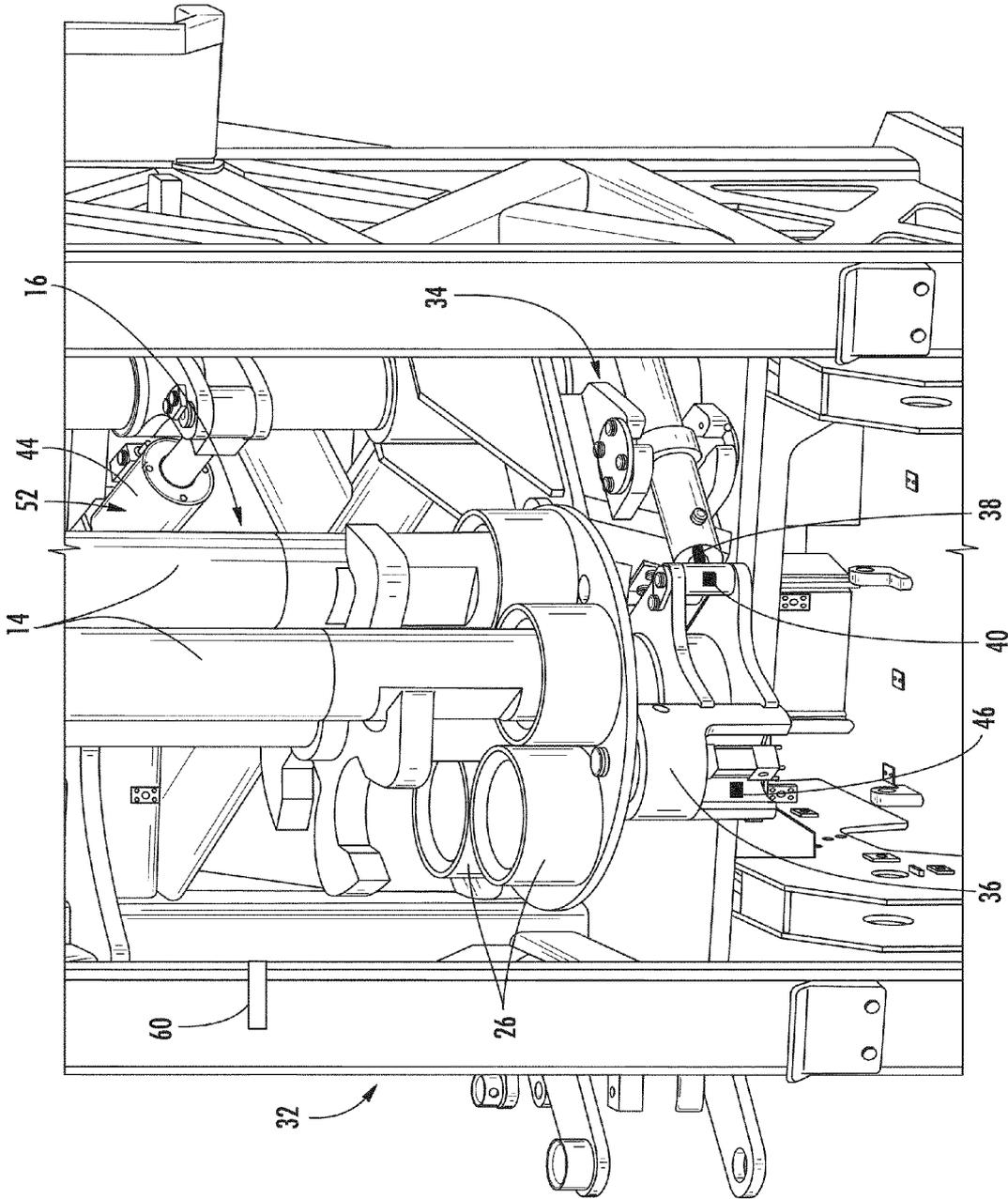


FIG. 5

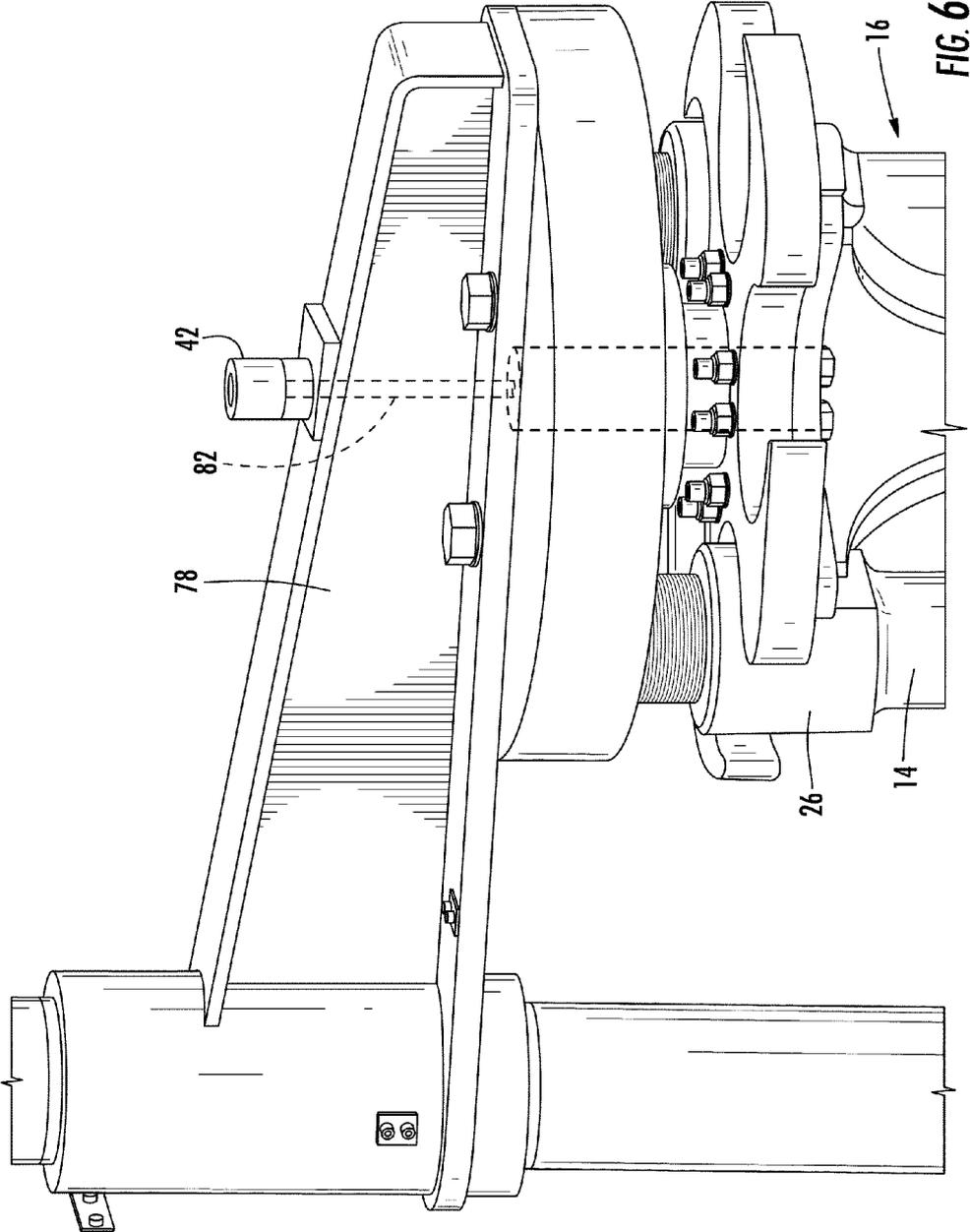


FIG. 6

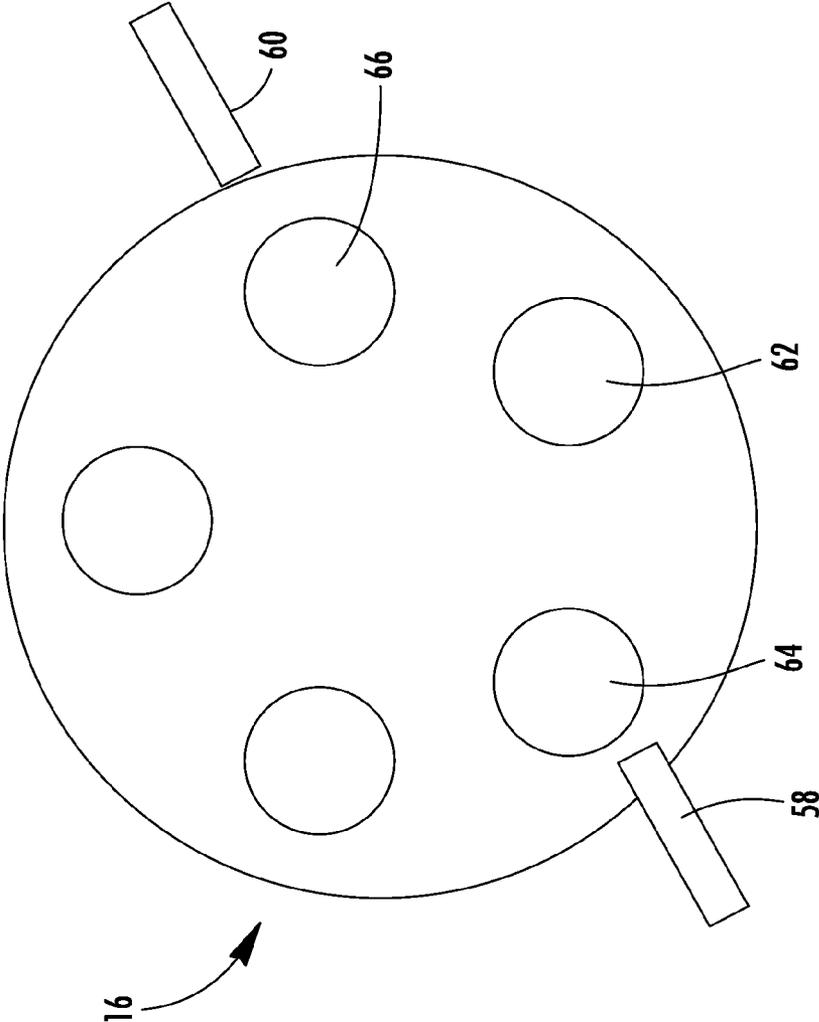


FIG. 7

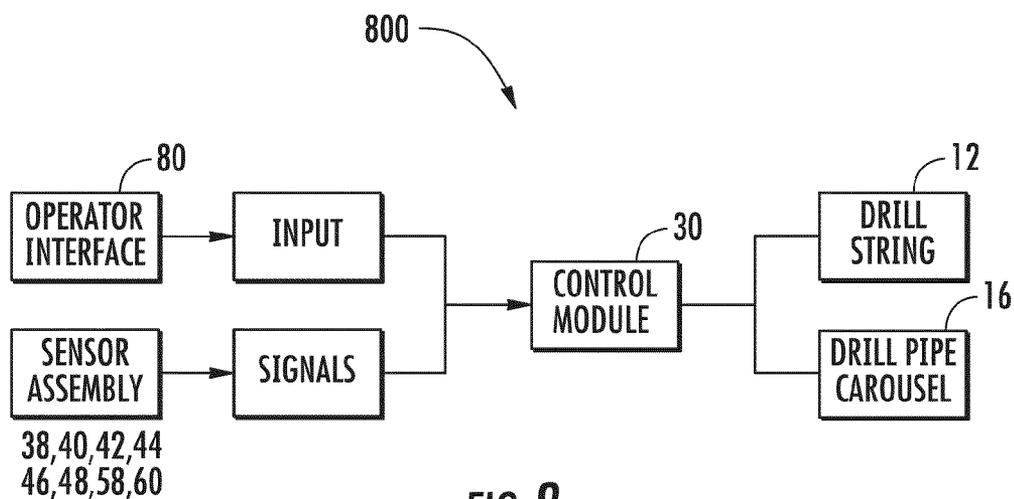


FIG. 8

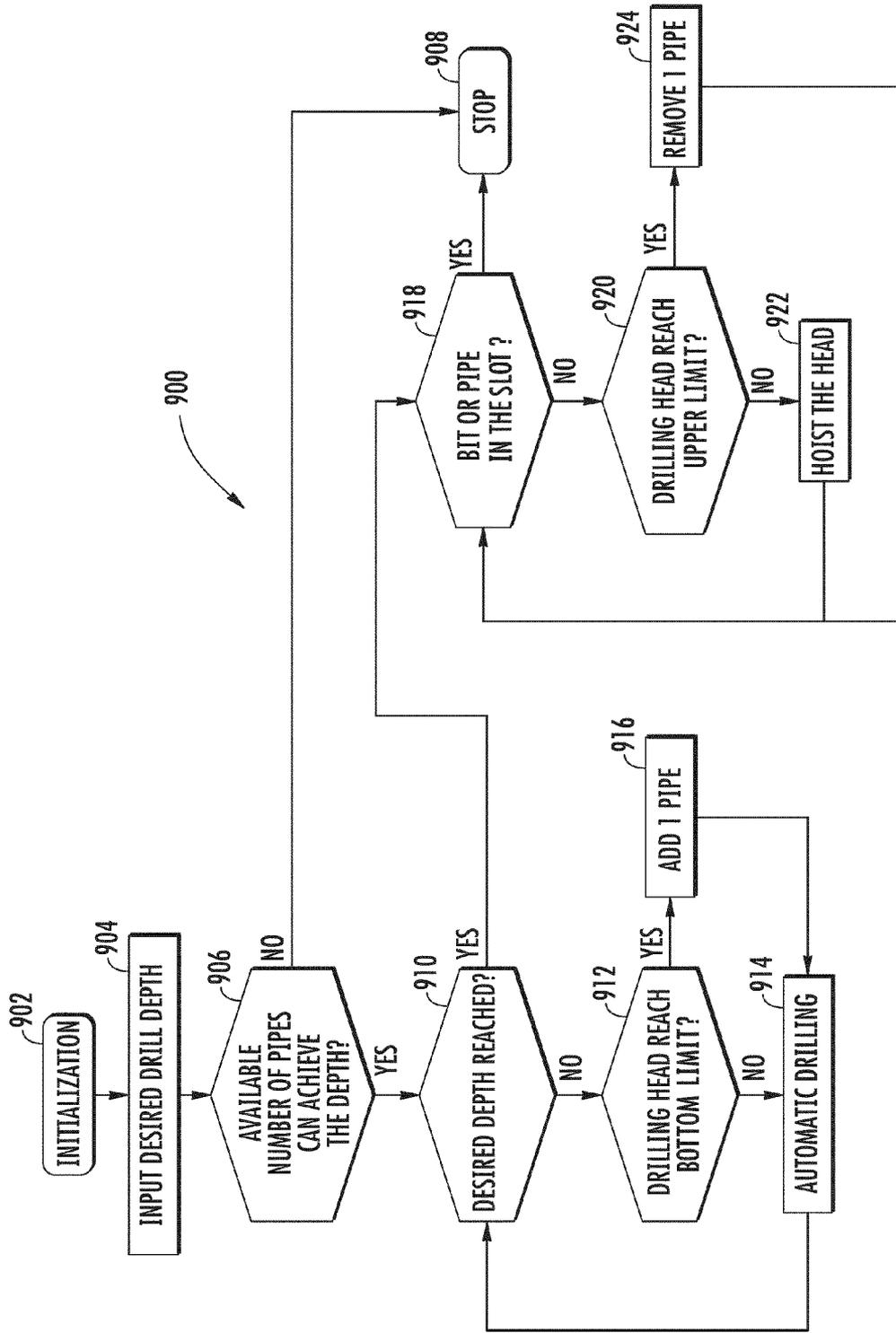


FIG. 9

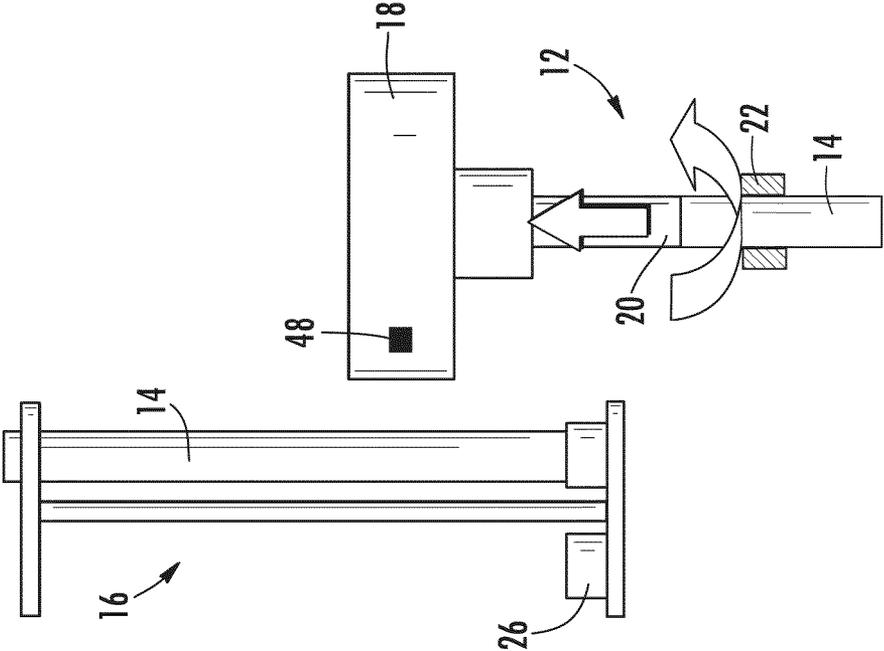


FIG. 10

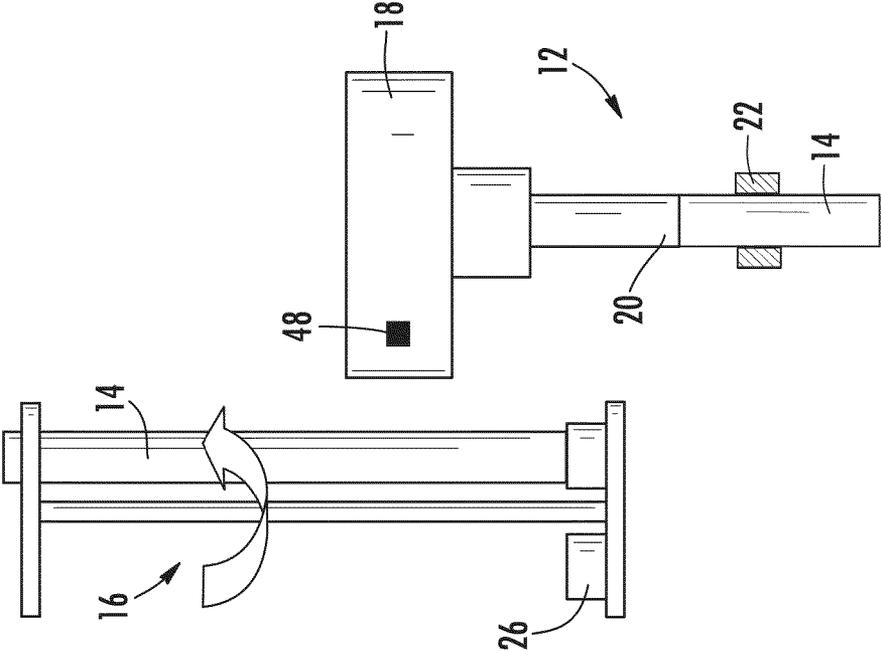
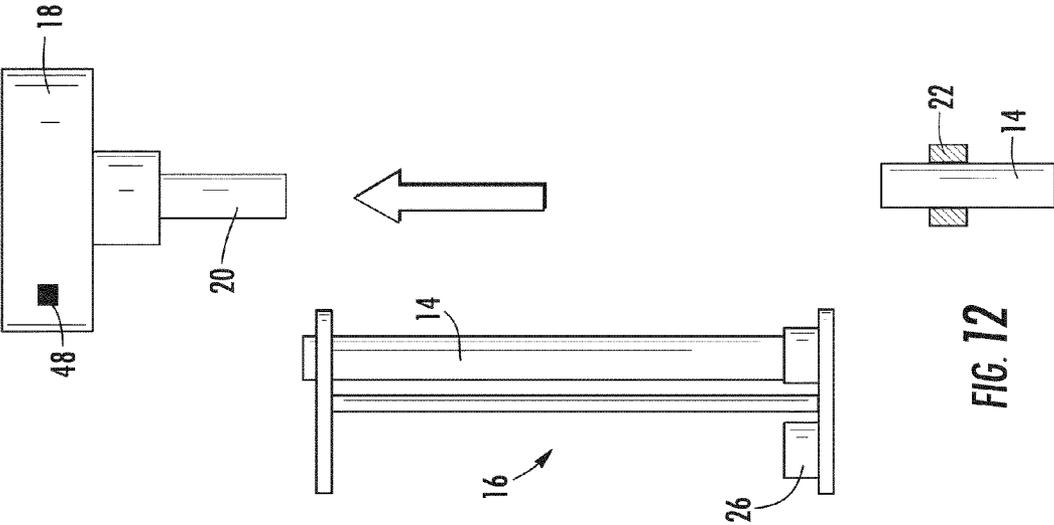
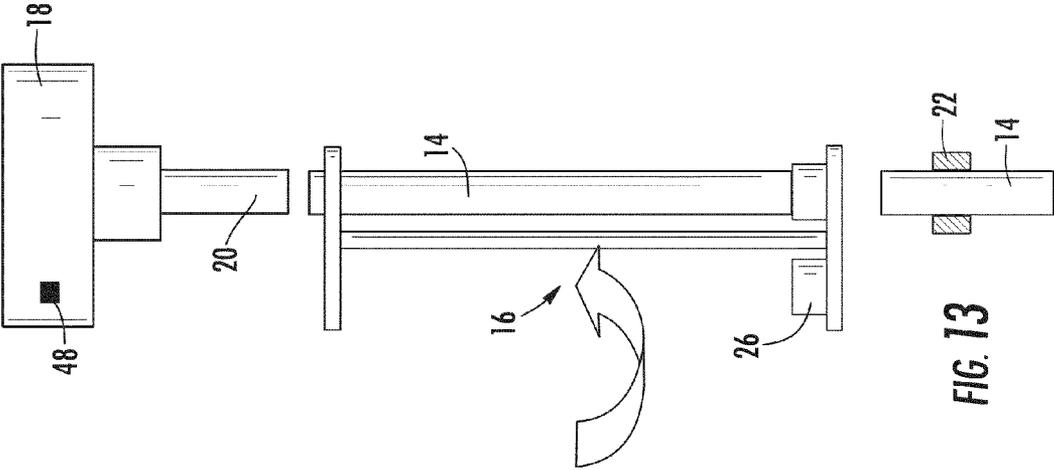
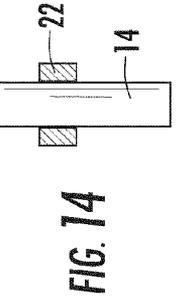
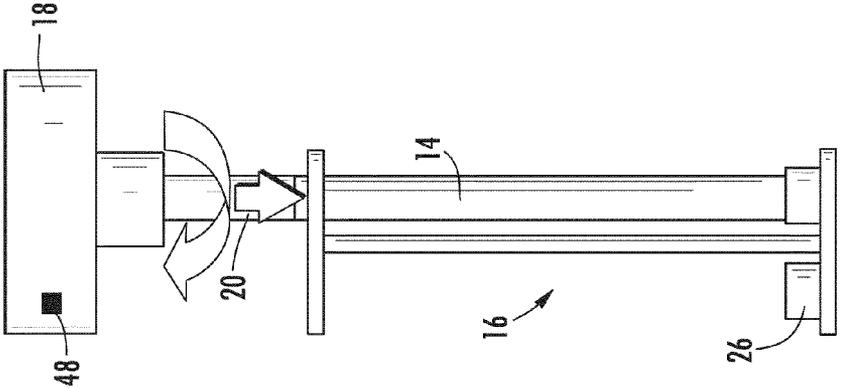
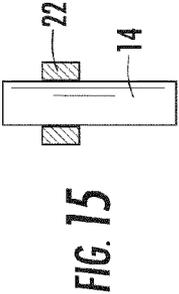
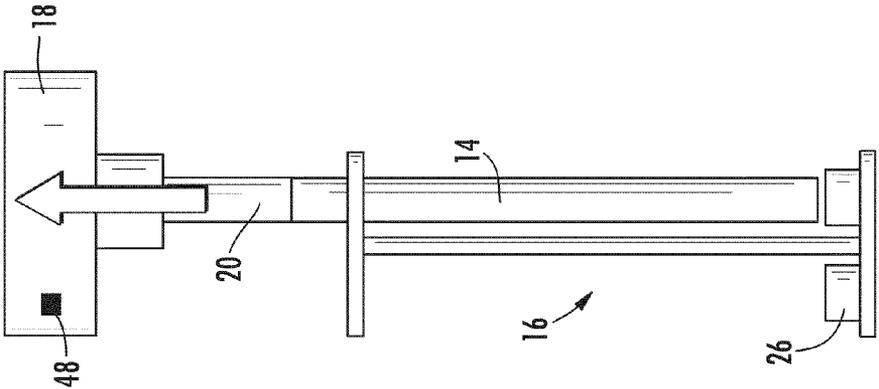
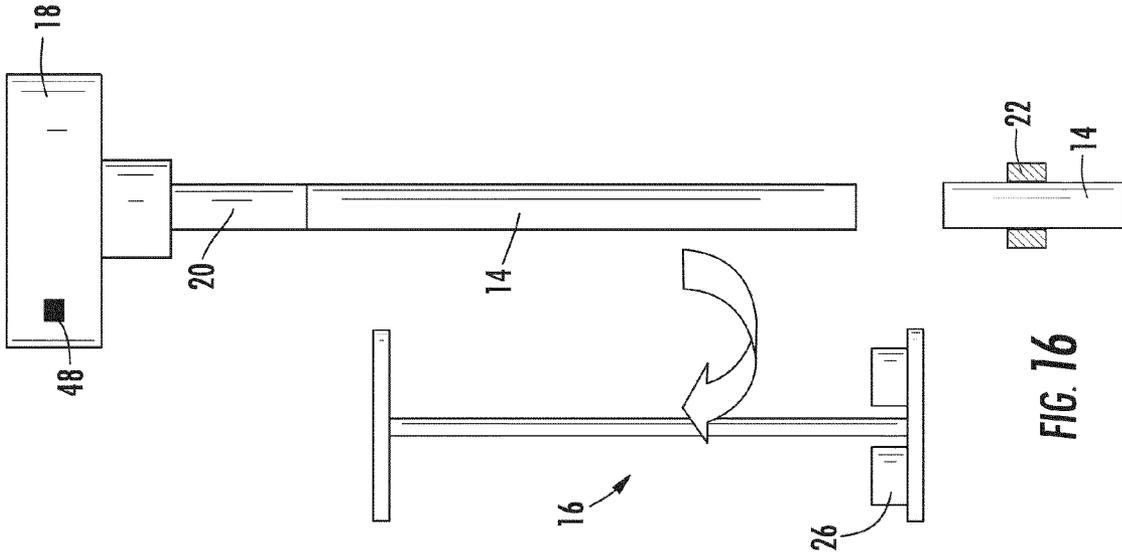
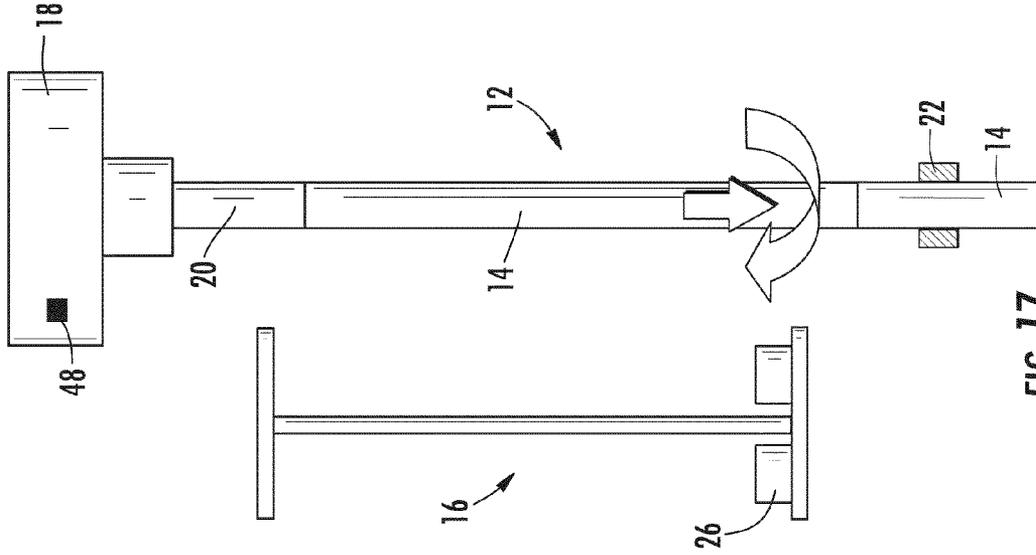


FIG. 11







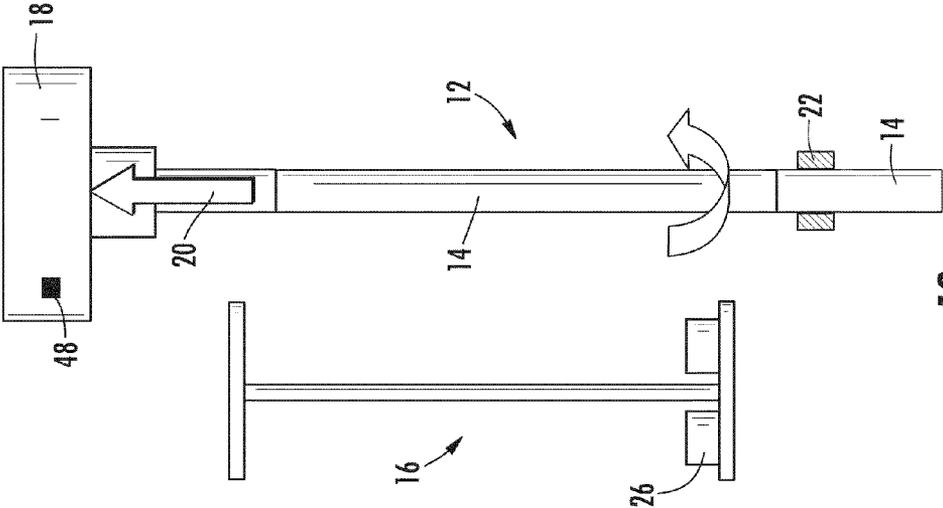


FIG. 19

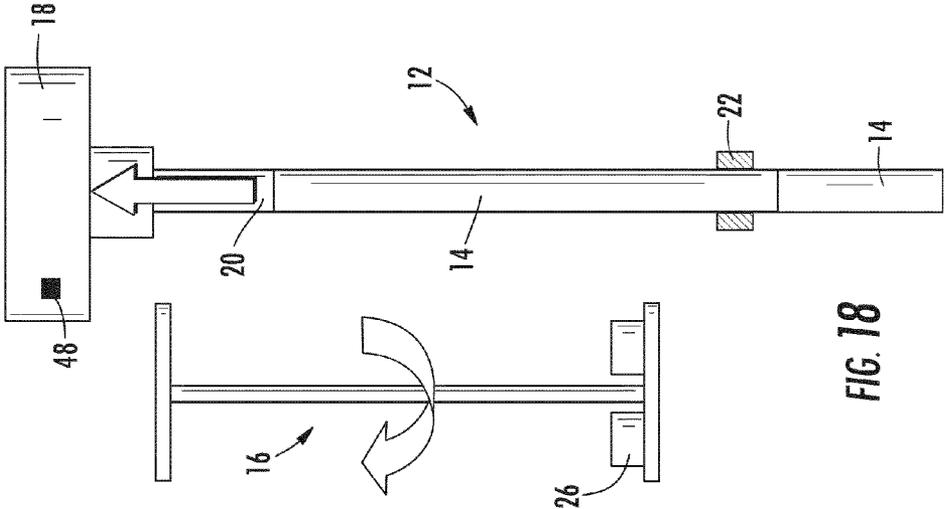


FIG. 18

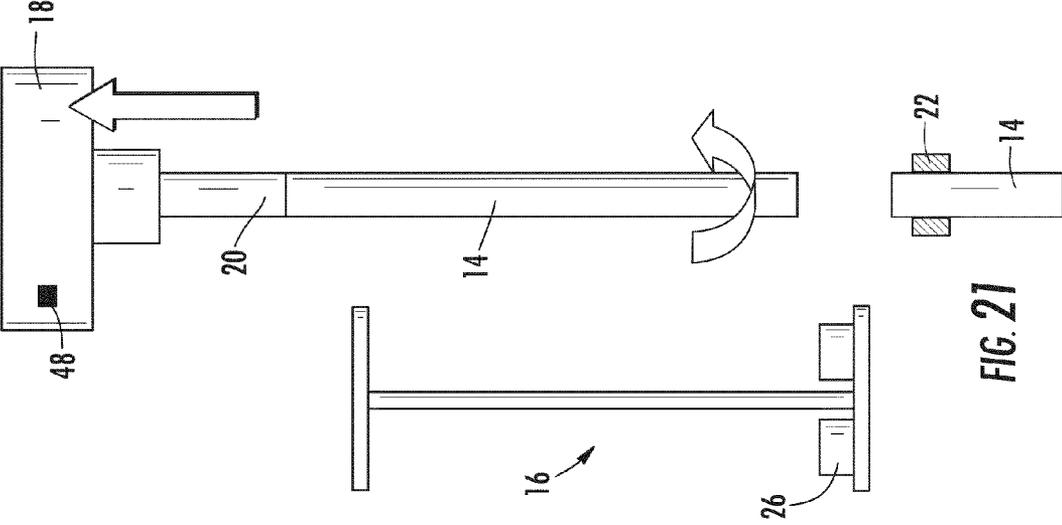


FIG. 20

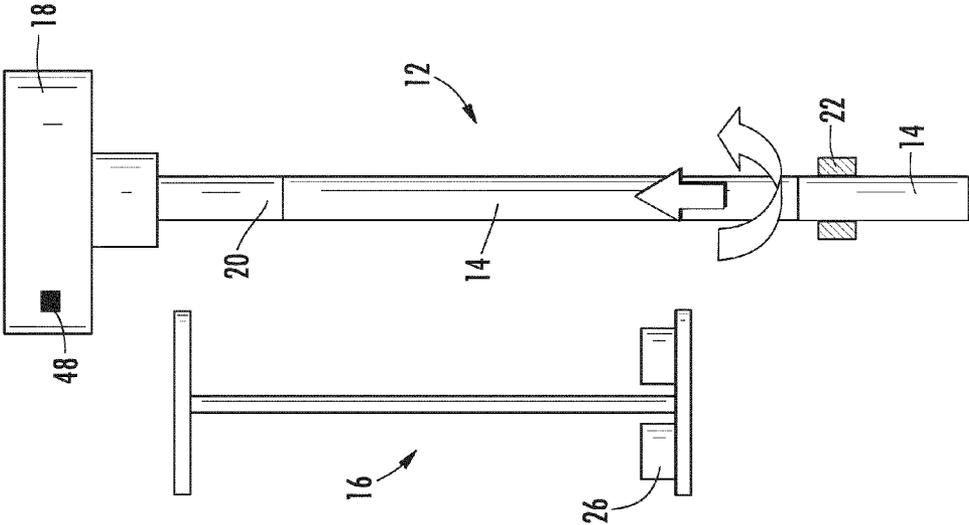
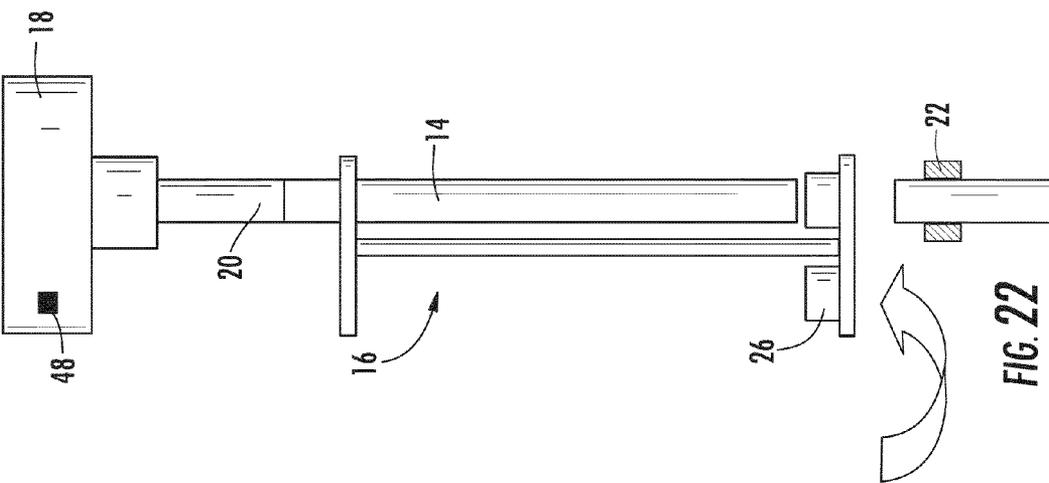
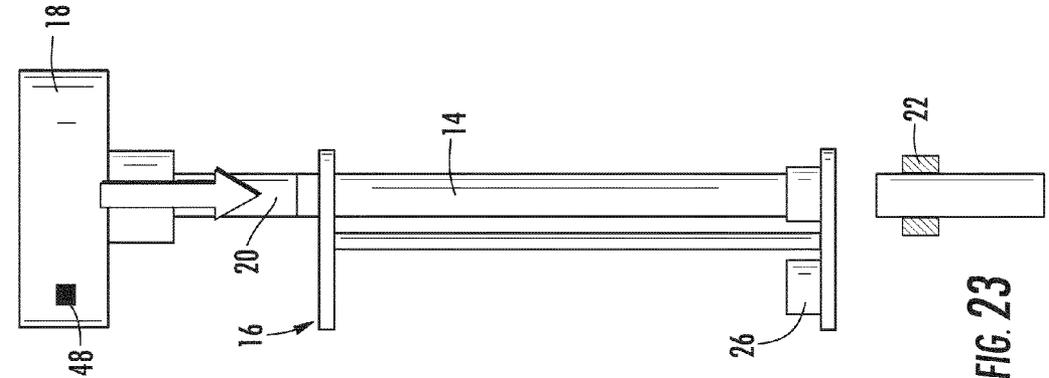
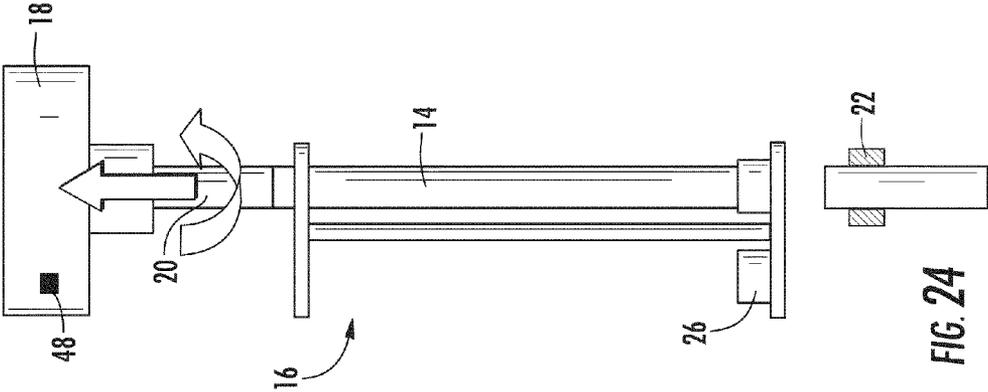
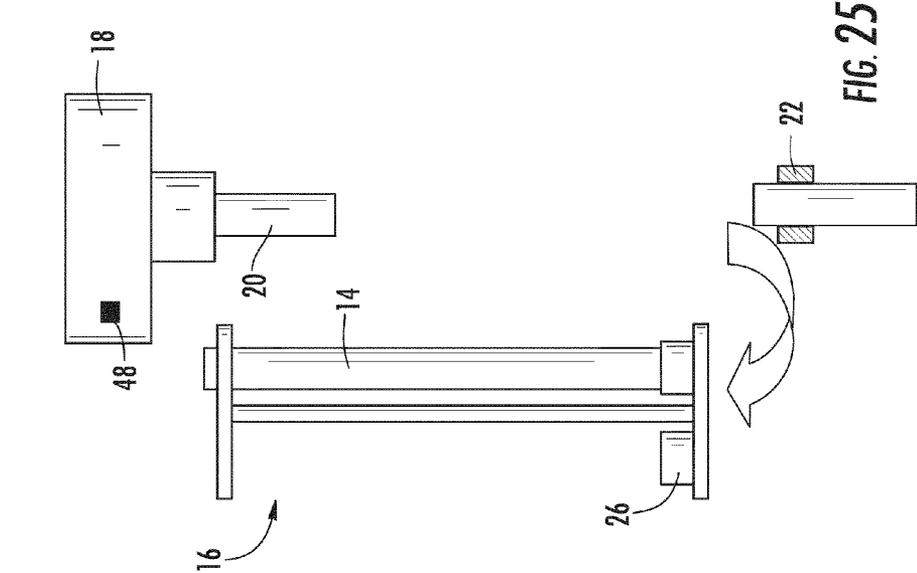


FIG. 21





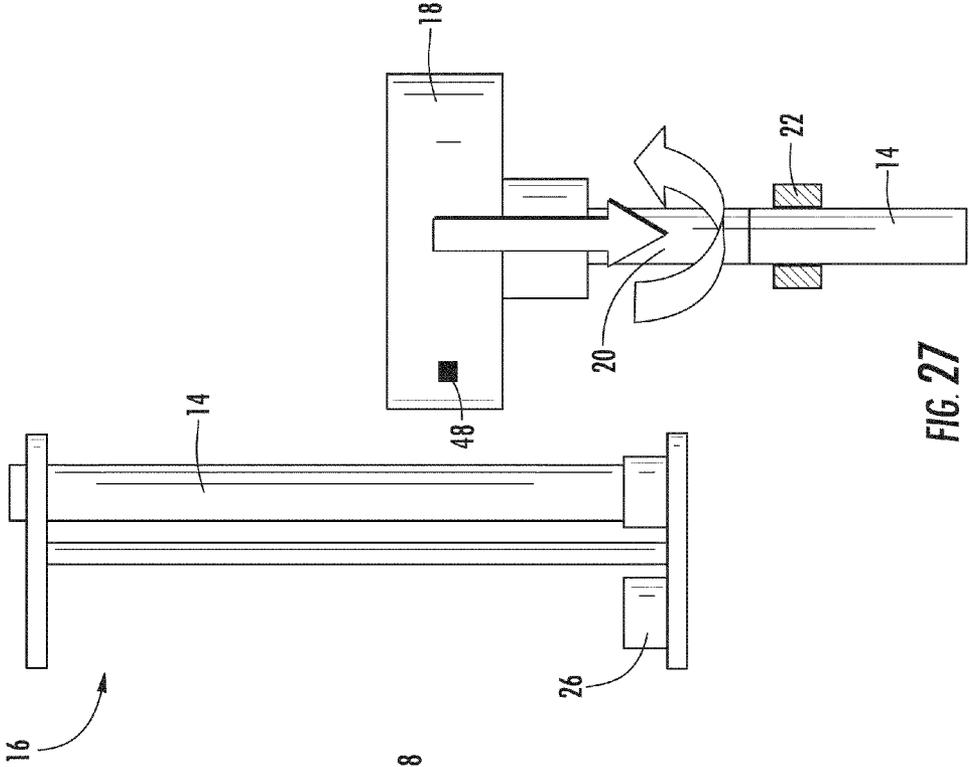


FIG. 26

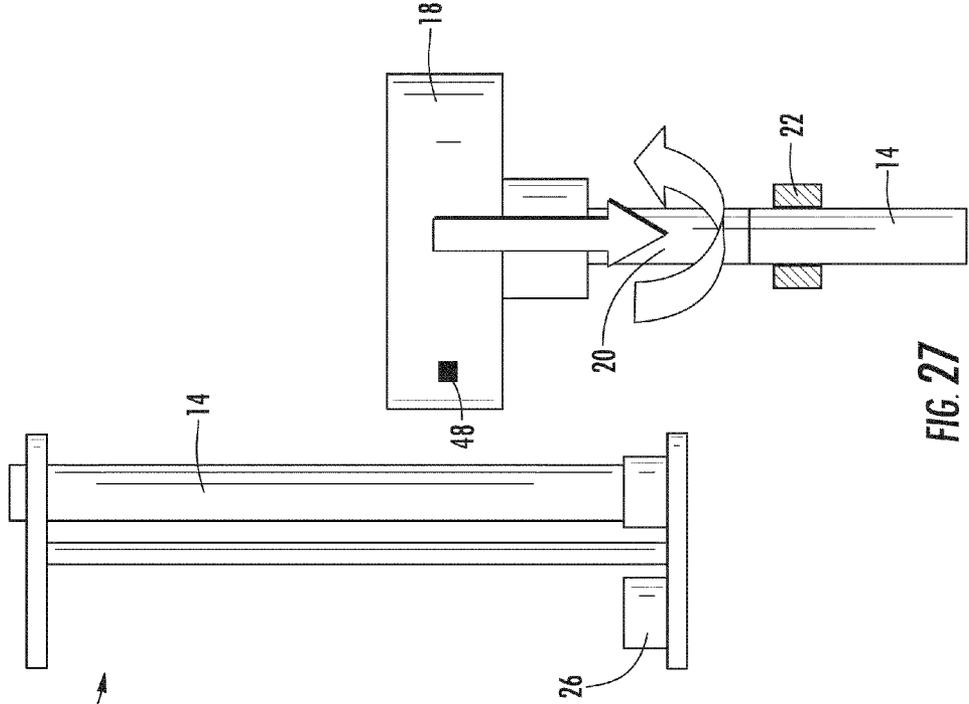


FIG. 27

AUTOMATIC DRILL PIPE ADD AND REMOVE SYSTEM

TECHNICAL FIELD

[0001] The present disclosure relates generally to drilling systems, and more particularly to an automated system for adding and removing drill pipe segments to modify the length of a drill string.

BACKGROUND

[0002] This section is intended to provide a background or context to the invention recited in the claims. The description herein may include concepts that could be pursued, but are not necessarily ones that have been previously conceived or pursued. Therefore, unless otherwise indicated herein, what is described in this section is not prior art to the description and claims in this application and is not admitted to be prior art by inclusion in this section.

[0003] Drilling systems are generally known to include a vertical drill tower (e.g. mast, etc.) constructed from structural members such as steel beams and reinforcing supports. The drill tower is often coupled to a mobile platform (e.g. which along with other components typically form a drilling rig) for positioning the drill tower in a desired location to conduct a drilling operation. The drill tower is often equipped with a drill carousel which is structured and adapted to support a drill string formed from a combination of pipe segments (e.g., drill pipes, drill rods, drill extenders, etc.). The drill carousel is used to selectively add the pipe segments to the drill string for drilling a hole having a desired depth. The drill carousel is intended to allow a drilling operation to progress into the drill hole by making readily available a continuous string of pipe segments as needed for advancing a drilling tool into a drill hole.

[0004] Throughout the drilling operation, it is often desirable or necessary to add or remove a pipe segment from the drill string in order to meet a desired drilling depth, such as a depth that is greater or deeper than the depth restricted by the length of the drill tower. To minimize downtime in the drilling operation due to adding or removing a pipe segment, systems and mechanisms may be provided to facilitate moving the drill carousel to a change-out position and adding or removing pipe segments from the drill string.

[0005] One example of such a mechanism can be found in U.S. Pat. No. 4,449,592, issued May 22, 1984, for "Automatic Drill String Section Changer," which discloses a mobile rock drill unit having a control system which automates the task of adding and removing drill string sections from the drill string. However, the disclosed mechanism requires an operator command for adding or removing a drill string section, rather than automatically adding or removing drill string segments based on the conditions of the drilling operation.

SUMMARY

[0006] An embodiment of the present disclosure relates to a drilling rig carousel assembly. The drilling rig carousel assembly includes a drilling rig carousel comprising a plurality of slots for holding drill components, a first actuator coupled to the drilling rig carousel and configured to axially rotate the drilling rig carousel, a second actuator coupled to the drilling rig carousel and configured to move the drilling rig carousel between a first position and a second position, and a sensor assembly. The sensor assembly includes a rota-

tion sensor configured to monitor an axial rotation of the drilling rig carousel, and a position sensor configured to provide a signal representative of whether the drilling rig carousel is in the first position or the second position.

[0007] Another embodiment of the present disclosure relates to a drilling rig for drilling at a desired drill depth. The drilling rig includes a drill string having a drill tool and comprising one or more drill pipe segments, a drill pipe storage rack configured to store the one or more drill pipe segments, a sensor assembly configured to monitor a position of the drill string and a position of the drill pipe storage rack, an operator interface configured to receive one or more operator inputs, and a control module. The control module is configured to receive signals from the sensor assembly and the operator interface, and control a movement of the drill pipe storage rack and the drill string in order to add the one or more drill pipe segments from the drill pipe storage rack to the drill string, extending the drill string to reach the desired drill depth.

[0008] Another embodiment of the present disclosure relates to an automatic drill pipe add and remove system for a drilling rig having a drill string. The automatic drill pipe add and remove system includes a sensor assembly configured to monitor a position of the drill string and a position of a drill pipe storage rack, an operator interface configured to receive one or more operator inputs, and a control module. The control module is configured to receive signals from the sensor assembly, receive a desired drill depth from the operator interface, determine a desired drill string length for reaching the desired drill depth, and automatically add drill pipe segments to the drill string until the drill string reaches the desired drill string length.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The disclosure will become more fully understood from the following detailed description, taken in conjunction with the accompanying figures, wherein like reference numerals refer to like elements, in which:

[0010] FIG. 1 is a schematic image of a drilling rig of the present disclosure, according to an exemplary embodiment.

[0011] FIG. 2 is an exploded schematic image of components of the drilling rig of FIG. 1, including a drill tower, drill rods and drilling tools, according to an exemplary embodiment.

[0012] FIG. 3 is a schematic image of a drill string and a drill pipe carousel, according to an exemplary embodiment.

[0013] FIG. 4 is a perspective view of a portion of the drill tower of FIG. 2, according to an exemplary embodiment.

[0014] FIG. 5 is perspective view of another portion of the drill tower of FIG. 2, according to an exemplary embodiment.

[0015] FIG. 6 is a perspective view of the top of a drill pipe carousel, according to an exemplary embodiment.

[0016] FIG. 7 is a cross-section view of a drill pipe carousel, according to an exemplary embodiment.

[0017] FIG. 8 is a schematic representation of the automatic drill pipe add and remove system, according to an exemplary embodiment.

[0018] FIG. 9 is a flow chart representation of an algorithm for an automated drill pipe change-out system, according to an exemplary embodiment.

[0019] FIGS. 10-17 are schematic images of the drill string and drill pipe carousel of FIG. 3 in various stages of the drill pipe addition process, according to an exemplary embodiment.

[0020] FIGS. 18-27 are schematic images of the drill string and drill pipe carousel of FIG. 3 in various stages of the drill pipe removal process, according to an exemplary embodiment.

DETAILED DESCRIPTION

[0021] Before turning to the figures, which illustrate the exemplary embodiments in detail, it should be understood that the present application is not limited to the details or methodology set forth in the description or illustrated in the figures. It should also be understood that the terminology is for the purpose of description only and should not be regarded as limiting.

[0022] Referring to the Figures, an automatic drill pipe add and remove system for use with a rotary drilling machine such as a drilling rig 10 (or other suitable mobile or stationary drilling system) is shown according to an exemplary embodiment for use in mining, excavation, wells, blast hole drilling or other drilling or boring operations. Although the automatic drill pipe add and remove system is shown and described by way of example as being used with a mobile drilling rig 10, the automatic drill pipe add and remove system of the present disclosure is suitable for use with any of a wide variety of other mobile or stationary drilling systems, all of which are intended to be within the scope of this disclosure.

[0023] Referring to FIGS. 1 and 2, a drilling rig 10 having an automatic drill pipe add and remove system is shown, according to an exemplary embodiment. The automatic drill pipe add and remove system to be further described herein is intended to automatically (or semi-automatically) add or remove drill pipes or extenders (shown in FIG. 2 as pipe segments 14) from a drill string 12 of the drilling rig 10. In an exemplary embodiment, the automatic drill pipe add and remove system is intended to monitor one or more conditions of the drilling rig 10, and to facilitate the automatic addition or removal of drill pipes such as pipe segments 14 from the drill string 12 in order to meet a desired drilling depth of the drilling rig 10.

[0024] The drilling rig 10 includes a drill string 12 coupled to a drill tower 32. The drill string 12 includes one or more pipe segments 14 (i.e., drill pipe segments) for extending the length of the drill string 12 in order to meet the desired drilling depth. The pipe segments 14 may be coupled on a first end to a drill head 18 and on a second end to a drill tool 54 (e.g., hammer, etc.) by one or more adapters, such as adapters 20 and 24 shown in FIG. 3. The drill head 18 may include a rotation sensor shown as drill sensor 48 and configured to monitor a rotation of the drill head 18 or the drill string 12. The drill sensor 48 is described in further detail below. The drill string 12 is configured to apply a downward force (according to FIGS. 1 and 2) to a drilling surface, driving the drill tool 54 into the drilling surface in response to instructions received from a control device (e.g., control module 30, operator interface 80, etc.). The drill string 12 is shown and described in further detail in FIG. 3.

[0025] Referring now to FIG. 3, a schematic for the drill string 12 is shown, according to an exemplary embodiment. In this embodiment, the drill string 12 includes a single pipe segment 14 for extending the length of the drill string 12. The top adapter 20 and the bottom adapter 24 couple the pipe segment 14 to the other components of the drill string 12. In some embodiments, the adapters 20 and 24 and pipe segment 14 include corresponding threads configured to mate with each other (i.e., the pipe segment 14 to the adapters 20 and

24), removably coupling the adapters 20 and 24 to the pipe segment 14. In these embodiments, for instance, the pipe segment 14 may be joined with the adapter 20 by “screwing” the pipe segment 14 into the adapter 20 (i.e., rotating the pipe segment 14 in a clockwise direction such that the corresponding threads of the pipe segment 14 and the adapter 20 are mated). In an exemplary embodiment, each component of the drill string 12 include corresponding threads configured to mate with each other by screwing a first component into a second component. In the illustrated embodiment of FIG. 3, drill head 18 is coupled to the top adapter 20 and drill tool 54 is coupled to the bottom adapter 24. The drill head 18 may be configured to rotate in a clockwise direction in order to add (i.e., screw on) a pipe segment 14 or a counter-clockwise direction in order to remove (i.e., unscrew) a pipe segment 14. The drill tool 54 may be positioned at the bottom of the drill string 12 in order to drill a surface. The drill string 12 may also include a deck wrench 22 for clamping onto the bottom adapter 24. The deck wrench 22 is configured to hold the bottom adapter 24 stationary so that the pipe segment 14 may be connected to or removed from the bottom adapter 24 (i.e., by rotating the pipe segment 14 relative to the bottom adapter 24).

[0026] Still referring to FIG. 3, a drill pipe carousel 16 is shown, according to an exemplary embodiment. The drill pipe carousel 16 (i.e. drill pipe storage rack, drilling rig carousel, etc.) may be structured and adapted to support one or more drill components, such as pipe segments 14 or drill tools 54. The drill pipe carousel 16 may be used to selectively add pipe segments 14 and/or drill tools 54 to the drill string 12. The drill pipe carousel 16 is configured to “swing” or pivotally move between an add/remove position (i.e., in axial alignment with the drill string 12) for adding or removing pipe segments 14 to or from the drill string 12, and a stowed position (i.e., adjacent the drill string 12 during the drilling operation). In an exemplary embodiment, a carousel arm 78 (shown in FIG. 6) pivots the drill pipe carousel 16 about a pivot point shown as post 68 (shown in FIG. 6) in order to swing the drill pipe carousel 16 between the add/remove position and the stowed position. In this embodiment, the carousel arm 78 and the drill pipe carousel 16 may be controlled by a control device such as control module 30 (shown in FIG. 8). The drill pipe carousel 16 includes a plurality of slots 26 configured to hold drill components (e.g., pipe segments 14, drill tools 54, etc.). One or more slots 26 may be empty at any time for receiving pipe segments 14 or other drill components that are removed from the drill string 12.

[0027] From the add/remove position, the drill pipe carousel 16 is configured to “index” (i.e., rotate about its central axis) in a clockwise or counter-clockwise direction. While the swing motion pivots the drill pipe carousel 16 away from and toward the drill string 12, this indexing motion rotates the drill pipe carousel 16 around its center axis, with the center axis remaining stationary relative to the drill string 12. As the drill pipe carousel 16 is indexed, the slots 26 are rotated through a loading position (i.e., a position in line with the drill string 12 for removing or adding a pipe segment 14) for interacting with the drill string 12 (the loading position is shown in FIG. 7). In an exemplary embodiment, the drill pipe carousel 16 is indexed so that an empty slot 26 is moved to the loading position in order to remove a pipe segment 14 from the drill string 12, and the drill pipe carousel 16 is indexed so that a slot 26 holding a pipe segment 14 is moved to the loading position in order to add a pipe segment 14 to the drill string 12.

[0028] The automatic drill pipe add and remove system includes a sensor assembly configured to monitor one or more relevant conditions of the drilling rig 10, including the position and/or movement of one or more components of the drilling rig 10 (e.g., drill pipe carousel 16, drill string 12, etc.). The control module 30 is configured to receive one or more signals from the sensor assembly that represent the relevant conditions of the drilling rig 10. For instance, the sensor assembly may be configured to monitor the relative position of the drill pipe carousel 16, the presence of pipe segments 14 in the slots 26 of the drill pipe carousel 16, or any other relevant conditions of the drilling rig 10 or the automatic drill pipe add and remove system. The control module 30 may also be configured to receive one or more operator inputs from an operator interface 80 (shown in FIG. 8), such as a touch screen or a joystick. The automatic drill pipe add and remove system may use the signals and/or inputs to monitor and/or control one or more components of the drilling rig 10 to add or remove pipe segments 14 or other drill components from the drill string 12.

[0029] In an exemplary embodiment, the control module 30 receives a desired drilling depth as an operator input through the operator interface 80. In this embodiment, the control module 30 is configured to use the signals from the sensor assembly to control one or more components of the drilling rig 10 in order to add or remove pipe segments 14 and/or other drill components, as necessary. Pipe segments 14 may be automatically added to the drill string 12 by the automatic drill pipe add and remove system until the drill string 12 has a desired drill string length configured to reach the desired drilling depth. Once the desired drilling depth is reached, the control module 30 may be configured to remove pipe segments 14 and/or other drill components from the drill string 12, as necessary. An algorithm 900 for an exemplary embodiment of the automatic drill pipe add and remove system is shown in FIG. 9.

[0030] Referring now to FIGS. 4-7, the automatic drill pipe add and remove system may include one or more sensors (i.e. a sensor assembly) coupled to the drill pipe carousel 16 for monitoring the position or motion of the drill pipe carousel 16 or another component of the drilling rig 10. In the illustrated embodiment of FIG. 4, the system includes a position sensor (e.g., proximity sensor, pressure sensor, vision sensor, etc.) shown as swing sensor 44. The swing sensor 44 is configured to monitor the position of the drill pipe carousel 16, and to provide a signal representative of whether the drill pipe carousel 16 is in a first position or a second position. For instance, the swing sensor 44 may be configured to monitor a swing position of the drill pipe carousel 16 as the drill pipe carousel 16 moves between the add/remove position (i.e., in-line with the drill string 12, as shown in FIG. 5) and the stowed position. In the add/remove position, the drill pipe carousel 16 is positioned substantially within the drill tower 32 (i.e., in axial alignment with the drill string 12), such that pipe segments 14 may be removed from the drill pipe carousel 16 and connected to the drill string 12, or removed from the drill string 12 and stored within an empty slot 26 of the drill pipe carousel 16. In the stowed position, the drill pipe carousel 16 is positioned adjacent to the drill string 12 as not to interfere with the drilling operation.

[0031] In an exemplary embodiment, the drilling rig 10 includes an actuator configured to move or swing the drill pipe carousel 16 between a first position and a second position, which is shown as hydraulic cylinder 52 in the illustrated

embodiment of FIG. 4. In other embodiments, the actuator may be another actuating device (e.g., motor, etc.) suitable for moving or swinging the drill pipe carousel 16 as necessary for the purposes of the automatic drill pipe add and remove system. In an exemplary embodiment, the hydraulic cylinder 52 controls the swing movement of the drill pipe carousel 16, extending to swing (i.e., pivotally push) the drill pipe carousel 16 to the add/remove position, and retracting to swing (i.e., pivotally pull) the drill pipe carousel 16 to the stowed position. In this embodiment, the swing sensor 44 may be coupled to the hydraulic cylinder 52 and configured to detect whether the hydraulic cylinder 52 is in a retracted or extended position. The swing sensor 44 is thus able to detect whether the drill pipe carousel 16 is in the add/remove position (i.e., hydraulic cylinder 52 is in the extended position) or the stowed position (i.e., hydraulic cylinder 52 is in the retracted position). In other embodiments, the hydraulic cylinder 52 and drill pipe carousel 16 may be configured such that the hydraulic cylinder 52 retracts to swing the drill pipe carousel 16 to the add/remove position and extends to swing the drill pipe carousel 16 to the stowed position. In these embodiments, the swing sensor 44 may be configured accordingly to detect whether the drill pipe carousel 16 is in the add/remove position (i.e., hydraulic cylinder 52 is in the retracted position) or in the stowed position (i.e., hydraulic cylinder 52 is in the extended position).

[0032] In other embodiments, the swing sensor 44 may be coupled to the drill pipe carousel 16, coupled to the drill tower 32, or mounted or positioned in another location suitable for monitoring the swing position of the drill pipe carousel 16. The automatic drill pipe add and remove system is also shown to include detection sensors (e.g., proximity sensors, motion sensors, position sensors, etc.) shown as slot sensors 58 and 60. The slot sensors 58 and 60 are configured to detect the presence of drill components (e.g., pipe segments 14, drill tools 54, etc.) within the drill pipe carousel 16 in the illustrated embodiment of FIG. 4. The slot sensors 58 and 60 are shown and described in further detail in FIG. 7.

[0033] Referring further to FIG. 5, the drill pipe carousel 16 is shown in the add/remove position. In this position, the drill pipe carousel 16 is configured to rotationally index about its center axis in a clockwise or counter-clockwise direction, rotating a pipe segment 14, drill tool 54, or an empty slot 26 to the loading position. In the illustrated embodiment of FIG. 5, the drill pipe carousel 16 includes an actuator configured to control the axial rotation of the drill pipe carousel 16 and shown as hydraulic cylinder 34. In other embodiments, the actuator may be another actuating device suitable for axially rotating the drill pipe carousel 16, such as a motor. The hydraulic cylinder 34 may be coupled to the drill pipe carousel 16 in order to axially rotate the drill pipe carousel 16. In some embodiments, the hydraulic cylinder 34 is removably coupled to the drill pipe carousel 16. In these embodiments, a locking device 36 (i.e., cylinder lock, lock) may be positioned on the bottom of the drill pipe carousel 16 and configured to mate with a portion of the hydraulic cylinder 34. The locking device 36 of FIG. 5 has a locked position for clamping the hydraulic cylinder 34, thereby coupling the hydraulic cylinder 34 to the drill pipe carousel 16. The locking device 36 also has an unlocked position for de-coupling the hydraulic cylinder 34 from the drill pipe carousel 16, allowing the hydraulic cylinder 34 to move independent of the drill pipe carousel 16.

[0034] When the locking device 36 is in the locked position, the drill pipe carousel 16 rotates axially in relation to the movement of the hydraulic cylinder 34. According to the illustrated embodiment of FIG. 5, the drill pipe carousel 16 is indexed in a clockwise direction as the hydraulic cylinder 34 is moved from a retracted position to an extended position. For instance, the drill pipe carousel 16 and hydraulic cylinder 34 may be configured such that an adjacent slot 26 (i.e., adjacent to the loading position) is rotated clockwise to the loading position in response to the hydraulic cylinder 34 moving from a substantially retracted position to a substantially extended position.

[0035] In order to rotate the drill pipe carousel 16 in a counter-clockwise direction, the locking device 36 is moved to the unlocked position, de-coupling the hydraulic cylinder 34 from the drill pipe carousel 16. The hydraulic cylinder 34 may then be moved to the substantially extended position without rotating the drill pipe carousel 16. Once the hydraulic cylinder 34 is in the substantially extended position, the locking device 36 may be moved to the locked position, re-coupling the hydraulic cylinder 34 to the drill pipe carousel 16. In this configuration, as the hydraulic cylinder 34 is moved from the substantially extended position to the substantially retracted position, the coupled drill pipe carousel 16 is rotated in the counter-clockwise direction. In an exemplary embodiment and in this configuration, an adjacent slot 26 is moved counter-clockwise to the loading position when the hydraulic cylinder 34 is moved from the substantially extended position to the substantially retracted position.

[0036] Referring further to FIG. 5, the automatic drill pipe add and remove system may include one or more sensors configured to monitor the axial rotation of the drill pipe carousel 16. For instance, the automatic drill pipe add and remove system may include a stroke sensor 38 (e.g., linear transducer, displacement sensor, motion sensor, etc.) configured to monitor the axial rotation direction of the drill pipe carousel 16 by monitoring the stroke motion of the hydraulic cylinder 34 between a first and second position (e.g., between the extended and retracted positions, etc.). In the illustrated embodiment of FIG. 5, the hydraulic cylinder 34 is configured to axially rotate the drill pipe carousel 16 in a clockwise direction as the hydraulic cylinder 34 moves from the retracted position to the extended position, and the hydraulic cylinder 34 is configured to axially rotate the drill pipe carousel 16 in a counter-clockwise direction as the hydraulic cylinder 34 moves from the extended position to the retracted position. The stroke sensor 38 is configured to send one or more signals to the control module 30 representing the stroke motion of the hydraulic cylinder 34 and/or the axial rotation direction of the drill pipe carousel 16. In some embodiments, the control module 30 is configured to receive one or more signals representing the stroke motion of the hydraulic cylinder 34, and to interpret the signals to calculate or determine the axial rotation direction of the drill pipe carousel 16. The control module 30 may also interpret the signals from the stroke sensor 38 to create one or more responses as part of the automatic drill pipe add and remove system. In some embodiments, the stroke sensor 38 is coupled to the hydraulic cylinder 34 (as shown in FIG. 5), but the stroke sensor 38 may also be positioned or mounted in another location suitable for monitoring the stroke motion of the hydraulic cylinder 34 and/or the axial rotation direction of the drill pipe carousel 16.

[0037] In an exemplary embodiment, the automatic drill pipe add and remove system may also include one or more

proximity sensors 40 (e.g., electromagnetic sensors, photoelectric sensors, etc.) configured to detect when the drill pipe carousel 16 has indexed to move the next slot 26 to the loading position. In some embodiments, the position of the hydraulic cylinder 34 may be used to determine whether an adjacent slot 26 of the drill pipe carousel 16 is sufficiently within the loading position. In these embodiments, the proximity sensors 40 may be positioned on either end of the hydraulic cylinder 34, or in another position within the drill tower 32 suitable for detecting whether the hydraulic cylinder 34 is in the substantially extended or substantially retracted position. The proximity sensors 40 may be triggered or activated when the hydraulic cylinder 34 is moved to the substantially extended or substantially retracted position, perhaps indicating that the drill pipe carousel 16 has been indexed to the next slot 26. The proximity sensors 40 are configured to send one or more signals to the control module 30 when the proximity sensors 40 are triggered or activated.

[0038] The automatic drill pipe add and remove system may also include a lock sensor 46 (e.g., proximity sensor, electromagnetic sensor, photoelectric sensor, etc.) configured to detect whether the locking device 36 is in the locked position or the unlocked position. The lock sensor 46 may be coupled to the locking device 36 (as shown in FIG. 5), or mounted or positioned in another location within the drill tower 32 suitable for detecting whether the locking device 36 is in the locked position or the unlocked position. The lock sensor 46 may be triggered or activated when the locking device 36 is moved to the locked or unlocked position. The lock sensor 46 is configured to send one or more signals to the control module 30 when the lock sensor 46 is triggered or activated. In an exemplary embodiment, the control module 30 is programmed to use the signals from the lock sensor 46 to determine whether the locking device 36 is in the locked or unlocked position, and thus whether movement of the hydraulic cylinder 34 will cause the drill pipe carousel 16 to rotate.

[0039] The automatic drill pipe add and remove system may also include drill sensor 48 (e.g., proximity sensor, high frequency proximity switch, velocity monitoring device, etc.). In an exemplary embodiment, the drill sensor 48 is configured to monitor a rotation of the drill head 18, sending one or more signals to the control module 30 representing the rotation speed and/or other characteristics or conditions of the drill head 18. The control module 30 may receive and interpret the signals for use with the automatic drill pipe add and remove system, such as in the illustrated embodiments of FIGS. 12-28.

[0040] In the illustrated embodiment of FIG. 6, the automatic drill pipe add and remove system includes a rotation sensor shown as index encoder 42 (e.g., absolute encoder, proximity switch, motion sensor, etc.) configured to detect an axial rotation direction and position of the drill pipe carousel 16. Particularly, the index encoder 42 may be configured to detect which of the slots 26 is in the loading position. In an exemplary embodiment, the index encoder 42 is coupled to the drill pipe carousel 16. However, the index encoder 42 may be coupled to another component of the drill tower 32 or positioned in another location suitable for detecting the axial rotation direction and/or position of the drill pipe carousel 16. According to the illustrated embodiment of FIG. 6, the drill pipe carousel 16 includes an axle that extends through the center or axis of the drill pipe carousel 16, and a small extension shaft 82 that extends through a carousel arm 78 to couple

the drill pipe carousel 16 to the carousel arm 78. In this embodiment, the index encoder 42 is coupled to the extension shaft 82 and positioned such that the index encoder 42 is able to monitor the axial rotation and the position of the drill pipe carousel 16. From its location through the central axis of the drill pipe carousel 16, the index encoder 42 is configured to monitor the absolute rotation position of the drill pipe carousel 16, as well as the direction of rotation. The index encoder 42 is also configured to send one or more signals to the control module 30 representing the axial rotation and the rotational position of the drill pipe carousel 16.

[0041] Referring further to FIG. 7, a cross-section view of the drill pipe carousel 16 is shown, according to an exemplary embodiment. In the illustrated embodiment of FIG. 7, the drill pipe carousel 16 includes slots 62, 64, and 66, with the drill pipe carousel 16 oriented such that the slot 62 is located within the loading position. In this embodiment, the automatic drill pipe add and remove system includes slot sensors 58 and 60 coupled to the drill pipe carousel 16 and configured to detect the presence of pipe segments 14 within slots (e.g., slots 64 and 66, etc.) adjacent to the loading position. When the drill pipe carousel 16 is in the orientation of FIG. 7, the slot sensor 58 monitors slot 64 and the slot sensor 60 monitors slot 66 in order to determine whether the slots 64 and 66 are empty or holding a pipe segment 14. The slot sensors 58 and 60 are configured to send one or more signals to the control module 30 representing the availability of a pipe segment 14 or an empty slot. When the drill pipe carousel 16 is rotated in a clockwise direction, the slot sensor 60 may be used to locate a pipe segment 14 or an empty slot for adding or removing a pipe segment 14, respectively. Likewise, when the drill pipe carousel 16 is rotated in a counter-clockwise direction, the slot sensor 58 may be used to locate a pipe segment 14 or an empty slot for adding or removing a pipe segment 14, respectively.

[0042] Referring now to FIG. 8, a schematic 800 for the automatic drill pipe add and remove system is shown, according to an exemplary embodiment. In this embodiment, the control module 30 is configured to receive inputs (e.g., signals, instructions, commands, etc.) from one or more components (e.g., the sensor assembly, operator interface 80, etc.) of the automatic drill pipe add and remove system, and to create a response intended to facilitate the automatic addition or removal of pipe segments 14 from the drill string 12. The control module 30 may be configured to wirelessly communicate with one or more components of the automatic drill pipe add and remove system, receiving feedback data (e.g. equipment status, position of drilling rig 10 components, exceptions, alarms, etc.) from one or more components of the system and monitoring the actions and/or status of the system.

[0043] Referring now to FIG. 9, a flow chart representing an algorithm 900 for the automatic drill pipe add and remove system is shown, according to an exemplary embodiment. In this embodiment, the control module 30 is configured to initialize before beginning the drilling operation (step 902). In an exemplary embodiment, the operator inputs a desired drill depth for the drilling rig 10 into an operator interface 80 and the desired drill depth is sent to the control module 30 (step 904). In some embodiments, the operator may instruct the control module 30 to initiate the automated drill pipe add and remove process by pressing a single button, such as an "Auto-Drill" button located on the operator interface 80, or by taking another similar action suitable for sending a signal or instructions to the control module 30. The control module 30

determines whether there are enough pipe segments 14 available within the drill pipe carousel 16 to achieve the desired drill depth, or whether the available number of pipe segments 14 can achieve the depth (step 906). In some embodiments, the control module 30 is configured to interpret signals from the slot sensors 58 and 60 in order to determine how many pipe segments 14 are available within the drill pipe carousel 16. If the pipe segments 14 available will not provide enough length for the drill string 12 to reach the desired drill depth, the system is stopped (step 908), but if there are enough pipe segments 14, the control module 30 determines whether the desired drill depth has been reached (step 910). If the desired depth is not reached, the control module 30 determines whether the drill head 18 has reached the deck 28, or a bottom limit, of the drilling rig 10 (step 912). If the drill head 18 does not reach the deck 28, the control module 30 causes the drilling rig 10 to automatically drill (step 914). If the drill head 18 does reach the deck 28, the automatic drill pipe add and remove system automatically adds one pipe segment 14 to the drill string 12 (step 916) and the control module 30 causes the drilling rig 10 to automatically drill (step 914).

[0044] Referring now to FIGS. 10-17, the automatic drill pipe add and remove system automatically adds a pipe segment 14 to the drill string 12 by using the control module 30 to interpret signals from the sensor assembly and to control one or more components of the drilling rig 10. In an exemplary embodiment, the control module 30 is programmed to determine the position of the drill pipe carousel 16 based on signals received from the index encoder 42. If the slot 26 within the loading position is not holding a pipe segment 14, the control module 30 is programmed to determine whether an adjacent slot 26 holds a pipe segment 14 based on signals received from slot sensors 58 and 60. If an adjacent slot 26 holds a pipe segment 14, the control module 30 causes the drill pipe carousel 16 to rotate so that the slot 26 holding a pipe segment 14 is indexed to the loading position. The control module 30 may cause the drill pipe carousel 16 to index by causing the hydraulic cylinder 34 to retract or extend, depending on the signals received from stroke sensor 38 (measuring the axial rotation direction of the drill pipe carousel 16), proximity sensors 40 (determining whether the hydraulic cylinder 34 has substantially extended or retracted) and 46 (monitoring the position of the locking device 36), and slot sensors 58 and 60 (monitoring whether one or more slots 26 holds a pipe segment 14).

[0045] To disassemble the drill string 12, the control module 30 is configured to cause the drill string 12 to raise so that the pipe segment 14 of the drill string 12 is aligned with the deck wrench 22. The control module 30 then causes the deck wrench 22 to engage the pipe segment 14. The automatic drill pipe add and remove system may include a sensor (not shown) configured to detect whether the deck wrench 22 engages the pipe segment 14, and to send one or more signals to the control module 30 conveying the information. Once the pipe segment 14 is engaged, the control module 30 may cause the drill head 18 and top adapter 20 to rotate in order to disconnect from the pipe segment 14. Signals received from the sensor assembly may be used to determine a compatible unscrew rate for the drill head 18. For instance, the drill sensor 48 may be configured to monitor a rotation speed of the drill head 18, and to send one or more signals to the control module 30 representing the rotation speed of the drill head 18. In an exemplary embodiment, the drill sensor 48 includes a high frequency proximity switch configured to monitor the rota-

tion speed of the drill head 18. In this embodiment, the drill head 18 includes a drive gear having teeth, with each tooth configured to trigger the proximity switch as the drill head 18 rotates, creating one or more signals. In some embodiments, the drill sensor 48 uses the signals produced by the high frequency proximity switch to determine the rotation speed of the drill head 18, sending one or more signals to the control module 30 representing the rotation speed of the drill head 18. In other embodiments, the drill sensor 48 sends the signals directly from the proximity switch to the control module 30, and the control module 30 interprets the signals to calculate the rotation speed of the drill head 18. In other embodiments, the drill sensor 48 may be configured to send signals to the control module 30 representing any other conditions of the drill head 18 and/or the drill string 12 suitable for calculating or determining the rotation speed of the drill head 18. The control module 30 may be configured to use the signals from the drill sensor 48 or another sensor of the sensor assembly to calculate or determine a compatible unscrew rate, and/or to control the unscrew rate of the drill head 18.

[0046] Referring further to FIG. 12, once the drill head 18 and top adapter 20 are removed from the drill string 12, the control module 30 may raise the drill head 18 and top adapter 20 to a height above the drill pipe carousel 16. In some embodiments, a depth sensor (not shown) is used to monitor the height or another position of the drill head 18, the top adapter 20, or another component of the drilling rig 10. In these embodiments, the depth sensor is configured to send one or more signals representing the height or position of one or more components of the drilling rig 10 to the control module 30. The control module 30 is configured to interpret the signals from the depth sensor to control the position of one or more components of the drilling rig 10, such as the drill head 18 and the top adapter 20.

[0047] Referring further to FIG. 13, once the drill head 18 and top adapter 20 are raised above the drill pipe carousel 16, the control module 30 is configured to swing the drill pipe carousel 16 to the add/remove position. The swing sensor 44 monitors the position of the drill pipe carousel 16, and is configured to send one or more signals to the control module 30 representing the swing position of the drill pipe carousel 16. In an exemplary embodiment, the control module 30 receives signals from the swing sensor 44 and is programmed to determine the position of the drill pipe carousel 16 based on the signals. If the drill pipe carousel 16 is not in the add/remove position, the control module 30 is configured to cause the drill pipe carousel 16 to swing into the add/remove position.

[0048] Referring further to FIGS. 14 and 15, once the drill pipe carousel 16 is in the add/remove position, the control module 30 may cause the drill head 18 and top adapter 20 to rotate, connecting the top adapter 20 to the spare pipe segment 14 within the drill pipe carousel 16. The control module 30 may use signals from the depth sensor and/or the drill sensor 48 in order to determine the position of the components and/or the compatible screw-on rate for the components. The drill head 18 and top adapter 20 are rotated clockwise relative to the spare pipe segment 14 until the threads of the spare pipe segment 14 and the top adapter 20 are mated completely, connecting the spare pipe segment 14 to the top adapter 20 and coupling the spare pipe segment 14 to the drill head 18. Once the spare pipe segment 14 is coupled to the drill head 18 and top adapter 20, the control module 30 may raise the drill head 18, lifting the spare pipe segment 14 from the

slot 26 of the drill pipe carousel 16. The depth sensor may be configured to monitor the position of the spare pipe segment 14 in order to ensure that the spare pipe segment 14 is sufficiently clear from the slot 26 before the drill pipe carousel 16 is moved to the stowed position.

[0049] Referring further to FIGS. 16 and 17, once the spare pipe segment 14 is clear from the slot 26 of the drill pipe carousel 16, the control module 30 may cause the drill pipe carousel 16 to swing out to the stowed position. The swing sensor 44 may send one or more signals to the control module 30 to indicate that the drill pipe carousel 16 is in the stowed position. The control module 30 may then lower the coupled drill head 18, top adapter 20, and spare pipe segment 14 to connect the spare pipe segment 14 to the pipe segment held by the deck wrench 22 to extend the length of the drill string 12.

[0050] Referring again to FIG. 9, the control module 30 repeats the process of adding pipe segments 14 until the desired depth is reached. Once the desired depth is reached, the control module 30 determines whether a drill component, such as a pipe segment 14 or a drill tool 54, is in the slot 26 in the loading position (step 918). If a drill component is in the slot 26 in the loading position, the process is stopped (step 908). The drill pipe carousel 16 may be rotated until the slot 26 in the loading position is empty. If a drill component is not in the slot 26 in the loading position, the control module 30 determines whether the drill head 18 is above the height of the drill pipe carousel 16, or above some other upper limit (step 920). If so, the automatic drill pipe add and remove system is configured to remove one pipe segment 14 (step 924). If not, the drill head 18 is hoisted (step 922) until the drill head 18 is above the height of the drill pipe carousel 16 or another upper height limit, and then a pipe segment 14 is removed (step 924).

[0051] Referring now to FIGS. 18-27, in order to remove a pipe segment 14 from the drill string 12, the control module 30 indexes the drill pipe carousel 16 until an empty slot 26 is in the loading position. In an exemplary embodiment, the control module 30 hoists the drill head 18 so that the deck wrench 22 is aligned with the removable pipe segment 14. The control module 30 may cause the deck wrench 22 to engage the removable pipe segment 14 in order to detect an orientation of the removable pipe segment 14. The drill sensor 48 or another sensor within the sensor assembly may monitor an orientation of the removable pipe segment 14 and send one or more signals representing the orientation to the control module 30. The control module 30 may then disengage the deck wrench 22 from the removable pipe segment 14, and hoist the drill head 18 so that the deck wrench is aligned with a portion of the drill string 12 below the removable pipe segment 14. In this embodiment, the control module 30 causes the deck wrench 22 to engage the drill string 12 to prevent the portion of the drill string 12 below the removable pipe segment 14 from rotating.

[0052] Once the deck wrench 22 is engaged, the control module 30 may cause the drill head 18 to rotate in a counter-clockwise direction, de-coupling the drill head 18, top adapter 20, and the removable pipe segment 14 from the rest of the drill string 12. The control module 30 may then cause the drill head 18 to raise, lifting the removable pipe segment 14 to a height corresponding to the height of the drill pipe carousel 16. Once the removable pipe segment 14 has been lifted to the appropriate height, the control module 30 may cause the drill pipe carousel 16 to swing to the add/remove position, so that the removable pipe segment 14 is positioned

above an empty slot 26 of the drill pipe carousel 16. The drill head 18 may then be lowered to position the removable pipe segment 14 within the empty slot 26. In an exemplary embodiment, the empty slot 26 is configured to prevent the removable pipe segment 14 from rotating. In this embodiment, the control module 30 may rotate the drill head 18 and top adapter 20 when the removable pipe segment 14 is within the empty slot 26, disconnecting the removable pipe segment 14 from the drill head 18 and top adapter 20, and storing the removable pipe segment 14 within the drill pipe carousel 16. The control module 30 may then cause the drill pipe carousel 16 to swing to the stowed position away from the drill string 12. Referring further to FIG. 9, the automatic drill pipe add and remove system may repeat this step of removing a pipe segment 14 from the drill string 12 (step 924) until the drill string 12 includes a single pipe segment 14.

[0053] The construction and arrangements of the automatic drill pipe add and remove system, as shown in the various exemplary embodiments, are illustrative only. Although only a few embodiments have been described in detail in this disclosure, many modifications are possible (e.g., variations in sizes, dimensions, structures, shapes and proportions of the various elements, values of parameters, mounting arrangements, use of materials, colors, orientations, etc.) without materially departing from the novel teachings and advantages of the subject matter described herein. Some elements shown as integrally formed may be constructed of multiple parts or elements, the position of elements may be reversed or otherwise varied, and the nature or number of discrete elements or positions may be altered or varied. The order or sequence of any process, logical algorithm, or method steps may be varied or re-sequenced according to alternative embodiments. Other substitutions, modifications, changes and omissions may also be made in the design, operating conditions and arrangement of the various exemplary embodiments without departing from the scope of the present invention.

INDUSTRIAL APPLICABILITY

[0054] The disclosed automatic drill pipe add and remove system may be implemented into any drilling machine having a drill string made up of one or more drill pipe segments. The disclosed automatic drill pipe add and remove system is intended to eliminate the need for operator involvement in adding or removing drill pipe segments by providing a sensor assembly for monitoring one or more components of the drilling machine and a control module for controlling the components of the drilling machine in response to signals received from the sensor assembly.

[0055] It will be apparent to those skilled in the art that various modifications and variations can be made to the disclosed automatic drill pipe add and remove system. Other embodiments will be apparent to those skilled in the art from consideration of the specification and practice of the disclosed automatic drill pipe add and remove system. It is intended that the specification and examples be considered as exemplary only, with a true scope being indicated by the following claims and their equivalents.

What is claimed is:

1. A drilling rig carousel assembly, comprising:
 - a drilling rig carousel comprising a plurality of slots for holding drill components;
 - a first actuator coupled to the drilling rig carousel and configured to axially rotate the drilling rig carousel;

- a second actuator coupled to the drilling rig carousel and configured to move the drilling rig carousel between a first position and a second position; and
 - a sensor assembly, comprising:
 - a rotation sensor configured to monitor an axial rotation of the drilling rig carousel; and
 - a position sensor configured to provide a signal representative of whether the drilling rig carousel is in the first position or the second position.
2. The assembly of claim 1, further comprising:
 - a lock coupled to the drilling rig carousel and configured to removably couple the first actuator to the drilling rig carousel.
 3. The assembly of claim 2, wherein the sensor assembly further comprises a lock sensor configured to monitor whether the lock is in a locked position or an unlocked position.
 4. The assembly of claim 1, further comprising:
 - a control module configured to receive signals from the sensor assembly, and to control a movement of the drilling rig carousel.
 5. The assembly of claim 4, wherein the control module is configured to cause the drilling rig carousel to axially rotate such that one of the plurality of slots is indexed to a loading position.
 6. The assembly of claim 5, wherein the sensor assembly further comprises a slot sensor configured to detect the presence of the drill components within one or more of the plurality of slots.
 7. The assembly of claim 6, wherein the control module is configured to cause the drilling rig carousel to axially rotate based on the presence of the drill components within one or more of the plurality of slots.
 8. The assembly of claim 6, wherein the slot sensor comprises proximity sensors coupled to the drilling rig carousel and configured to detect the presence of a drill component with a slot of the drilling rig carousel.
 9. The assembly of claim 1, wherein the assembly is part of a drilling rig, the drilling rig further comprising:
 - a drill string comprising one or more drill components; and
 - a control module configured to:
 - receive signals from the sensor assembly; and
 - control a movement of the drill string and the drilling rig carousel in order to add one or more of the drill components to the drill string from the drilling rig carousel, or to remove one or more of the drill components from the drill string and store within the drilling rig carousel.
 10. The assembly of claim 9, wherein the sensor assembly further comprises a drill sensor configured to monitor a rotation of the drill string.
 11. The assembly of claim 9, wherein the drilling rig carousel is positioned in axial alignment with the drill string in the first position, and the drilling rig carousel is positioned adjacent to the drill string in the second position.
 12. A drilling rig for drilling at a desired drill depth, the drilling rig comprising:
 - a drill string having a drill tool and comprising one or more drill pipe segments;
 - a drill pipe storage rack configured to store the one or more drill pipe segments;
 - a sensor assembly configured to monitor a position of the drill string and a position of the drill pipe storage rack;

an operator interface configured to receive one or more operator inputs; and
 a control module configured to:
 receive signals from the sensor assembly and the operator interface; and
 control a movement of the drill pipe storage rack and the drill string in order to add the one or more drill pipe segments from the drill pipe storage rack to the drill string, extending the drill string to reach the desired drill depth.

13. The drilling rig of claim **12**, wherein the sensor assembly comprises:
 a rotation sensor configured to monitor an axial rotation of the drill pipe storage rack; and
 a position sensor configured to provide a signal representative of whether the drill pipe storage rack is in a first position or a second position.

14. The drilling rig of claim **13**, further comprising:
 a first actuator coupled to the drill pipe storage rack and configured to axially rotate the drill pipe storage rack about a center axis of the drill pipe storage rack.

15. The drilling rig of claim **13**, further comprising:
 a second actuator coupled to the drill pipe storage rack and configured to move the drill pipe storage rack between the first position and the second position.

16. The drilling rig of claim **12**, wherein the sensor assembly further comprises a drill sensor configured to monitor a rotation of the drill string.

17. The drilling rig of claim **12**, wherein the drill pipe storage rack comprises a plurality of slots for holding the one or more drill pipe segments.

18. The drilling rig of claim **17**, wherein the sensor assembly comprises a slot sensor configured to monitor one or more slots of the drill pipe storage rack to determine whether a drill pipe segment is present within one of the plurality of slots.

19. An automatic drill pipe add and remove system for a drilling rig having a drill string, the system comprising:
 a sensor assembly configured to monitor a position of the drill string and a position of a drill pipe storage rack;
 an operator interface configured to receive one or more operator inputs; and
 a control module configured to:
 receive signals from the sensor assembly;
 receive a desired drill depth from the operator interface;
 determine a desired drill string length for reaching the desired drill depth; and
 automatically add drill pipe segments to the drill string until the drill string reaches the desired drill string length.

20. The system of claim **19**, wherein the control module is configured to automatically remove one or more of the drill pipe segments once the desired drill depth is reached such that the drill string comprises a single drill pipe segment.

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