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United States Patent Application Publication 20250263997
Kind Code A1
Publication Date August 21, 2025
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# ELECTRIC ANNULAR BLOWOUT PREVENTER WITH RADIAL COMPRESSION OF PACKER


## Abstract

An annular blowout preventer includes an annular body including a central bore extending therethrough, a plurality of electric motors disposed circumferentially around the annular body; a packer assembly disposed within the annular body about the central bore; and a plurality of pusher plates disposed in the annular body; each pusher plate configured to radially engage the packer assembly. The packer assembly includes a packer element and a donut that circumferentially surrounds the packer element. The plurality of pusher plates is correspondingly connected to the plurality of electric motors via a connecting rod.



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**Family ID:** **1000008630982**

**Appl. No.:** **19/111322**

**Filed (or PCT Filed):** **September 25, 2023**

**PCT No.:** **PCT/US2023/075023**


## Publication Classification

**Int. Cl.:** **E21B33/06** (20060101)

**U.S. Cl.:**

CPC **E21B33/061** (20130101);

## Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION [0001] This application claims the benefit of and priority to U.S. Provisional Patent Application No. 63/377,645, entitled “ELECTRIC ANNULAR BLOWOUT PREVENTER WITH RADIAL COMPRESSION OF PACKER” and filed Sep. 29, 2022, and U.S. Provisional Patent Application No. 63/498,066, entitled “ELECTRIC ANNULAR BLOWOUT PREVENTER WITH RADIAL COMPRESSION OF PACKER” and filed Apr. 25, 2023, which are incorporated by reference herein in their entirety.

BACKGROUND

[0002] Current blowout preventer (“BOP”) systems utilize either direct hydraulic control or an electro/hydraulic hybrid to power and operate the installed BOP. In recent operator driven purchasing specifications, BOP equipment has been required to operate in deeper and more challenging environments while at the same time improving operational availability. These increased requirements have provided situations where a failure of the hydraulic operating system can result in significant and costly downtime. Accordingly, there is a need to electrically control and operate BOPs.

SUMMARY

[0003] One or more embodiments of the present disclosure is directed to an annular BOP including an annular body including a central bore extending therethrough, a plurality of electric motors disposed circumferentially around the annular body, a packer assembly disposed within the annular body about the central bore, the packer assembly including a packer element, and a donut that circumferentially surrounds the packer element, and a plurality of pusher plates disposed in the annular body, each pusher plate configured to radially engage the packer assembly, wherein the plurality of pusher plates is correspondingly connected to the plurality of electric motors via a connecting rod.

[0004] According to one or more embodiments of the present disclosure, an annular BOP includes an annular body including a central bore extending therethrough, at least one pivot point fixed to a top surface of the annular body, an electric motor pivotally connected to the at least one pivot point, a pushrod disposed longitudinally within the electric motor, a cam ring disposed around an exterior outer diameter of the annular body, a packer assembly disposed within the annular body about the central bore, the packer assembly including a packer element, and a donut that circumferentially surrounds the packer element, at least one pusher plate disposed in the annular body, the at least one pusher plate configured to radially engage the packer assembly, a connecting rod that directly engages the at least one pusher plate, wherein the cam ring directly interfaces with the connecting rod, and at least one pivot pin disposed in an axial position with respect to the annular body, wherein the cam ring provides a housing for the at least one pivot pin, wherein an end of the pushrod is fixed within the at least one pivot pin, and wherein rotation of the cam ring by the electric motor via the pushrod and the pivot pin is a first direction drives the connecting rod into the at least one pusher plate.

[0005] According to one or more embodiments of the present disclosure, a method of operating an annular BOP, including an annular body having a central bore extending therethrough; and a packer assembly disposed within the annular body about the central bore, includes actuating a plurality of actuators disposed circumferentially around the annular body, wherein the plurality of actuators are correspondingly connected to the plurality of pusher plates disposed in the annular body via a connecting rod; radially compressing the packer assembly via the plurality of pusher plates; and moving the annular BOP from an open position to a closed position.

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## Description

## BRIEF DESCRIPTION OF THE DRAWINGS

[0006] Certain embodiments of the disclosure will hereafter be described with reference to the accompanying drawings, wherein like reference numerals denote like elements. It should be understood, however, that the accompanying figures illustrate the various implementations described herein and are not meant to limit the scope of various technologies described herein, and:

[0007] FIG. **1** shows a schematic view of an embodiment of a drilling system including a BOP, according to one or more embodiments of the present disclosure;

[0008] FIG. **2** shows a front view of a BOP stack including an annular BOP, according to one or more embodiments of the present disclosure;

[0009] FIG. **3**A shows a cutaway view of an annular BOP, according to one or more embodiments of the present disclosure;

[0010] FIG. **3**B shows a cutaway view of an annular BOP, according to one or more embodiments of the present disclosure;

[0011] FIGS. **4**A and **4**B show an annular BOP that implements a cam ring for actuation, according to one or more embodiments of the present disclosure;

[0012] FIGS. **5**A-**5**G show an annular BOP that implements a cam ring for actuation, according to one or more embodiments of the present disclosure; and

[0013] FIGS. **6**A and **6**B show an annular BOP that implements a lever arm for actuation, according to one or more embodiments of the present disclosure.

## DETAILED DESCRIPTION

[0014] In the following description, numerous details are set forth to provide an understanding of some embodiments of the present disclosure. 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 disclosure. These are, of course, merely examples and are not intended to be limiting. However, it will be understood by those of ordinary skill in the art that the system and/or methodology may be practiced without these details and that numerous variations or modifications from the described embodiments are possible. This description is not to be taken in a limiting sense, but rather made merely for the purpose of describing general principles of the implementations. The scope of the described implementations should be ascertained with reference to the issued claims.

[0015] As used herein, the terms “connect”, “connection”, “connected”, “in connection with”, and “connecting” are used to mean “in direct connection with” or “in connection with via one or more elements”; and the term “set” is used to mean “one element” or “more than one element”. Further, the terms “couple”, “coupling”, “coupled”, “coupled together”, and “coupled with” are used to mean “directly coupled together” or “coupled together via one or more elements”. As used herein, the terms “up” and “down”; “upper” and “lower”; “top” and “bottom”; and other like terms indicating relative positions to a given point or element are utilized to more clearly describe some elements. Commonly, these terms relate to a reference point at the surface from which drilling operations are initiated as being the top point and the total depth being the lowest point, wherein the well (e.g., wellbore, borehole) is vertical, horizontal or slanted relative to the surface.

[0016] Recent developments in electric motor control and control system methodologies have provided the flexibility and feasibility to control and operate BOPs electrically rather than using hydraulics. Accordingly, one or more embodiments of the present disclosure relate to electric BOP systems and methods of using the same, which may be used to seal, control, and monitor hydrocarbon wells. Advantageously, these electric BOP systems may be more reliable and efficient than hydraulic BOP systems, while reducing operating costs, and size and weight for the overall pressure control equipment.

[0017] Referring now to FIG. **1**, a drilling system **10** for drilling and/or producing a well is shown. According to one or more embodiments of the present disclosure, the system **10** includes a BOP

stack **11** mounted to a wellhead **12** disposed at the surface **13** above a wellbore **19** extending into an earthen subterranean formation **23**. According to one or more embodiments of the present disclosure, the BOP stack **11** includes an annular BOP **100** at an upper end thereof, as shown in FIG. **2**, for example. As also shown in FIG. **2**, the BOP stack **11** may also include a plurality of ram-type BOPs **14** in addition to the annular BOP **100**. As will be further described below, the annular BOP **100** includes an annular packer engaged by one or more actuators, where upon actuation, the annular packer seals the bore of the annular BOP **100**.

[0018] Referring back to FIG. **1**, a drill string **16** extends from a drilling rig or platform **20**. According to one or more embodiments of the present disclosure, platform **20** includes a derrick or mast **21** that extends from a rig floor **22** of platform **20**. A primary conductor **18** of well system **10** extends from wellhead **12** into wellbore **19**. BOP stack **11** (including annular BOP **100**), wellhead **12**, and conductor **18** are arranged such that each shares a common central or longitudinal axis **25**. In other words, BOP stack **11**, wellhead **12**, and conductor **18** are coaxially aligned.

[0019] During operation of drilling system **10**, drill string **16** extends into wellbore **19** via an internal bore of BOP stack **11** and wellhead **12**, where the drill string **16** includes a drill bit **17** coupled to a lower end thereof. In this operation, drilling fluid is pumped from platform **20**, through drill string **16**, and into wellbore **19** via ports disposed in drill bit **17**. From wellbore **19**, the pumped drilling fluid is recirculated to platform **20** via an annulus **27** extending between an outer surface of drill string **16** and an inner surface of wellbore **19**. During operation of well system **10**, it may become necessary to fluidly isolate wellbore **19** from surrounding environment, such as in the case of an uncontrolled influx of fluid into wellbore **19** from the subterranean earthen formation **23**. In such an event, BOP stack **11** (including annular BOP **100**) is configured to restrict fluid communication between wellbore **19** and the surrounding environment. According to one or more embodiments of the present disclosure, annular BOP **100** is actuated from a first or open position to a second or closed position sealing against drill pipe **16** in response to an uncontrolled influx of fluid into wellbore **19** from formation **23**. In other instances, annular BOP **100** may be actuated from the open position to the closed position to seal wellbore **9** from the surrounding environment when drill string **16** is disposed within the bore of BOP **100**. Although annular BOP **100** is shown as forming a part of BOP stack **11** of drilling system **10**, in other embodiments of the present disclosure, annular BOP **100** may be used in other well drilling systems, including offshore well systems, for example.

[0020] One or more embodiments of the present disclosure include apparatus and methods of driving connecting rods to radially compress a packer of an annular BOP, thereby closing the bore through the annular BOP. For example, FIGS. **3**A and **3**B are cutaway views of an annular BOP **100** showing direct-acting radial push by a plurality of connecting rods **114**. To facilitate discussion, the annular BOP **100** and its components may be described with reference to an axial axis or direction **30**, a radial axis or direction **32**, and a circumferential axis or direction **34**. Referring to FIG. **3**A, the annular BOP **100** includes an annular body **102** having a central bore **104** extending axially therethrough. Drill strings, tools, and other objects may be passed through the central bore **104** of the annular body **102** of the annular BOP **100**, according to one or more embodiments of the present disclosure. The annular BOP **100** according to one or more embodiments of the present disclosure includes an open position, which provides fluid communication through the central bore **104** of the annular body **102**, and a closed position, which restricts fluid communication through the central bore **104** of the annular body **102**. As shown in FIG. **3**A, the annular BOP **100** may also include an annular top **103** coupled to the annular body **102**, according to one or more embodiments of the present disclosure.

[0021] As further shown in FIG. **3**A, the annular BOP **100** also includes a plurality of actuators **106** disposed circumferentially around the annular body **102** of the annular BOP **100**. As shown in FIG. **3**A, for example, the plurality of actuators may be disposed in a radial position circumferentially around the annular body **102** of the annular BOP **100**. According to one or more embodiments of

the present disclosure, the plurality of actuators **106** includes a plurality of electric motors as described in more detail below. However, the plurality of actuators **106** may employ other devices and methodologies for actuation of the annular BOP **100** without departing from the scope of the present disclosure. As shown in FIG. **3**A, for example, the plurality of actuators **106** disposed circumferentially around the annular body **102** of the annular BOP **100** may include at most four actuators. However, this number is not limiting, and the plurality of actuators **106** may include other amounts of actuators disposed circumferentially around the annular body **102** of the annular BOP **100** without departing from the scope of the present disclosure. For example, the plurality of actuators **106** includes a number of actuators that provides at least a minimum amount of force necessary to squeeze a packer assembly of the annular BOP **100** around an object disposed in the central bore **104** of the annular BOP **100**, or to otherwise seal an open central bore **104** of the annular BOP **100**, as further described below.

[0022] As further shown in FIG. **3**A, the annular BOP **100** includes a packer assembly **107** disposed within the annular body **102** about the central bore **104**, according to one or more embodiments of the present disclosure. The packer assembly **107** according to one or more embodiments of the present disclosure includes a packer element **108**, and a donut **110** that circumferentially surrounds the packer element **108**. According to one or more embodiments of the present disclosure, the packer element **108** and the donut **110** each include a flexible material, such as an elastomeric material, for example. According to one or more embodiments of the present disclosure, the packer element **108** and the donut **110** may be made of the same or different flexible materials. Moreover, the packer element **108** and the donut **110** may be formed as separate or integral components according to one or more embodiments of the present disclosure.

[0023] The packer assembly **107** according to one or more embodiments of the present disclosure may also include at least one insert **109** extending axially through the packer element **108**. According to one or more embodiments of the present disclosure, the at least one insert **109** may include a rigid material such as a metal or a metal alloy, for example. Advantageously, the at least one insert **109** provides support and reinforcement to the packer element **108**, according to one or more embodiments of the present disclosure. It should be appreciated that the packer element **108**, the at least one insert **109**, and the donut **110** of the packer assembly **107** may have any of a variety of configurations without departing from the scope of the present disclosure.

[0024] As further shown in FIG. **3**A, the annular BOP **100** includes a plurality of pusher plates **112** disposed in the annular body **102** of the annular BOP **100**, according to one or more embodiments of the present disclosure. As shown in FIG. **3**A, the plurality of pusher plates **112** is correspondingly connected to the plurality of actuators **106** disposed circumferentially around the annular body **102** of the annular BOP **100** via a connecting rod **114**. As also shown in FIG. **3**A, each pusher plate of the plurality of pusher plates **112** is configured to radially engage the packer assembly **107** via a contacting surface **113** of the pusher plate **112**, according to one or more embodiments of the present disclosure. With this configuration of the annular BOP **100**, in operation, each actuator of the plurality of actuators **106** may work in unison to drive the connecting rod **114** into the corresponding pusher plate **112**. Because the plurality of pusher plates **112** radially engages the packer assembly **107** via the contacting surface **113** of the pusher plate **112**, driving the connecting rod **114** into the corresponding pusher plate **112** of the plurality of pusher plates **112** radially compresses the packer assembly **107**, thereby squeezing the donut **110** and applying a radial pressure on an outer circumference of the packer element **108** to seal the central bore **104** of the annular BOP **100**. In this way, the annular BOP **100** is able to move from the open position to the closed position, as previously described. According to one or more embodiments of the present disclosure, in the closed position, the packer element **108** engages with an external surface of and seals around an object (e.g., a tubular, a drill string, a tool, etc.) positioned in the central bore **104** of the annular body **102**. Alternatively, if there is no object positioned in the central bore **104** of the annular body **102**, the packer element **108** may seal the

open central bore **104** of the annular BOP **100** while in the closed position. According to one or more embodiments of the present disclosure, using the plurality of actuators **106** to reverse the direction of travel of the connecting rod **114** releases the radial pressure applied to the packer element **108** by the donut **110** via the plurality of pusher plates **112**, thus allowing the packer clement **108** and the donut **110** to relax, thereby moving the annular BOP **100** from the closed position back to the open position.

[0025] As previously described, the plurality of pusher plates **112** of the annular BOP **100** is correspondingly connected to the plurality of actuators **106** disposed circumferentially around the annular body **102** of the annular BOP **100** via a connecting rod **114**. As such, the plurality of pusher plates **112** is disposed around an inner circumference of the annular body **102** of the annular BOP **100**. According to one or more embodiments of the present disclosure, the plurality of pusher plates **112** is spaced around the inner circumference of the annular body **102** of the annular BOP **100** such that adjacent pusher plates of the plurality of pusher plates **112** do not interlock with one another when the annular BOP **100** is in the closed position. However, adjacent pusher plates of the plurality of pusher plates **112** may substantially overlap with each other to prevent unwanted extrusion of the donut **110** and/or the packer element **108** of the annular BOP **100**, according to one or more embodiments of the present disclosure.

[0026] As previously described, the plurality of actuators **106** disposed circumferentially around the annular body **102** of the annular BOP **100** may include a plurality of electric motors according to one or more embodiments of the present disclosure. In operation, actuation of the plurality of electric motors **106** of the annular BOP **100** in unison drives the connecting rod **114** into the corresponding pusher plate of the plurality of pusher plates **112** to move the annular BOP **100** from the open position to the closed position. According to one or more embodiments of the present disclosure, each electric motor of the plurality of electric motors **106** may be connected to a gearbox and a roller screw to facilitate the driving of the connecting rod **114** into the corresponding pusher plate of the plurality of pusher plates **112**. In such embodiments, the gearbox may be a cycloidal gearbox according to one or more embodiments of the present disclosure. More specifically, for example, actuation of the plurality of electric motors **106** of the annular BOP **100** in unison includes rotating each electric motor, transmitting rotary motion from the electric motor to the gearbox, transforming the rotary motion into linear motion using the roller screw, and using the linear motion to drive the connecting rod **114** into the corresponding pusher plate of the plurality of pusher plates **112**, according to one or more embodiments of the present disclosure. Additional details as to how rotary motion from each electric motor of the plurality of electric motors **106** may be transformed into linear motion to drive the connecting rod **114** are provided in U.S. Provisional Patent Application No. 63/363,727 entitled “ELECTRIC BLOWOUT PREVENTER BONNET USING LINEAR ACTUATED ROLLER SCREWS,” filed Apr. 28, 2022, which is incorporated by reference herein in its entirety.

[0027] Referring now to FIG. **3**B, a cutaway view of an annular BOP **100** showing directing-acting radial push by the connecting rods **114** is shown. To facilitate discussion, the annular BOP **100** of FIG. **3**B and its components may be described with reference to an axial axis or direction **30**, a radial axis or direction **32**, and a circumferential axis or direction **34**. Similar to the annular BOP **100** shown in FIG. **3**A, the annular BOP **100** of FIG. **3**B includes an annular body **102** having a central bore **104** extending therethrough, a plurality of electric motors **106** disposed circumferentially around the annular body **102**, a packer assembly **107** disposed within the annular body **102** about the central bore **104**, and a plurality of pusher plates **112** disposed in the annular body **102**, as previously described.

[0028] As previously described, each electric motor of the plurality of electric motors **106** may be connected to a gearbox and a roller screw to facilitate driving of the connecting rod **114** into the corresponding pusher plate of the plurality of pusher plates **112**, according to one or more embodiments of the present disclosure. As shown in FIG. **3**B, for example, the connecting rod **114**

may be disposed in a front housing **111** connected to the annular body **102**, and a roller screw assembly **124** including the roller screw **126** may be disposed in a rear housing **115** connected to the front housing **111**. Indeed, each electric motor of the plurality of electric motors **106** may be directly coupled to the gearbox **105**, or alternatively, may be coupled to the gearbox **105** via a clutch **117** disposed in a clutch housing **119**, as shown in FIG. **3**B, according to one or more embodiments of the present disclosure. As shown, the gearbox **105** may be disposed in a rear clutch housing **116** connected to the clutch housing **119**, according to one or more embodiments of the present disclosure. As further shown in FIG. **3**B, the gearbox **105** may be offset from the roller screw assembly **124**, according to one or more embodiments of the present disclosure. Moreover, the gearbox **105** may be offset from the roller screw assembly **124** in an axial direction as shown in FIG. **3**B, for example, according to one or more embodiments of the present disclosure. However, the orientation of the gearbox **105** with respect to the roller screw assembly **124** is non-limiting. Indeed, the gearbox **105** may be disposed in line with the roller screw assembly **124**, for example, according to one or more embodiments of the present disclosure.

[0029] Still referring to FIG. **3**B, a gearbox connector **118** may be disposed in the rear clutch housing **116** along with the gearbox **105**, the gearbox connector **118** being directly connected to the gearbox **105**, according to one or more embodiments of the present disclosure. Further, a roller screw connector **120** may be disposed in the rear housing **115** along with the roller screw **126**, the roller screw connector **120** being directly connected to the roller screw **126**, according to one or more embodiments of the present disclosure. As further shown in FIG. **3**B, a linkage **122** connects the offset gearbox **105** to the roller screw **126** via the gearbox connector **118** and the roller screw connector **120**, according to one or more embodiments of the present disclosure. Due to this configuration, actuation of the plurality of electric motors **106** of the annular BOP **100** in unison includes rotating each electric motor **106**, transmitting rotary motion from the electric motor **106** to the gearbox **105**, transmitting the rotary motion from the gearbox **105** to the roller screw **126** of the roller screw assembly **124** via the linkage **122** connected to the gearbox connector **118** and the roller screw connector **120**, transforming the rotary motion into linear motion using the roller screw assembly **124**, and using the linear motion to drive the connecting rod **114** into the corresponding pusher plate of the plurality of pusher plates **112**, according to one or more embodiments of the present disclosure. According to one or more embodiments of the present disclosure, an anti-rotation sleeve **121** may be disposed between the roller screw assembly **124** and the connecting rod **114**, as shown in FIG. **3**B for example, to prevent the connecting rod **114** from rotating. Additional details as to how rotary motion from each electric motor of the plurality of electric motors **106** may be transformed into linear motion to drive the connecting rod **114** are provided in U.S. Provisional Patent Application No. 63/363,727 entitled “ELECTRIC BLOWOUT PREVENTER BONNET USING LINEAR ACTUATED ROLLER SCREWS,” filed Apr. 28, 2022, which is incorporated by reference herein in its entirety.

[0030] Driving the connecting rod **114** into the corresponding pusher plate of the plurality of pusher plates **112** according to the embodiment shown in FIG. **3**B radially compresses the packer assembly **107** of the annular BOP **100**, thereby closing the bore **104** through the annular BOP **100**, as previously described. As also previously described, using the plurality of electric motors **106** to reverse the direction of travel of the connecting rod **114** releases the radial pressure applied to the packer element **108** by the donut **110** of the packer assembly **107** via the plurality of pusher plates **112**, thus allowing the packer element **108** and the donut **110** to relax, thereby moving the annular BOP **100** from the closed position back to the open position, according to one or more embodiments of the present disclosure.

[0031] Referring now to FIGS. **4**A and **4**B, an annular BOP **100** that implements a cam ring **123** for actuation is shown, according to one or more embodiments of the present disclosure. Specifically, FIG. **4**A shows a cutaway cross-sectional view of the annular BOP **100** implementing the cam ring **123**, and FIG. **4**B shows a top cross-sectional view of the same, according to one or more

embodiments of the present disclosure. To facilitate discussion, the annular BOP **100** of FIGS. **4**A and **4**B and its components may be described with reference to an axial axis or direction **30**, a radial axis or direction **32**, and a circumferential axis or direction **34**. Similar to the annular BOP **100** described above with respect to FIGS. **3**A and **3**B, the annular BOP **100** of FIG. **4**A includes an annular body **102** having a central bore **104** extending therethrough, a plurality of electric motors **106** disposed circumferentially around the annular body **102**, a packer assembly **107** disposed within the annular body **102** about the central bore **104**, and a plurality of pusher plates **112** disposed in the annular body **102**, as previously described. As shown in FIG. **4**A, for example, the plurality of electric motors **106** is disposed in an axial position according to one or more embodiments of the present disclosure.

[0032] As further shown in FIGS. **4**A and **4**B, the annular BOP **100** according to one or more embodiments of the present disclosure also includes a cam ring **123** disposed around an exterior outer diameter of the annular body **102**. As further shown in FIGS. **4**A and **4**B, the cam ring **123** may directly interface with the connecting rod **114**, according to one or more embodiments of the present disclosure. According to one or more embodiments of the present disclosure, the cam ring **123** is coupled to a given electric motor of the plurality of electric motors **106** via a gear and pinion assembly **125**, which includes a gear **127** and a pinion **129** connected to or integral within the given electric motor of the plurality of electric motors **106**. According to one or more embodiments of the present disclosure, the cam ring **123** provides a housing for the gear and pinion assembly **125**. According to one or more embodiments of the present disclosure, actuation of the of the plurality of electric motors **106** in unison causes the corresponding pinions **129** of the plurality of electric motors **106** to drive the gear **127** within the cam ring **123**, causing the cam ring **123** to rotate. Rotation of the cam ring **123** by the plurality of electric motors **106** in a first direction drives the connecting rod **114** into the corresponding pusher plate of the plurality of pusher plates **112**, according to one or more embodiments of the present disclosure. Driving the connecting rod **114** into the corresponding pusher plate of the plurality of pusher plates **112** according to the embodiment shown in FIGS. **4**A and **4**B radially compresses the packer assembly **107** of the annular BOP **100**, thereby closing the bore **104** through the annular BOP **100**, as previously described. As also previously described, using the plurality of electric motors **106** to reverse the direction of travel of the connecting rod **114** releases the radial pressure applied to the packer element **108** by the donut **110** of the packer assembly **107** via the plurality of pusher plates **112**, thus allowing the packer element **108** and the donut **110** to relax, thereby moving the annular BOP **100** from the closed position back to the open position, according to one or more embodiments of the present disclosure.

[0033] Referring now to FIGS. **5**A-**5**G, an annular BOP **100** that implements a cam ring **123** for actuation is shown, according to one or more embodiments of the present disclosure. Specifically, FIG. **5**A shows a perspective view of the annular BOP **100** implementing the cam ring **123**, FIG. **5**B shows a cutaway cross-sectional view of the same, FIG. **5**C shows a cross-sectional view of the same, FIG. **5**D shows a cross-sectional view of an electric motor **106** of the same, and FIGS. **5**F through **5**G show a sequence of how the electric motor **106** operates to rotate the cam ring **123** to drive the connecting rod **114** of the annular BOP **100**, according to one or more embodiments of the present disclosure. To facilitate discussion, the annular BOP **100** of FIGS. **5**A-**5**G and its components may be described with reference to an axial axis or direction **30**, a radial axis or direction **32**, and a circumferential axis or direction **34**. The annular BOP **100** of FIGS. **5**A-**5**C includes an annular body **102** having a central bore **104** extending therethrough and at least one pivot point **131** fixed to a top surface of the annular body **102**. According to one or more embodiments of the present disclosure, an electric motor **106** is pivotally connected to the at least one pivot point **131**. The annular BOP **100** according to one or more embodiments of the present disclosure also includes a pushrod **126** disposed longitudinally within the electric motor **106** that is configured to impart motion on the cam ring **123**. As further described below, this pushrod **126** may

be a roller screw, for example, according to one or more embodiments of the present disclosure.
[0034] Referring to FIGS. **5**A and **5**B, the annular BOP **100** according to one or more embodiments of the present disclosure also includes a cam ring **123** disposed around an exterior outer diameter of the annular body **102**, and at least one pivot pin **133** disposed in an axial position with respect to the annular body **102**. As shown in FIGS. **5**A and **5**B, the cam ring **123** provides a housing for the at least one pivot pin **133**, according to one or more embodiments of the present disclosure. Moreover, as best shown in FIG. **5**D, an end of the roller screw **126** is fixed within the at least one pivot pin **133**, according to one or more embodiments of the present disclosure. As further shown in FIGS. **5**A and **5**D, the at least one pivot pin **133** and the roller screw **126** are oriented to be substantially perpendicular to each other according to one or more embodiments of the present disclosure.
[0035] Similar to the annular BOP **100** described above with respect to FIGS. **3**A, **3**B, and **4**A, the annular BOP **100** shown in FIGS. **5**B-**5**C includes a packer assembly **107** disposed within the annular body **102** about the central bore **104** and at least one pusher plate **112** disposed in the annular body **102**, as previously described. As further shown in FIGS. **5**B-**5**C, the connecting rod **114** directly engages the at least one pusher plate **112**, and the cam ring **123** may directly interface with the connecting rod **114**, according to one or more embodiments of the present disclosure.
[0036] Referring now to FIG. **5**D, a cross-sectional view of the electric motor **106** of the annular BOP **100** implementing the cam ring **123** is shown according to one or more embodiments of the present disclosure. As previously described, the annular BOP **100** according to one or more embodiments of the present disclosure includes a roller screw **126** disposed longitudinally within the electric motor **106**. Specifically, the annular BOP **100** according to one or more embodiments of the present disclosure includes a motor adapter **139** having an aperture therethrough, and the roller screw **126** extends longitudinally through the aperture of the motor adapter **139**. As also shown in FIG. **5**D, a roller element **141** is disposed between the motor adapter **139** and the roller screw **126**. That is, the roller screw **126** and the roller element **141** are included in a roller screw assembly **124** of the annular BOP **100** according to one or more embodiments of the present disclosure. The electric motor **106** of the annular BOP **100** according to one or more embodiments of the present disclosure includes a rotor **135** and a stator **137**. As shown in FIG. **5**D, for example, the rotor **135** is disposed between the stator **137** and the motor adapter **139**. In operation, the rotor **135** rotates in response to electrical power supplied to the rotor **135** and/or the stator **137**, which may include a plurality of magnets, for example. As the rotor **135** rotates, the rotor **135** rotates the motor adapter **139**, which rotates the roller screw assembly **124** (i.e., the roller element **141** and the roller screw **126** extending longitudinally through the aperture of the motor adapter **139**). Rotation of the roller screw **126**, the end of which being fixed within the at least one pivot pin **133** as previously described, causes the at least one pivot pin **133** to pivot and the cam ring **123** to rotate. Because the cam ring **123** directly interfaces with the connecting rod **114**, rotation of the cam ring **123** by the rotor **135** of the electric motor **106** via the roller screw assembly **124** and the at least one pivot pin **133** in a first direction drives the connecting rod **114** into the at least one pusher plate **112**, as shown in FIGS. **5**B-**5**G, for example. Driving the connecting rod **114** into the at least one pusher plate **112** according to the embodiment shown in FIGS. **5**B and **5**C radially compresses the packer assembly **107** of the annular BOP **100**, thereby closing the bore **104** through the annular BOP **100**, as previously described. As also previously described, using the electric motor **106** to reverse the direction of travel of the connecting rod **114** releases the radial pressure applied to the packer element **108** by the donut **110** of the packer assembly **107** via the at least one pusher plate **112**, thus allowing the packer element **108** and the donut **110** to relax, thereby moving the annular BOP **100** from the closed position back to the open position, according to one or more embodiments of the present disclosure.
[0037] Referring now to FIGS. **5**E-**5**G, a sequence of how the electric motor **106** of the annular BOP **100** operates to rotate the cam ring **123** to drive the connecting rod **114** is shown, according to

one or more embodiments of the present disclosure. As shown in sequence from FIGS. **5**E-**5**G, the roller screw **126** extends into an extended position as the cam ring **123** rotates in a first direction (i.e., a clockwise direction) and drives the connecting rod **114** into the at least one pusher plate **112**, according to one or more embodiments of the present disclosure. On the other hand, as shown in sequence from FIGS. **5**G-**5**E, the roller screw **126** retracts into a retracted position as the cam ring **123** rotates in a second direction opposite the first direction (i.e., a counter-clockwise direction), causing the connecting rod **114** to move in the radially outward direction, according to one or more embodiments of the present disclosure. As further shown in FIGS. **5**E-**5**G, the electric motor **106** pivots with respect to the at least one pivot point **131** as the cam ring **123** rotates, according to one or more embodiments of the present disclosure.

[0038] Still referring to FIGS. **5**A-**5**G, the annular BOP **100** according to one or more embodiments of the present disclosure may include a plurality of pivot points **131** circumferentially fixed to the top surface of the annular body **102**; a plurality of electric motors **106** correspondingly pivotally connected to the plurality of pivot points **131**, each electric motor of the plurality of electric motors **106** having the roller screw **126** disposed longitudinally therewithin; a plurality of pivot pins **133** disposed in an axial position with respect to the annular body **102**, an end of a given roller screw **126** being fixed within each pivot pin of the plurality of pivot pins **133**; a plurality of pusher plates **112** disposed in the annular body **102**, each pusher plate of the plurality of pusher plates **112** configured to radially engage the packer assembly **107**; and a plurality of connecting rods **114** that correspondingly directly engages the plurality of pusher plates **112**. As shown in FIGS. **5**A-**5**B, the plurality of pivot points **131** may include four pivot points **131**, the plurality of electric motors **106** may include four electric motors **131**, the plurality of pivot pins **133** may include four pivot pins **133**, the plurality of pusher plates **112** may include four pusher plates **112**, and the plurality of connecting rods **114** may include four connecting rods **114**. However, these numbers are not limiting, and other amounts of components of the annular BOP **100** may be included without departing from the scope of the present disclosure. For example, the plurality of electric motors **106** includes a number of electric motors that provides at least a minimum amount of force necessary to squeeze a packer assembly of the annular BOP **100** around an object disposed in the central bore **104** of the annular BOP **100**, or to otherwise seal an open central bore **104** of the annular BOP **100**. Moreover, the number of the plurality of pivot points **131**, the number of the plurality of pivot pins **133**, the number of the plurality of pusher plates **112**, and the number of the plurality of connecting rods **114** may be the same as the number of the plurality of electric motors **106**, according to one or more embodiments of the present disclosure.

[0039] Still referring to FIGS. **5**A-**5**G, in the annular BOP **100** having a plurality of electric motors **106** according to one or more embodiments of the present disclosure, the plurality of electric motors **106** works in unison to rotate the cam ring **123** in the first direction to drive the plurality of connecting rods **114** into the corresponding pusher plates **112**, as previously described, which compresses the donut **110**, causing the donut **110** to apply a radial pressure on an outer circumference of the packer element **108**, thereby moving the annular BOP **100** from an open position to a closed position. As the cam ring **123** rotates in the first direction, the roller screw **126** extends to an extended position, and the plurality of electric motors **106** pivots with respect to the corresponding plurality of pivot points **131**, according to one or more embodiments of the present disclosure. Further, rotation of the cam ring **123** by the plurality of electric motors **106** in the second direction opposite to the first direction causes the plurality of connecting rods **114** to move in a radially outward direction, as previously described, which allows the packer element **108** and the donut **110** to relax, thereby moving the annular BOP **100** from the closed position to the open position. As the cam ring **123** rotates in the second direction opposite to the first direction, the roller screw **126** retracts to a retracted position, and the plurality of electric motors **106** pivots with respect to the corresponding plurality of pivot points **131**, according to one or more embodiments of the present disclosure.

[0040] Referring now to FIGS. **6**A and **6**B, an annular BOP **100** that implements a lever arm **143** for actuation is shown, according to one or more embodiments of the present disclosure. Specifically, FIG. **6**A shows a cutaway cross-sectional view of the annular BOP **100** implementing the lever arm **143** for actuation, and FIG. **6**B shows a top cross-sectional view of the same, according to one or more embodiments of the present disclosure. To facilitate discussion, the annular BOP **100** of FIGS. **6**A and **6**B and its components may be described with reference to an axial axis or direction **30**, a radial axis or direction **32**, and a circumferential axis or direction **34**. Similar to the annular BOP **100** described above with respect to FIGS. **3**A, **3**B, and **4**A, the annular BOP **100** of FIG. **6**A includes an annular body **102** having a central bore **104** extending therethrough, a plurality of electric motors **106** disposed circumferentially around the annular body **102**, a packer assembly **107** disposed within the annular body **102** about the central bore **104**, and a plurality of pusher plates **112** disposed in the annular body **102**, as previously described.

[0041] According to one or more embodiments of the present disclosure, the plurality of electric motors **106** includes a rotating motor or a linear actuator motor, for example.

[0042] As further shown in FIGS. **6**A and **6**B, the annular BOP **100** according to one or more embodiments of the present disclosure also includes a lever arm **143** powered by a given electric motor of the plurality of electric motors **106**, according to one or more embodiments of the present disclosure. As further shown in FIGS. **6**A and **6**B, the lever arm **143** is supported by a lever support **144** that extends radially outward from an exterior surface of the annular body **102** of the annular BOP **100**, and the lever arm **143** may directly interface with the connecting rod **114**, according to one or more embodiments of the present disclosure. That is, according to one or more embodiments of the present disclosure, each connecting rod **114** of the annular BOP **100** may have its own corresponding electric motor **106** and lever arm **143**. According to one or more embodiments of the present disclosure, the orientation of the lever arm **143** may be anywhere from perpendicular to parallel to the axis of the annular BOP **100**, for example. According to one or more embodiments of the present disclosure, actuation of the plurality of electric motors **106** in unison actuates the lever arm **143** corresponding to a given electric motor of the plurality of electric motors **106** in a first direction, which drives the connecting rod **114** directly interfacing with the lever arm **143** into the corresponding pusher plate **112** of the plurality of pusher plates **112**. Driving the connecting rod **114** into the corresponding pusher plate of the plurality of pusher plates **112** according to the embodiment shown in FIGS. **6**A and **6**B radially compresses the packer assembly **107** of the annular BOP **100**, thereby closing the bore **104** through the annular BOP **100**, as previously described. Reversing the direction of the rotating motor or de-energizing the linear actuator motor reverses the direction of travel of the connecting rod **114**, which releases the radial pressure applied to the packer element **108** by the donut **110** of the packer assembly **107** via the plurality of pusher plates **112**, thus allowing the packer element **108** and the donut **110** to relax, thereby moving the annular BOP **100** from the closed position back to the open position, according to one or more embodiments of the present disclosure.

[0043] As previously described, one or more embodiments of the present disclosure include apparatus and methods of driving connecting rods **114** into corresponding pusher plates **112** to radially compress a packer assembly **107** of an annular BOP **100**, thereby closing the bore **104** through the annular BOP **100**. According to one or more embodiments of the present disclosure, each connecting rod **114** of the annular BOP **100** may drive into a corresponding pusher plate **112** of the annular BOP **100**, and the annular BOP **100** may include pusher plates having different relative sizes without departing from the scope of the present disclosure. For example, the annular BOP **100** may include at least one pusher plate **112** having a first size, and the annular BOP **100** may include at least one pusher plate **112** having a second size smaller than the first size, according to one or more embodiments of the present disclosure.

[0044] Language of degree used herein, such as the terms “approximately,” “about,” “generally,” “substantially,” and “significantly” as used herein represent a value, amount, or characteristic close

to the stated value, amount, or characteristic that still performs a desired function or achieves a desired result. For example, the terms “approximately,” “about,” “generally,” “substantially,” and “significantly,” may refer to an amount that is within less than 10% of, within less than 5% of, within less than 1% of, within less than 0.1% of, and/or within less than 0.01% of the stated amount. As another example, in certain embodiments, the terms “generally parallel” and “substantially parallel” or “generally perpendicular” and “substantially perpendicular” refer to a value, amount, or characteristic that departs from exactly parallel or perpendicular, respectively, by less than or equal to 15 degrees, 10 degrees, 5 degrees, 3 degrees, 1 degree, or 0.1 degree.

[0045] Although a few embodiments of the disclosure have been described in detail above, those of ordinary skill in the art will readily appreciate that many modifications are possible without materially departing from the teachings of this disclosure. Accordingly, such modifications are intended to be included within the scope of this disclosure as defined in the claims. It is also contemplated that various combinations or sub-combinations of the specific features and aspects of the embodiments described may be made and still fall within the scope of the disclosure. It should be understood that various features and aspects of the disclosed embodiments can be combined with, or substituted for, one another in order to form varying modes of the embodiments of the disclosure. Thus, it is intended that the scope of the disclosure herein should not be limited by the particular embodiments described above.

## Claims

**1-18**. (canceled)

**19**. An annular blowout preventer (BOP), comprising: an annular body comprising a central bore extending therethrough; at least one pivot point fixed to a top surface of the annular body; an electric motor pivotally connected to the at least one pivot point; a pushrod disposed longitudinally within the electric motor; a cam ring disposed around an exterior outer diameter of the annular body; a packer assembly disposed within the annular body about the central bore, the packer assembly comprising: a packer element; and a donut that circumferentially surrounds the packer element; at least one pusher plate disposed in the annular body, the at least one pusher plate configured to radially engage the packer assembly; a connecting rod that directly engages the at least one pusher plate, wherein the cam ring directly interfaces with the connecting rod; and at least one pivot pin disposed in an axial position with respect to the annular body, wherein the cam ring provides a housing for the at least one pivot pin, wherein an end of the pushrod is fixed within the at least one pivot pin, and wherein rotation of the cam ring by the electric motor via the pushrod and the pivot pin in a first direction drives the connecting rod into the at least one pusher plate.

**20**. The annular BOP of claim 19, wherein driving the connecting rod into the at least one pusher plate compresses the donut, causing the donut to apply a radial pressure on an outer circumference of the packer element, thereby moving the annular BOP from an open position to a closed position.

**21**. The annular BOP of claim 20, wherein rotation of the cam ring by the electric motor via the pushrod and the pivot pin in a second direction opposite to the first direction causes the connecting rod to move in a radially outward direction, which allows the packer element and the donut to relax, thereby moving the annular BOP from the closed position to the open position.

**22**. The annular BOP of claim 19, wherein the electric motor pivots with respect to the at least one pivot point as the cam ring rotates.

**23**. The annular BOP of claim 19, further comprising: a plurality of pivot points circumferentially fixed to the top surface of the annular body; a plurality of electric motors correspondingly pivotally connected to the plurality of pivot points, each electric motor of the plurality of electric motors having the pushrod disposed longitudinally therewithin; a plurality of pusher plates disposed in the annular body, each pusher plate configured to radially engage the packer assembly; and a plurality of connecting rods that correspondingly directly engages the plurality of pusher plates.

**24**. The annular BOP of claim 23, wherein the plurality of electric motors works in unison to drive the plurality of connecting rods into the corresponding pusher plates, which compresses the donut, causing the donut to apply a radial pressure on an outer circumference of the packer element, thereby moving the annular BOP from an open position to a closed position.
**25**. The annular BOP of claim 24, wherein rotation of the cam ring by the plurality of electric motors via the pushrod and the at least one pivot pin in a second direction opposite to the first direction causes the plurality of connecting rods to move in a radially outward direction, which allows the packer element and the donut to relax, thereby moving the annular BOP from the closed position to the open position.
**26**. The annular BOP of claim 20, wherein the pushrod extends into an extended position as the cam ring rotates in the first direction and drives the connecting rod into the at least one pusher plate.
**27**. The annular BOP of claim 21, wherein the pushrod retracts into a retracted position as the cam ring rotates in the second direction, causing the connecting rod to move in the radially outward direction.
**28**. The annular BOP of claim 24, wherein the pushrod extends into an extended position as the cam ring rotates in the first direction and drives the plurality of connecting rods into the plurality of pusher plates.
**29**. The annular BOP of claim 25, wherein the pushrod retracts into a retracted position as the cam ring rotates in the second direction, causing the plurality of connecting rods to move in the radially outward direction.
**30**. The annular BOP of claim 19, further comprising: a motor adapter having an aperture therethrough, wherein the pushrod extends longitudinally through the aperture of the motor adapter; and a roller element disposed between the motor adapter and the pushrod, wherein the electric motor comprises: a rotor; and a stator, and wherein rotation of the rotor rotates the motor adapter, thereby imparting rotary motion to the pushrod via the roller element.
**31**. The annular BOP of claim 23, wherein the plurality of electric motors pivots with respect to the corresponding plurality of pivot points as the cam ring rotates.
**32**. The annular BOP of claim 19, wherein the at least one pivot pin and the pushrod are oriented to be substantially perpendicular to each other.
**33**. The annular BOP of claim 19, wherein the pushrod comprises a roller screw.
**34-40**. (canceled)