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(54) **COMMUNICATING WITH BLOWOUT PREVENTER CONTROL SYSTEM**

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E21B 33/06	(2006.01)
E21B 47/06	(2012.01)

(52) **U.S. Cl.**

CPC ***E21B 21/08*** (2013.01); ***E21B 33/061*** (2013.01); ***E21B 47/06*** (2013.01)

(58) **Field of Classification Search**

CPC E21B 21/08; E21B 33/061; E21B 47/06; E21B 34/16; E21B 21/00; E21B 21/082; E21B 21/085; E21B 33/06

See application file for complete search history.

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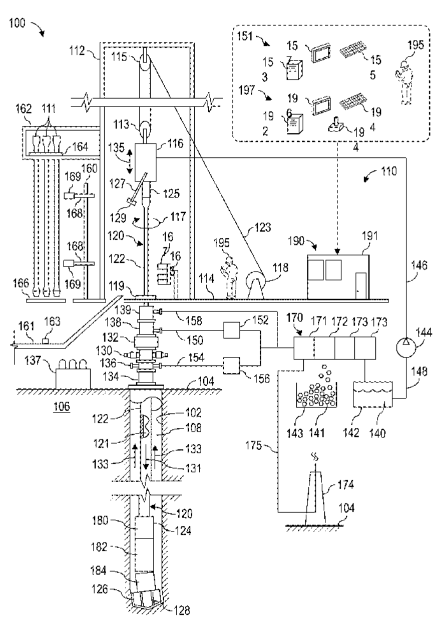
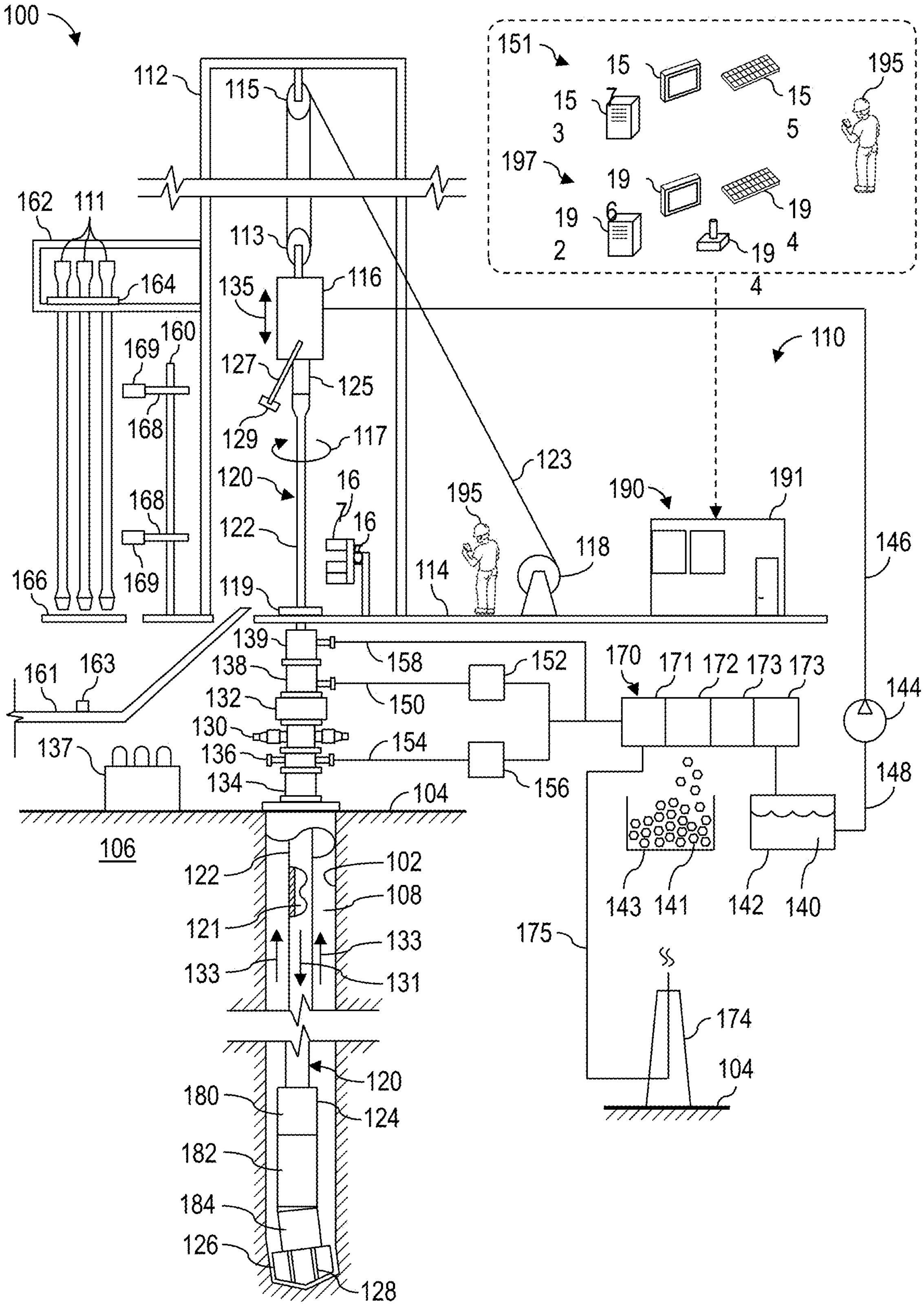
(57) **ABSTRACT**

A system includes a rig control system for controlling rig equipment operable to perform drilling operations to drill a wellbore at a wellsite, wherein the rig equipment includes a drawworks for raising or lowering a drill string, a pressure control system for controlling a pressure control manifold fluidly connected with the wellbore, and a blowout preventer (BOP) control system for controlling BOP equipment. The BOP control system is communicatively connected with the rig control system and the pressure control system, receives rig data, pressure data, and flow rate data from sensors included in the rig control system and the pressure control system, displays information indicative of an influx of formation fluid based at least one of the pressure data and the flow rate data, and causes the BOP equipment to close about the drill string.

5 Claims, 4 Drawing Sheets

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108
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133
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124
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FIG. 1

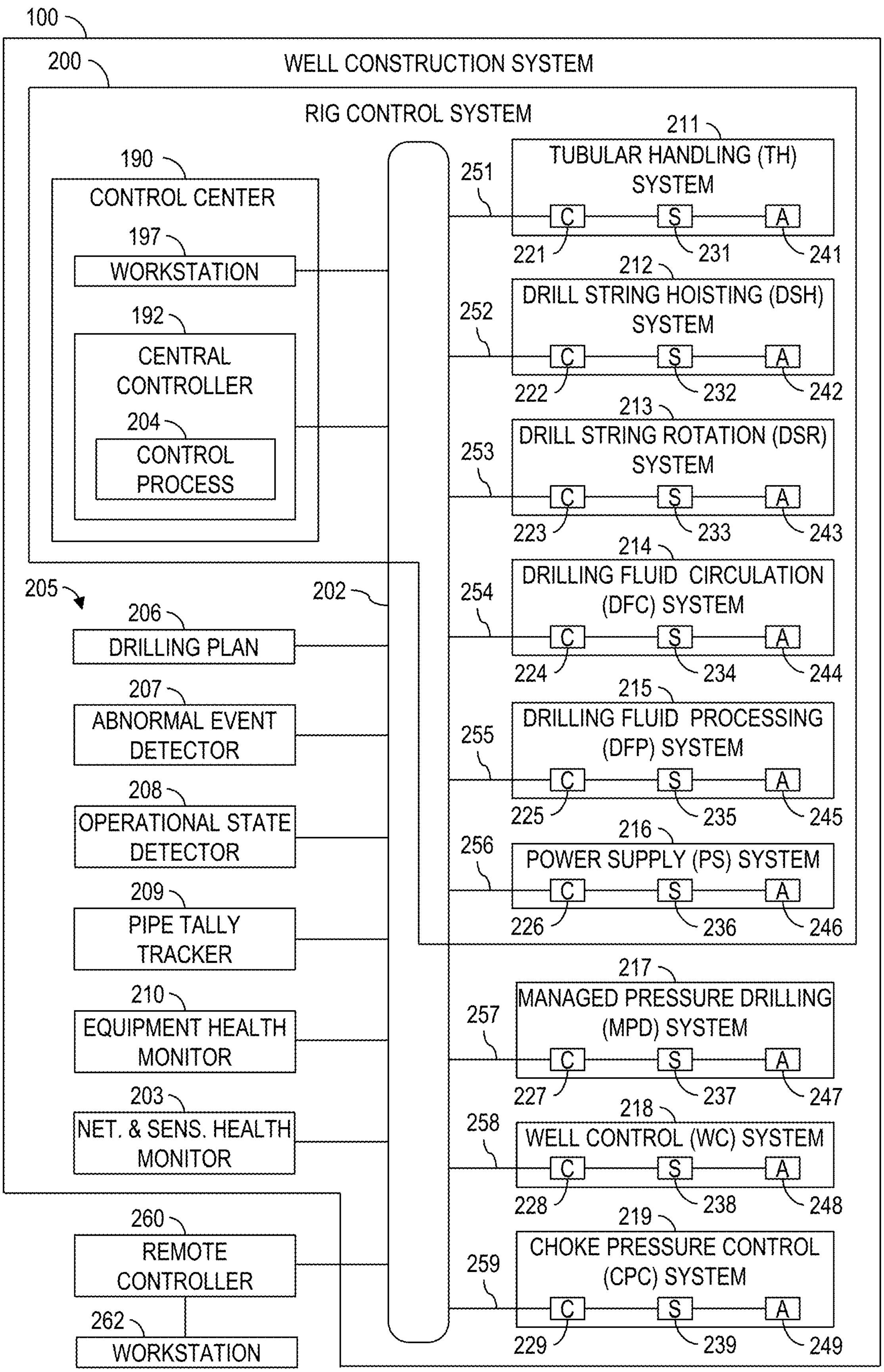

100
WELL CONSTRUCTION SYSTEM
200
RIG CONTROL SYSTEM
190
CONTROL CENTER
197
WORKSTATION
192
CENTRAL CONTROLLER
204
CONTROL PROCESS
211
TUBULAR HANDLING (TH) SYSTEM
212
DRILL STRING HOISTING (DSH) SYSTEM
213
DRILL STRING ROTATION (DSR) SYSTEM
214
DRILLING FLUID CIRCULATION (DFC) SYSTEM
215
DRILLING FLUID PROCESSING (DFP) SYSTEM
216
POWER SUPPLY (PS) SYSTEM
217
MANAGED PRESSURE DRILLING (MPD) SYSTEM
218
WELL CONTROL (WC) SYSTEM
219
CHOKE PRESSURE CONTROL (CPC) SYSTEM
C
S
A
221 231 241
222 232 242
223 233 243
224 234 244
225 235 245
226 236 246
227 237 247
228 238 248
229 239 249
251 252 253 254 255 256 257 258 259
202
205
206
DRILLING PLAN
207
ABNORMAL EVENT DETECTOR
208
OPERATIONAL STATE DETECTOR
209
PIPE TALLY TRACKER
210
EQUIPMENT HEALTH MONITOR
203
NET. & SENS. HEALTH MONITOR
260
REMOTE CONTROLLER
262
WORKSTATION

FIG. 2

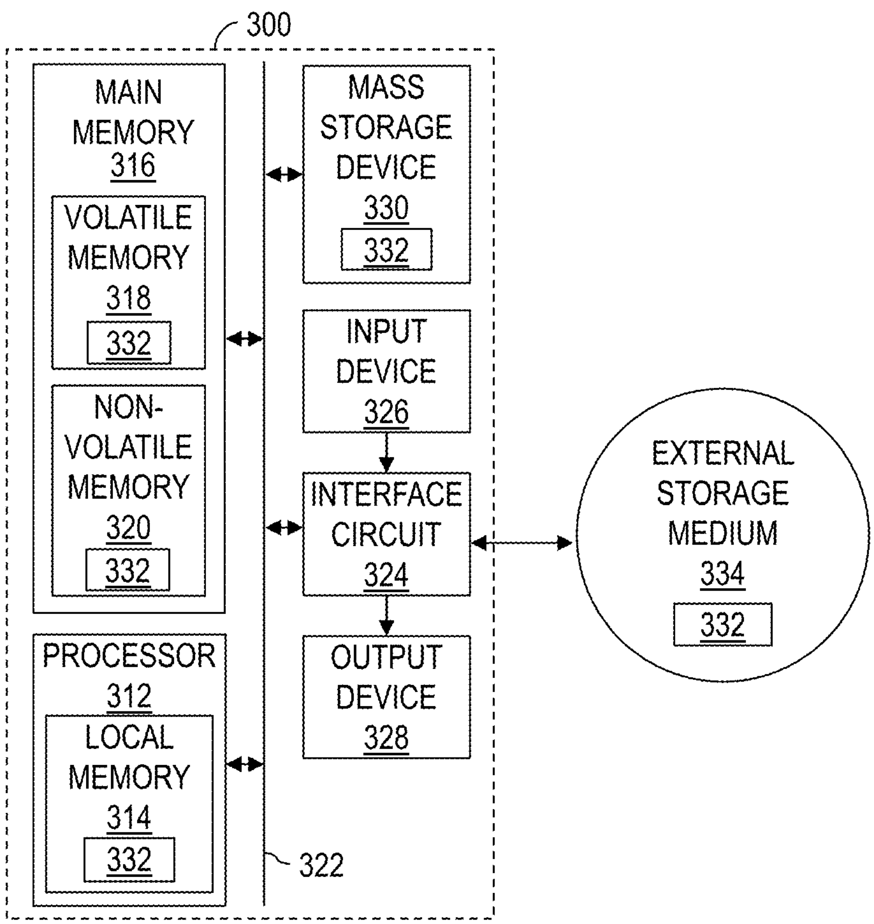
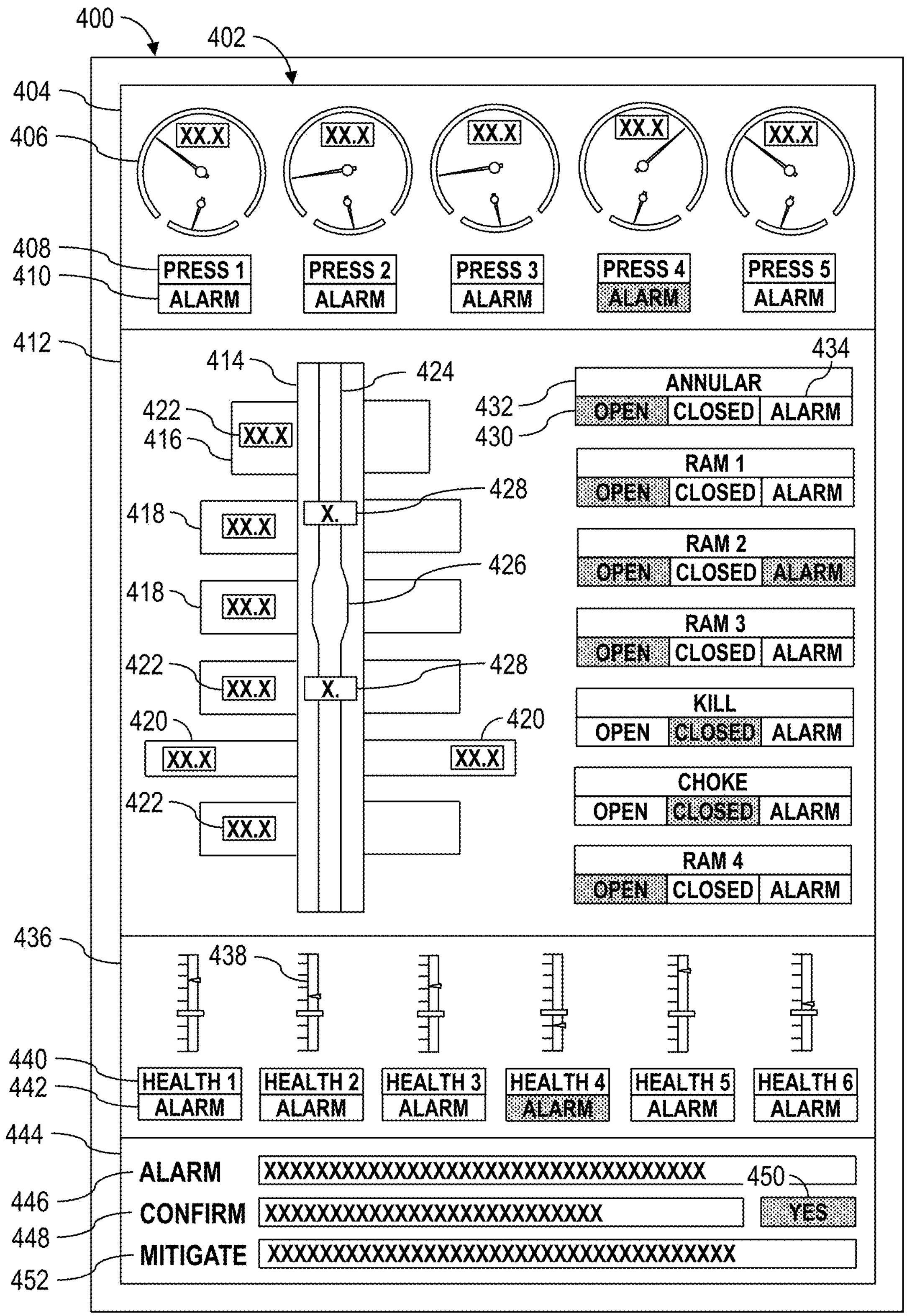

300
MAIN MEMORY 316
VOLATILE MEMORY 318
332
NON-VOLATILE MEMORY 320
332
PROCESSOR 312
LOCAL MEMORY 314
332
MASS STORAGE DEVICE 330
332
INPUT DEVICE 326
INTERFACE CIRCUIT 324
OUTPUT DEVICE 328
322
EXTERNAL STORAGE MEDIUM 334
332

FIG. 3


400
402
404
406
XX.X
PRESS 1
PRESS 2
PRESS 3
PRESS 4
PRESS 5
ALARM
408
410
412
414
424
422
416
418
428
426
420
434
432
430
ANNULAR
RAM 1
RAM 2
RAM 3
KILL
CHOKE
RAM 4
OPEN
CLOSED
ALARM
X.
436
438
440
442
HEALTH 1
HEALTH 2
HEALTH 3
HEALTH 4
HEALTH 5
HEALTH 6
444
446
448
452
450
CONFIRM
MITIGATE
YES
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
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XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

FIG. 4

COMMUNICATING WITH BLOWOUT PREVENTER CONTROL SYSTEM

CROSS REFERENCE TO RELATED APPLICATION

This application is a continuation of U.S. application Ser. No. 17/653,228, filed on Mar. 2, 2022, which claims priority to and the benefit of U.S. Provisional Application No. 63/155,438, filed on Mar. 2, 2021, the entireties of which are incorporated herein by reference.

BACKGROUND OF THE DISCLOSURE

Wells extend into the ground or ocean bed to facilitate recovery of natural deposits of oil, gas, and other materials that are trapped in subterranean geological formations. Well construction (e.g., drilling) operations may be performed at a wellsite by a well construction system (e.g., a drilling rig) having various surface and subterranean well construction equipment operating in a coordinated manner. For example, a drive mechanism, such as a top drive located at a wellsite surface, may be utilized to rotate and advance a drill string into the subterranean formation to drill a wellbore. The drill string may include a plurality of drill pipes coupled together and terminating with a drill bit. Length of the drill string may be increased by adding additional drill pipes as depth of the wellbore increases. Drilling fluid may be pumped from the wellsite surface down through the drill string to the drill bit. The drilling fluid lubricates and cools the drill bit and carries drill cuttings from the wellbore to the wellsite surface. The drilling fluid returning to the wellsite surface may then be cleaned and again pumped through the drill string. The well construction equipment of the well construction system may be grouped into various subsystems, wherein each subsystem performs a different operation.

The well construction equipment includes rig equipment for performing drilling operations to drill the wellbore at the wellsite surface and safety equipment for controlling pressure of the drilling fluid (and formation fluid) within the wellbore being drilled by the rig equipment. The safety equipment includes blowout preventer (BOP) equipment selectively operable to block the opening of the wellbore at the wellsite surface to therefore prevent or inhibit flow of the drilling fluid out of the wellbore. The rig equipment is controlled (or operated) by or via a rig control system and the BOP equipment is controlled by or via a BOP control system. The BOP control system can be used to manually control the BOP equipment by rig personnel and/or the BOP control system can automatically control the BOP equipment based on predetermined programming and sensor data facilitated by BOP sensors disposed in association with the BOP equipment. The sensor data facilitated by the BOP sensors provides limited information to the BOP control system and the rig personnel using the BOP control system. Such limited information can result in the BOP control system or the rig personnel controlling the BOP equipment in a less than optimal manner or in a manner that can damage the BOP equipment. Sensor data facilitated by rig sensors disposed in association with the rig equipment provides a wide range of information to the rig control system. However, the BOP control system is not communicatively connected with the rig control system or the rig sensors and, thus, the BOP control system does not have access to the sensor data facilitated by rig sensors.

SUMMARY OF THE DISCLOSURE

This summary is provided to introduce a selection of concepts that are further described below in the detailed description. This summary is not intended to identify indispensable features of the claimed subject matter, nor is it intended for use as an aid in limiting the scope of the claimed subject matter.

The present disclosure introduces a system including a pressure control system and a BOP control system. The pressure control system controls a pressure control manifold fluidly connected with a wellbore. The pressure control system includes a sensor operable to output pressure data indicative of wellbore pressure. The BOP control system controls BOP equipment. The BOP control system includes a sensor operable to output BOP data indicative of operational status of the BOP equipment. The BOP control system also includes a BOP human-machine interface (HMI) usable by a human user to monitor and control the BOP equipment. The BOP control system is communicatively connected with the pressure control system and receives the pressure data. The BOP control system also displays, on the BOP HMI, information based on the pressure data.

The present disclosure also introduces a system including a rig control system and a BOP control system. The rig control system controls rig equipment operable to perform drilling operations to drill a wellbore at a wellsite. The rig control system includes sensors operable to output rig data indicative of operational status of the rig equipment. The rig control system also includes a pressure control system for controlling a pressure control manifold fluidly connected with the wellbore. The pressure control system includes a sensor operable to output pressure data indicative of wellbore pressure. The BOP control system controls BOP equipment. The BOP control system includes a sensor operable to output BOP data indicative of operational status of the BOP equipment. The BOP control system also includes a BOP HMI usable by a human user to monitor and control the BOP equipment. The BOP control system is communicatively connected with the rig control system and the pressure control system and receives the rig data and the pressure data. The BOP control system also displays, on the BOP HMI, information based on the rig data and the pressure data.

The present disclosure also introduces a system including a BOP control system and a health monitoring system. The BOP control system controls BOP equipment at a wellsite and includes a sensor operable to output BOP data indicative of operational status of the BOP equipment. The health monitoring system is communicatively connected with the BOP control system. The health monitoring system records the BOP data to a memory and determines operational health of the BOP equipment based on the BOP data.

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

BRIEF DESCRIPTION OF THE DRAWINGS

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

FIG. **1** is a schematic side view of at least a portion of an example implementation of apparatus according to one or more aspects of the present disclosure.

FIG. **2** is a schematic view of at least a portion of an example implementation of apparatus according to one or more aspects of the present disclosure.

FIG. **3** is a schematic view of at least a portion of an example implementation of apparatus according to one or more aspects of the present disclosure.

FIG. **4** is a schematic view of at least a portion of an example implementation of apparatus according to one or more aspects of the present disclosure.

DETAILED DESCRIPTION

It is to be understood that the following disclosure describes many example implementations for different aspects introduced herein. Specific examples of components and arrangements are described below to simplify the present disclosure. These are merely examples, and are not intended to be limiting. In addition, the present disclosure may repeat reference numerals and/or letters in the various examples. This repetition is for simplicity and clarity, and does not in itself dictate a relationship between the various implementations described herein. Moreover, the formation of a first feature over or on a second feature in the description that follows may include implementations in which the first and second features are formed in direct contact, and may also include implementations in which additional features may be formed interposing the first and second features, such that the first and second features may not be in direct contact.

Systems and methods (e.g., processes, operations, etc.) according to one or more aspects of the present disclosure may be utilized or otherwise implemented in association with an automated well construction system (i.e., well construction rig) at an oil and gas wellsite, such as for constructing a well (including drilling a wellbore) for extracting hydrocarbons (e.g., oil and/or gas) from a subterranean formation. FIG. **1** is a schematic view of at least a portion of an example implementation of a well construction system **100** according to one or more aspects of the present disclosure. The well construction system **100** represents an example environment in which one or more aspects of the present disclosure described below may be implemented. The well construction system **100** may be or comprise a well construction (e.g., drilling) rig and associated well construction equipment. Although the well construction system **100** is depicted as an onshore implementation, the aspects described below are also applicable or readily adaptable to offshore implementations.

The well construction system **100** is depicted in relation to a wellbore **102** formed by rotary and/or directional drilling from a wellsite surface **104** and extending into a subterranean formation **106**. The well construction system **100** comprises or is associated with various well construction equipment (i.e., wellsite equipment), including surface equipment **110** located at the wellsite surface **104** and a drill string **120** suspended within the wellbore **102**. The surface equipment **110** may include a mast, a derrick, and/or other support structure **112** disposed over a rig floor **114**. The drill string **120** may be suspended within the wellbore **102** from the support structure **112**. The support structure **112** and the rig floor **114** are collectively supported over the wellbore **102** by legs and/or other support structures (not shown).

The drill string **120** may comprise a bottom-hole assembly (BHA) **124** and means **122** for conveying the BHA **124** within the wellbore **102**. The conveyance means **122** may comprise a plurality of interconnected tubulars, such as drill pipe, heavy-weight drill pipe (HWDP), wired drill pipe (WDP), tough logging condition (TLC) pipe, and drill collars, among other examples. The conveyance means **122** may instead comprise coiled tubing for conveying the BHA **124** within the wellbore **102**. A downhole end of the BHA **124** may include or be coupled to a drill bit **126**. Rotation of the drill bit **126** and the weight of the drill string **120** collectively operate to form the wellbore **102**. The drill bit **126** may be rotated from the wellsite surface **104** and/or via a downhole mud motor **184** connected with the drill bit **126**. The BHA **124** may also include various downhole devices and/or tools **180**, **182**.

The support structure **112** may support a driver, such as a top drive **116**, operable to connect with an upper end of the drill string **120**, and to impart rotary motion **117** and vertical motion **135** to the drill string **120**, including the drill bit **126**. However, other drivers, such as a kelly and rotary table (neither shown), may be utilized instead of or in addition to the top drive **116** to impart the rotary motion **117** to the drill string **120**. The top drive **116** and the connected drill string **120** may be suspended from the support structure **112** via hoisting equipment, which may include a traveling block **113**, a crown block **115**, and a drawworks **118** storing a support cable or line **123**. The crown block **115** may be connected to or otherwise supported by the support structure **112**, and the traveling block **113** may be coupled with the top drive **116**. The drawworks **118** may be mounted on or otherwise supported by the rig floor **114**. The crown block **115** and traveling block **113** comprise pulleys or sheaves around which the support line **123** is reeved to operatively connect the crown block **115**, the traveling block **113**, and the drawworks **118** (and perhaps an anchor). The drawworks **118** may thus selectively impart tension to the support line **123** to lift and lower the top drive **116**, resulting in the vertical motion **135**. The drawworks **118** may comprise a drum, a base, and an actuator (e.g., an electric motor) (not shown) operable to drive the drum to rotate and reel in the support line **123**, causing the traveling block **113** and the top drive **116** to move upward. Similarly, the drawworks **118** is operable to reel out the support line **123** via controlled rotation of the drum, causing the traveling block **113** and the top drive **116** to move downward.

The top drive **116** may comprise a grabber, a swivel (neither shown), elevator links **127** terminating with an elevator **129**, and a drive shaft **125** operatively connected with a rotary actuator (e.g., an electric motor) (not shown), such as via a gear box or transmission (not shown). The drive shaft **125** may be selectively coupled with the upper end of the drill string **120** and the rotary actuator may be selectively operated to rotate the drive shaft **125** and the drill string **120** coupled with the drive shaft **125**. Thus, during drilling operations, the top drive **116**, in conjunction with operation of the drawworks **118**, may advance the drill string **120** into the formation **106** to form the wellbore **102**. The elevator links **127** and the elevator **129** of the top drive **116** may handle tubulars (e.g., singles or stands of drill pipe, drill collars, casing joints, etc.) that are not mechanically coupled to the drive shaft **125**.

The drill string **120** may be conveyed within the wellbore **102** through various fluid control equipment (or devices) disposed at the wellsite surface **104** over an opening of the wellbore **102** and perhaps below the rig floor **114**. The fluid control equipment may be operable to control fluid within the wellbore **102**. The fluid control equipment may include a BOP ram stack **130** and an annular preventer **132** for maintaining well pressure control. The fluid control equipment may also include a rotating control device (RCD) **138** mounted above the annular preventer **132**. The BOP ram stack **130**, the annular preventer **132**, and the RCD **138** may each comprise one or more fluid barriers (e.g., annular packing elements, rams, etc.) selectively operable to block, limit, or otherwise control flow of drilling fluid (and formation fluid) out of the wellbore **102**. The fluid control equipment **130**, **132**, **138** may be mounted on top of a wellhead **134**. The drilling fluid may exit the wellbore via the RCD **138**, via a ported adapter **136** (e.g., a spool, cross adapter, a wing valve, etc.) located below one or more of the fluid control equipment **130**, **132**, **138**, or via a bell nipple **139** located above one or more of the fluid control equipment **130**, **132**, **138**.

A power unit **137** (i.e., a BOP control or closing unit) may be operatively connected with one or more of the fluid control equipment **130**, **132**, **138** and operable to actuate, drive, operate, or otherwise control one or more of the fluid control equipment **130**, **132**, **138**. The power unit **137** may be or comprise a hydraulic fluid power unit fluidly connected with the fluid control equipment **130**, **132**, **138** and selectively operable to hydraulically drive (e.g., open, close, etc.) various portions (e.g., rams, valves, seals) of the fluid control equipment **130**, **132**, **138**. The power unit **137** may comprise one or more hydraulic pumps actuated by electric motors and operable to pressurize hydraulic fluid stored in hydraulic accumulators for operating the fluid control equipment **130**, **132**, **138**.

The well construction system **100** may further include drilling fluid circulation equipment operable to circulate fluids between the surface equipment **110** and the drill bit **126** during drilling and other operations. For example, the drilling fluid circulation equipment may be operable to inject a drilling fluid from the wellsite surface **104** into the wellbore **102** via an internal fluid passage **121** extending longitudinally through the drill string **120**. The drilling fluid circulation equipment may comprise a pit, a tank, and/or other fluid container **142** holding the drilling fluid **140** (i.e., drilling mud), and one or more mud pump units **144** (i.e., drilling fluid pumps) operable to move the drilling fluid **140** from the container **142** into the fluid passage **121** of the drill string **120** via a fluid conduit **146** extending from the pump units **144** to the top drive **116** and an internal passage extending through the top drive **116**. Each pump unit **144** may comprise a fluid pump (not shown) operable to pump the drilling fluid **140** and a rotary actuator (e.g., an electric motor) (not shown) operable to drive the corresponding fluid pump. The fluid conduit **146** may comprise one or more of a pump discharge line, a stand pipe, a rotary hose, and a gooseneck connected with a fluid inlet of the top drive **116**. The pumps **144** and the container **142** may be fluidly connected by a fluid conduit **148**, such as a suction line.

During drilling operations, the drilling fluid may continue to flow downhole through the internal passage **121** of the drill string **120**, as indicated by directional arrow **131**. The drilling fluid may exit the BHA **124** via ports **128** in the drill bit **126** and then circulate uphole through a wellbore annulus **108** of the wellbore **102** defined between an outer surface of the drill string **120** and a sidewall of the wellbore **102**, such flow being indicated by directional arrows **133**. In this manner, the drilling fluid lubricates the drill bit **126** and carries formation cuttings uphole to the wellsite surface **104**. The returning drilling fluid may exit the wellbore annulus **108** via different fluid control equipment during different stages or scenarios of well drilling operations. For example, the drilling fluid may exit the wellbore annulus **108** via the bell nipple **139**, the RCD **138**, or the ported adapter **136**.

During normal drilling operations (e.g., when the well is overbalanced), the drilling fluid may exit the wellbore annulus **108** via the bell nipple **139** and then be directed toward drilling fluid reconditioning equipment **170** via a fluid conduit **158** (e.g., gravity return line) to be cleaned and/or reconditioned, as described below, before being returned to the container **142** for recirculation. During managed pressure drilling (MPD) operations (e.g., when the well is underbalanced), the drilling fluid may exit the wellbore annulus **108** via the RCD **138** and then be directed into an MPD manifold **152** via a fluid conduit **150** (e.g., a drilling pressure control line). The MPD manifold **152** may include at least one choke and a plurality of fluid valves collectively operable to control the flow of the drilling fluid through and out of the MPD manifold **152**. The MPD manifold **152** may generate backpressure that is applied to the upper (i.e., uphole) end of the wellbore annulus **108** to control pressure within the entire wellbore annulus **108** of the wellbore **102** by variably restricting the flow rate of the drilling fluid through the MPD manifold **152** as part of MPD operations. The greater the restriction to flow through the MPD manifold **152**, the greater the backpressure applied to the upper end of the wellbore annulus **108** and the greater the pressure along the entire wellbore annulus **108**. The drilling fluid exiting the MPD manifold **152** may then pass through the drilling fluid reconditioning equipment **170** before being returned to the container **142** for recirculation.

During well pressure control operations (e.g., during influx of formation fluid into the well), such as when one or more rams of the BOP stack **130** is closed, the drilling fluid may exit the wellbore annulus **108** via the ported adapter **136** and be directed into a choke and kill (CK) manifold (or a rig choke manifold) **156** via a fluid conduit **154** (e.g., a rig choke line). The CK manifold **156** may include at least one choke and a plurality of fluid valves collectively operable to control the flow of the drilling fluid (and perhaps formation fluid) through and out of the CK manifold **156**. The CK manifold **156** may variably restrict the flow rate of the drilling fluid through the CK manifold **156** as part of well pressure control operations to thereby facilitate pressure control of the drilling fluid within the wellbore **102**. The drilling fluid exiting the CK manifold **156** may then pass through the drilling fluid reconditioning equipment **170** before being returned to the container **142** for recirculation.

Before being returned to the container **142**, the drilling fluid returning to the wellsite surface **104** may be cleaned and/or reconditioned via the drilling fluid reconditioning equipment **170**, which may include one or more of liquid-gas (i.e., mud gas) separators **171**, shale shakers **172**, and other drilling fluid cleaning and reconditioning equipment **173**. The cleaned and reconditioned drilling fluid may be transferred to the fluid container **142**, the solid particles **141** removed from the drilling fluid may be transferred to a solids container **143** (e.g., a reserve pit), and/or the removed gas may be transferred to a flare stack **174** via a conduit **175** (e.g., a flare line) to be burned or to a container (not shown) for storage and removal from the wellsite.

The surface equipment **110** may include tubular handling equipment operable to store, move, connect, and disconnect tubulars (e.g., drill pipe) to assemble and disassemble the conveyance means **122** of the drill string **120** during drilling operations. For example, a catwalk **161** may be utilized to convey tubulars from a ground level (e.g., along the wellsite surface **104**) to the rig floor **114**, thereby permitting the elevator **129** to grab and lift the tubulars above the wellbore

102 for connection with previously deployed tubulars. The catwalk 161 may have a horizontal portion and an inclined portion that extends between the horizontal portion and the rig floor 114. The catwalk 161 may comprise a skate 163 movable along a groove (not shown) extending longitudinally along the horizontal and inclined portions of the catwalk 161. The skate 163 may be operable to convey (e.g., push) the tubulars along the catwalk 161 to the rig floor 114. The tubular handling equipment may further include a tubular handling manipulator (THM) 160 disposed in association with a vertical pipe rack 162 for storing tubulars 111 (e.g., drill pipe, drill collars, drill pipe stands, casing joints, etc.). The vertical pipe rack 162 may comprise or support a fingerboard 164 defining a plurality of slots configured to support or otherwise hold the tubulars 111 within or above a setback 166 (e.g., a platform) located adjacent to, along, or below the rig floor 114. The THM 160 may be operable to transfer the tubulars 111 between the fingerboard 164/setback 166 and the drill string 120 (i.e., space above the suspended drill string 120). For example, the THM 160 may include arms 168 terminating with clamps 169, such as may be operable to grasp and/or clamp onto one of the tubulars 111. The arms 168 of the THM 160 may extend and retract, and/or at least a portion of the THM 160 may be rotatable and/or movable toward and away from the drill string 120, such as may permit the THM 160 to transfer the tubular 111 between the fingerboard 164/setback 166 and the drill string 120.

Power tongs 165 (e.g., an iron roughneck) may be positioned on the rig floor 114. The power tongs 165 may comprise a torqueing portion 167, such as may include a spinner and a torque wrench comprising a lower tong and an upper tong. The torqueing portion 167 of the power tongs 165 may be moveable toward and at least partially around the drill string 120, such as may permit the power tongs 165 to make up and break out connections of the drill string 120.

A set of slips 119 may be located on the rig floor 114, such as may accommodate therethrough the drill string 120 during tubular make up and break out operations and during drilling operations. The slips 119 may be in an open position during drilling operations to permit advancement of the drill string 120, and in a closed position to clamp the upper end (e.g., the uppermost tubular) of the drill string 120 to thereby suspend and prevent advancement of the drill string 120 within the wellbore 102, such as during the make up and break out operations.

During drilling operations, the various well construction equipment of the well construction system 100 may progress through a plurality of coordinated operations (i.e., operational sequences) to drill or otherwise construct the wellbore 102. The operational sequences may change based on a well construction plan, status of the well, status of the subterranean formation, stage of drilling operations (e.g., tripping, drilling, tubular handling, etc.), and type of downhole tubulars (e.g., drill pipe) utilized, among other examples.

The surface equipment 110 of the well construction system 100 may also comprise a control center 190 from which various portions of the well construction system 100, such as the top drive 116, the hoisting equipment 113, 118, 123, the tubular handling equipment 160, 161, 165, the drilling fluid circulation equipment 142, 144, the drilling fluid reconditioning equipment 170, the pressure control manifolds 152, 156, the fluid control equipment 130, 132, 136, 138, and the BHA 124, among other examples, may be monitored and controlled. The control center 190 may comprise a facility 191 (e.g., a room, a cabin, a trailer, etc.) located on the rig floor 114 or other location of the well construction system 100.

The control center 190 may comprise a central controller 192 (e.g., a processing device, a computer, etc.) located within the facility 191. The central controller 192 may be operable to receive, process, and output information to monitor operations of and control one or more portions of the well construction system 100. For example, the central controller 192 may be communicatively connected with the various surface and downhole equipment described herein, and may be operable to receive signals from and transmit signals to such equipment to perform various automated or semi-automated operations described herein. The central controller 192 may store executable computer program code, instructions, and/or operational parameters or set-points, including for implementing one or more aspects of methods and operations described herein. Although it is possible that the entirety of the central controller 192 is implemented within one device, it is also contemplated that one or more components or functions of the central controller 192 may be implemented across multiple devices, some or an entirety of which may be implemented as part of the control center 190 and/or located within the facility 191.

The control center 190 may comprise a rig control workstation 197 located within the facility 191. The rig control workstation 197 may be operated by rig personnel 195 (e.g., a driller or other human rig operator) to monitor and manually control various well construction equipment or portions of the well construction system 100. The rig control workstation 197 may be communicatively connected with the central controller 192. The rig control workstation 197 may be operable for entering or otherwise communicating control data (e.g., commands, signals, information, etc.) to the central controller 192 and other equipment controllers by the rig personnel 195, and for displaying or otherwise communicating information from the central controller 192 and other equipment controllers to the rig personnel 195. The rig control workstation 197 may be or comprise an HMI, including one or more input devices 194 (e.g., a keyboard, a mouse, a joystick, a touchscreen, etc.) and one or more output devices 196 (e.g., a video monitor, a touchscreen, a printer, audio speakers, etc.). Communication between the central controller 192, the input and output devices 194, 196, and the various well construction equipment may be via wired and/or wireless communication means. However, for clarity and case of understanding, such communication means are not depicted, and a person having ordinary skill in the art will appreciate that such communication means are within the scope of the present disclosure.

The control center 190 may comprise a BOP controller 153 (e.g., a processing device, a computer, etc.) operable to receive, process, and output data to monitor and control operations of the BOP ram stack 130 and the annular preventer 132 ("BOP equipment"). The BOP controller 153 may be operable to store executable computer program code, instructions, and/or operational parameters or set-points, including for implementing one or more BOP operations described herein. The BOP controller 153 may be operable to control the BOP control unit 137 and, thus, control the BOP equipment 130, 132. For example, the BOP controller 153 may be communicatively connected with the BOP control unit 137 and the BOP equipment 130, 132, and operable to monitor and control operations of the BOP equipment 130, 132 via the BOP control unit 137.

The control center 190 may comprise a BOP control workstation 151 communicatively connected with the BOP controller **153** and operable to receive control commands entered by the rig personnel **195** (e.g., the driller, BOP engineer, etc.) for controlling the BOP equipment **130**, **132**, to communicate such control commands to the BOP controller **153**, and to display or otherwise communicate information indicative of operational status of the BOP equipment **130**, **132** and the BOP control unit **137** to the rig personnel **195**. The BOP control workstation **151** may be or comprise an HMI, including one or more input devices **155** (e.g., buttons, keys, a touchscreen, etc.) and one or more output devices **157** (e.g., a video monitor, gauges, audio speakers, a touchscreen, etc.). The input and output devices **155**, **157** of the BOP control workstation **151** may be disposed in association with and/or integrated within a housing or enclosure and permit the rig personnel **195** to enter commands or other information to the BOP control workstation **151** to control the BOP equipment **130**, **132** and receive information from the BOP control workstation **151** to monitor operational status of the BOP equipment **130**, **132**.

The BOP control workstation **151**, the BOP controller **153**, and the BOP control unit **137** may be operatively connected via electrical, pneumatic, and/or hydraulic means. However, for clarity and case of understanding, such communication means are not depicted, and a person having ordinary skill in the art will appreciate that such communication means are within the scope of the present disclosure. For example, control commands output by the BOP controller **153** and/or entered by the rig personnel **195** via the input devices **155** may be transmitted from the BOP control workstation **151** in the form of electrical, pneumatic, and/or hydraulic control signals to operate various portions (e.g., valves) of the BOP control unit **137** to control the BOP equipment **130**, **132**. Feedback information indicative of operational status of the BOP control unit **137** and the BOP equipment **130**, **132** may be transmitted in the form of electrical, pneumatic, and/or hydraulic feedback signals from various sensors of the BOP control unit **137** and the BOP equipment **130**, **132** to the BOP control workstation **151** and/or the BOP controller **153**. The feedback information may be displayed to the rig personnel **195** via the output devices **157** of the BOP control workstation **151**.

The BOP control workstation **151** and the BOP controller **153** may be contained within an intrinsically safe enclosure, an explosion proof enclosure (e.g., Class 1 rating), a weatherproof enclosure, a dust and/or water proof enclosure (e.g., IP66 rating, IP55 rating), and/or may be certified for use in Zone 1, Zone 2, hazardous, and/or safe areas of the wellsite. Although the BOP control workstation **151** and the BOP controller **153** are shown located within the facility **191**, the BOP control workstation **151** and/or the BOP controller **153** may be located outside of the facility **191**, such as on the rig floor **114** or the wellsite surface **104**.

Well construction systems within the scope of the present disclosure may include more or fewer components than as described above and depicted in FIG. **1**. Additionally, various equipment and/or subsystems of the well construction system **100** shown in FIG. **1** may include more or fewer components than as described above and depicted in FIG. **1**. For example, various engines, electric motors, hydraulics, actuators, valves, and/or other components not explicitly described herein may be included in the well construction system **100**, and are within the scope of the present disclosure.

The present disclosure further provides various implementations of systems and/or methods for controlling one or more portions of the well construction system **100**. FIG. **2** is a schematic view of at least a portion of various control systems and control devices for monitoring and controlling various well construction equipment of the well construction system **100** shown in FIG. **1**. Such control systems and devices may comprise one or more features of the well construction system **100**, including where indicated by the same reference numerals. Accordingly, the following description refers to FIGS. **1** and **2**, collectively.

The well construction equipment of the well construction system **100** may be grouped into several subsystems, each operable to perform a corresponding operation and/or a portion of the well construction operations described herein. For example, the well construction system **100** may comprise a rig drilling operations control system **200** ("rig control system") for monitoring and controlling various operational equipment for performing drilling operations. The rig control system **200** may be operable to control well construction equipment of a tubular handling (TH) system **211**, a drill string hoisting system (DSH) system **212**, a drill string rotation system (DSR) system **213**, a drilling fluid circulation (DFC) system **214**, a drilling fluid processing (DFP) system **215**, and a power supply (PS) system **216**. The well construction system **100** may also comprise a plurality of safety systems for monitoring and controlling various safety equipment, including for controlling wellbore fluid (e.g., drilling fluid, formation fluid, etc.) within the wellbore **102**. Such safety systems may comprise an MPD system **217**, a well control (WC) system **218**, and a choke pressure control (CPC) system **219**.

The TH system **211** may comprise, for example, the support structure **112**, the pipe rack **162**, the THM **160**, the catwalk **161**, the slips **119**, the power tongs **165**, and/or other tubular handling equipment. The TH system **211** may perform tubular handling operations and serve as a support platform for tubular rotation equipment and a staging ground for rig operations, such as connection make up and break out operations.

The DSH system **212** may comprise, for example, the blocks **113**, **115**, the line **123**, and the drawworks **118** for collectively hoisting the top drive **116** and the drill string **120** connected to the top drive **116**. The DSH system **212** may perform drill string hoisting operations.

The DSR system **213** may comprise, for example, the top drive **116** and/or the rotary table and kelly. The DSR system **213** may perform drill string rotation operations.

The DFC system **214** may comprise, for example, the mud pumps **144**, the bell nipple **139**, the fluid container **142**, the fluid conduits **146**, **148**, **158**, and other drilling fluid circulation equipment. The DFC system **214** may be operable to pump and circulate the drilling fluid downhole through the drill string **120** and uphole through the wellbore annulus **108**.

The DFP system **215** may comprise, for example, the drilling fluid cleaning and reconditioning equipment **170**, the solids container **143**, and the gas flare stack **174**. The DFP system **215** may perform drilling fluid cleaning, reconditioning, and mixing operations.

The PS system **216** may comprise various sources of electrical power operable to power the well construction equipment of the well construction system **100**, including the well construction equipment of the subsystems **211-219**. The PS system **216** may also include various means for transferring and/or distributing electrical power and fuel to the well construction equipment and between various pieces of equipment of the PS system **216**, including electrical power conductors, electrical connectors, electrical relays, fluid conductors, fluid connectors, and fluid valves, among other examples. The sources of electrical power may include combustion engine/electrical power generator units, solar/electrical power generation units, electrical power regeneration units, wind/electrical power generation units, electrical power grid, electrical power storage units (e.g., batteries, capacitors, etc.), and fuel storage devices, among other examples.

The MPD system **217** may comprise, for example, the RCD **138**, the MPD manifold **152**, and the fluid conduit **150**. The RCD **138** may be operable to seal the wellbore annulus **108** from the atmosphere and direct the drilling fluid flowing out of the wellbore **102** though the MPD manifold **152** to control (i.e., restrict) the flow of the drilling fluid out of the wellbore **102** and, thus, apply back pressure to the upper end of the wellbore annulus **108**. The RCD **138** permits the drill string **120** to rotate while sealing the wellbore annulus **108** to thereby permit MPD operations.

The WC system **218** may comprise the BOP stack **130**, the annular preventer **132**, the power unit **137**, the BOP control workstation **151**, and the BOP controller **153**. The BOP equipment **130**, **132** may be operable to seal the wellbore annulus **108** of the wellbore **102** from the atmosphere and, thus, direct the drilling fluid (and perhaps formation fluid) flowing out of the wellbore **102** through the ported adapter **136** and the CK manifold **156**.

The CPC system **219** may comprise the CK manifold **156**, the ported adapter **136**, and the fluid conduit **154**. The CK manifold **156** may be operable to control (i.e., restrict) the flow of the drilling fluid out of the wellbore **102** via the ported adapter **136** when one of the BOP equipment **130**, **132** is closed to thereby apply back pressure to the upper end of the wellbore annulus **108** and, thus, facilitate control of annular pressure of the drilling fluid within the wellbore **102**.

Each of the equipment subsystems **211**-**219** may further comprise various communication devices (e.g., modems, network interface cards, etc.) and communication lines (e.g., cables, conductors, etc.), communicatively connecting sensors and/or actuators of each subsystem **211**-**219** with a central controller **192** and a control workstation **197**. Although the equipment listed above and shown in FIG. **1** is associated with certain subsystems **211**-**219** depicted in FIG. **2**, such associations are merely examples that are not intended to limit or prevent such equipment from being associated with two or more subsystems **211**-**219** and/or different subsystems **211**-**219**.

The equipment subsystems **211**-**219** may include various local controllers **221**-**229** (e.g., processing devices, computers, etc.), each operable to control various equipment of the corresponding subsystem **211**-**219** and/or an individual piece of equipment of the corresponding subsystem **211**-**219**. Each subsystem **211**-**219** includes various equipment that may comprise corresponding actuators **241**-**249** for actuating such equipment to thereby facilitate performance of corresponding well construction operations. Each subsystem **211**-**219** may include various sensors **231**-**239** operable to generate or otherwise output sensor data (e.g., signals, information, measurements, etc.) indicative of operational status of the equipment of each subsystem **211**-**219** and/or indicative of environmental conditions associated with the equipment of each subsystem **211**-**219**. Each local controller **221**-**229** may output control data (e.g., commands, signals, information, etc.) to one or more actuators **241**-**249** to perform corresponding actions of a piece of equipment or subsystem **211**-**219**. Each local controller **221**-**229** may receive sensor data output by one or more sensors **231**-**239**. Although the local controllers **221**-**229**, the sensors **231**-**239**, and the actuators **241**-**249** are each shown as a single block, it is to be understood that one or more of the local controllers **221**-**229**, the sensors **231**-**239**, and/or the actuators **241**-**249** may be or comprise a plurality of local controllers, sensors, and/or actuators, respectively.

The sensors **231**-**239** may include sensors utilized for operation of the various subsystems **211**-**219** of the well construction system **100**. For example, the sensors **231**-**239** may include cameras, position sensors, speed sensors, acceleration sensors, pressure sensors, force sensors, temperature sensors, flow rate sensors, vibration sensors, electrical current sensors, electrical voltage sensors, resistance sensors, gesture detection sensors or devices, voice actuated or recognition devices or sensors, chemical sensors, exhaust sensors, and/or other examples. The sensor data may include signals, information, and/or measurements indicative of a property (i.e., a parameter) of or associated with a piece of equipment. The sensor data may be indicative of, for example, equipment operational status (e.g., on or off, percent load, up or down, set or released, etc.), equipment operational performance (e.g., flow rate, operational speed, position, pressure, etc.), drilling parameters (e.g., depth, hook load, torque, etc.), auxiliary parameters (e.g., vibration data, temperature, etc.), or environmental conditions (e.g., temperature, pressure, etc.). The acquired sensor data may include or be associated with a timestamp (e.g., date and/or time) indicative of when the sensor data has been acquired. The sensor data may also or instead be aligned with a depth or other drilling parameter.

The central controller **192**, the control workstation **197**, the local controllers **221**-**229**, the sensors **231**-**239**, and the actuators **241**-**249** may be communicatively connected. The central controller **192** and the control workstation **197** may be communicatively connected to or along a central communication network **202** (e.g., a data bus, a field bus, a wide-area-network (WAN), a local-area-network (LAN), etc.). The local controllers **221**-**229**, the sensors **231**-**239**, and the actuators **241**-**249** of the corresponding subsystems **211**-**219** may be communicatively connected to or along corresponding local communication networks **251**-**259** (e.g., a field bus, a LAN, etc.). Each local communication network **251**-**259** may be communicatively connected with the central communication network **202** to communicatively connect the central controller **192** and the control workstation **197** with the subsystems **211**-**219**.

The rig control system **200** may comprise the control workstation **197**, the central controller **192**, the local controllers **221**-**226**, and the sensors **231**-**236** collectively operable to facilitate central (e.g., manual or automated) and/or local control of the various actuators **241**-**246** (i.e., rig equipment) of the subsystems **211**-**216**. The central communication network **202** may be a part of the rig control system **200**. The subsystems **217**-**219** (i.e., the safety systems) may therefore be communicatively connected with the central controller **192**, the control workstation **197**, and the subsystems **211**-**216** of the rig control system **200** via the central communication network **202** to further facilitate central and local control of the various actuators **247**-**249** (i.e., safety equipment) of the subsystems **217**-**219**.

The sensor data output by the sensors **231**-**239** of the subsystems **211**-**219** may be communicated to the central controller **192** and/or the local controllers **221**-**229**. Similarly, control data output by the central controller **192** and/or the local controllers **221**-**229** may be communicated to the various actuators **241**-**249** of the subsystems **211**-**219**, perhaps pursuant to predetermined programming, such as to facilitate well construction operations and/or other operations described herein. Although the central controller **192** is shown as a single device (i.e., a discrete hardware component), it is to be understood that the central controller **192** may be or comprise a plurality of controllers and/or other electronic control devices collectively operable to monitor and control operations (i.e., computational processes or methods) of the well construction system **100**. The central controller **192** may be located within or form a portion of the control center **190**, although a portion of the central controller **192** may instead be external to the control center **190**.

The sensors **231-239** and the actuators **241-249** may be monitored and/or controlled by corresponding local controllers **221-229** and/or the central controller **192**. For example, the central controller **192** may be operable to receive sensor data from the sensors **231-239** of the subsystems **211-219** in real-time, and to output real-time control data directly to the actuators **241-249** of the subsystems **211-219** based on the received sensor data. However, certain operations of the actuators **241-249** of each subsystem **211-219** may be controlled by a corresponding local controller **221-229**, which may control the actuators **241-249** based on sensor data received from the sensors **231-239** of the corresponding subsystem **211-219** and/or based on control data received from the central controller **192**.

The rig control system **200** may be a tiered control system, wherein control of the subsystems **211-219** of the well construction system **100** may be provided via a first tier formed by the local controllers **221-229** and a second tier formed by the central controller **192**. The central controller **192** may facilitate control of one or more of the subsystems **211-219** at the level of each individual subsystem **211-219**. For example, in the DFP system **215**, sensor data may be fed into the local controller **225**, which may respond to control the actuators **245**. However, for control operations that involve multiple subsystems **211-219**, the control may be coordinated through the central controller **192** operable to coordinate control of the equipment of two, three, four, or more (or each) of the subsystems **211-219**. For example, coordinated control operations may include the control of downhole pressure during tripping. The downhole pressure may be affected by the DFC system **214** (e.g., pump rate) and the TH system **211** (e.g., tripping speed). Thus, when it is intended to maintain a certain downhole pressure during tripping, the central controller **192** may output control data to two or more of the participating subsystems **211-219**.

As described above, the central controller **192** may control various operations of the subsystems **211-219** via analysis of the sensor data from one or more of the subsystems **211-219** to facilitate coordinated control between the subsystems **211-219**. The central controller **192** may generate or otherwise output control data to coordinate operations of various equipment of the subsystems **211-219**. The control data may include, for example, commands from rig personnel, such as turn on or turn off a pump, switch on or off a fluid valve, or update a physical property setpoint, among other examples. The local controllers **221-229** may each include a fast control loop that directly obtains sensor data and executes, for example, a control algorithm to output the control data. The central controller **192** may include a slow control loop to periodically obtain sensor data and output the control data.

The central controller **192** and the local controllers **221-229** may each or collectively operate to receive and store machine-readable and executable program code instructions (e.g., computer program code, algorithms, programmed processes or operations, etc.) on a memory device (e.g., a memory chip, a memory disk, etc.) and then execute the program code instructions to run, operate, or perform various processes for monitoring and/or controlling the equipment of the well construction system **100**.

The central controller **192** may run (i.e., execute) a central control process **204** (e.g., a coordinated control process) and each local controller **221-229** may run a corresponding local control process. Two or more of the local controllers **221-229** may run their local control processes to collectively coordinate operations between the equipment of two or more of the subsystems **211-219**. The control process **204** of the central controller **192** may operate as a mechanization manager of the rig control system **200**, coordinating operational sequences of the equipment of the well construction system **100**.

The well construction system **100** may also be operated manually by rig personnel **195** (e.g., a driller) via the control workstation **197**. The control workstation **197** may be utilized to monitor, configure, control, and/or otherwise operate one or more of the subsystems **211-219** by the rig personnel **195**. The control workstation **197** may be operable for entering or otherwise communicating control data (e.g., commands, signals, information, etc.) to the central controller **192** and the local controllers **221-229** by the rig personnel **195**, and for displaying or otherwise communicating information from the central controller **192** and the local controllers **221-229** to the rig personnel **195**. The control workstation **197** may be communicatively connected with the central controller **192** and/or the local controllers **221-229** via the communication networks **202**, **251-259** and may be operable to receive sensor data from the sensors **231-239** and transmit control data to the central controller **192** and/or the local controllers **221-229** to control the actuators **241-249**. Accordingly, the control workstation **197** may be utilized by the rig personnel **195** to monitor and control the actuators **241-249** and other portions of the subsystems **211-219** via the central controller **192** and/or local controllers **221-229**.

During manual operation of the well construction system **100**, the rig personnel may operate as the mechanization manager of the rig control system **200** by manually coordinating operations of various equipment, such as to achieve an intended operational status (or drilling state) of the well construction operations, including tripping in or drilling at an intended rate of penetration (ROP). The control process of each local controller **221-229** may facilitate a lower (e.g., basic) level of control within the rig control system **200** to operate a corresponding piece of equipment or a plurality of pieces of equipment of a corresponding subsystem **211-219**. Such control process may facilitate, for example, starting, stopping, and setting or maintaining an operational speed of a piece of equipment. During manual operation of the well construction system **100**, the rig personnel **195** manually controls the individual pieces of equipment to achieve the intended operational status of each piece of equipment.

During automatic or semi-automatic operation of the well construction system **100**, the control process **204** of the central controller **192** may output control data directly to the actuators **241-249** to control the well construction operations. The control process **204** may also or instead output control data to the local control process of one or more local controllers **221-229**, wherein each local control process may then output control data to the actuators **241-249** of the corresponding subsystem **211-219** to control a portion of the well construction operations performed by that subsystem **211-219**. Thus, the control processes of the central controller **192** and the local controllers **221-229** of the rig control system **200** individually and collectively perform monitoring and control operations described herein, including monitoring and controlling well construction operations. The program code instructions forming the basis for the control processes described herein may comprise rules (e.g., algorithms) based on the laws of physics for drilling and other well construction operations, among other examples.

Each control process being run by the controllers **192**, **221-229** of the rig control system **200** may receive and process (i.e., analyze) sensor data from the sensors **231-239** according to the program code instructions, and may output control data (i.e., control signals or information) to operate or otherwise control the actuators **241-249** of the equipment. The controllers **192**, **221-229** within the scope of the present disclosure can include, for example, programmable logic controllers (PLCs), industrial computers (IPCs), personal computers (PCs), soft PLCs, variable frequency drives (VFDs), and/or other controllers or processing devices operable to store and execute program code instructions, receive sensor data, and output control data to cause operation of the equipment based on the program code instructions, sensor data, and/or control data.

The well construction system **100** further comprises a plurality of operational data sources **205** operable to output operational data indicative of or otherwise associated with various operational aspects of the well construction system **100** and/or well construction operations performed by the well construction system **100**. Each operational data source **205** may be communicatively connected to the central communication network **202** to communicatively connect the operational data sources **205** with the central controller **192**, the control workstation **197**, and the subsystems **211-219** of the rig control system **200**.

One or more of the operational data sources **205** and the local controllers **227-229** of the safety systems **217-219** may be communicatively connected with the rig control system **200** via corresponding fieldbus couplers (not shown). Such fieldbus couplers (e.g., PN/PN, DP/DP, etc.) may operate as network interfaces, communicatively connecting one or more of the operational data sources **205** and the local controllers **227-229** to the communication network **202** and, thus, communicatively connecting one or more of the operational data sources **205** and the local controllers **227-229** to the central controller **192** and/or the local controllers **221-226** of the rig control system **200**. Accordingly, the BOP controller **228** may be communicatively connected with and operable to receive data (e.g., sensor data, control commands, etc.) output by one or more of the local controllers **227**, **229** of the other safety systems **217**, **219**, the operational data sources **205**, and the local controllers **221-226** of the subsystems **211-216**.

Although the operational data sources **205** are shown as being external to the rig control system **200**, one or more of the operational data sources **205** may be or form a portion of the rig control system **200**. For example, one or more of the operational data sources **205** may be stored (i.e., recorded) and/or performed by the central controller **192** or other processing devices of the rig control system **200**. Furthermore, although the operational data sources **205** are shown as being implemented as part of the well construction system **100**, one or more of the operational data sources **205** may be external to the well construction system **100** and located remote from the wellsite **104**. For example, one or more of the operational data sources **205** may be stored (i.e., recorded) and/or performed by a remote controller **260** (e.g., a processing device). The remote controller **260** may be communicatively connected to the communication network **202** and, thus, communicatively connected to one or more of the central controller **192**, the local controllers **221-229**, and the sensors **231-239**. A remote control workstation **262** may be communicatively connected to the remote controller **260**. The workstation **262** may be operable for entering or otherwise communicating control data (e.g., commands, signals, information, etc.) to the remote controller **260** and other equipment controllers (e.g., central controller **192**, local controllers **221-229**, etc.) by the rig personnel **195**, and for displaying or otherwise communicating information from the remote controller **260** and other equipment controllers to the rig personnel **195**. The remote controller **260** and the workstation **262** may comprise one or more features and/or modes of operation of the central controller **192** and the workstation **197**, respectively, as described above.

The operational data sources **205** may comprise a data storage device operable to receive and store a well construction plan (or drilling plan) **206** for drilling and/or otherwise constructing a planned well. The well construction plan **206** may include well specifications, operational parameters, and other information indicative of the planned well and the well construction equipment of the well construction system **100**. For example, the well construction plan **206** may include properties of the subterranean formation through which the planned well is to be drilled and otherwise constructed, the path (e.g., direction, curvature, orientation, etc.) along which the planned well is to be formed through the formation, the depth (e.g., true vertical depth (TVD) and/or measured depth (MD)) of the planned well, operational specifications (e.g., power output, weight, torque capabilities, speed capabilities, dimensions, size, etc.) of the well construction equipment (e.g., top drive, mud pumps, **144**, downhole mud motor **184**, etc.) that is planned to be used to construct the planned well, and/or specifications (e.g., diameter, length, weight, etc.) of tubulars (e.g., drill pipe) that are planned to be used to construct the planned well. The well construction plan **206** may include knowledge (e.g., efficiency of various parameters) learned from offset wells that have been drilled. Optimal parameters associated with the offset wells may then be used as the recommended parameters in a current well construction plan **206**. The knowledge learned from the offset wells, including operation limits, such as maximum WOB, top drive speed (RPM), ROP, and/or tripping speed versus depth, may be applied and used as an operation limit within the well construction plan **206**.

The well construction plan **206** may further include well construction operations schedule (e.g., order and/or time of well constriction operations) for a plurality of planned well construction tasks (i.e., well construction objectives) that are intended to be achieved to complete the well construction plan **206**. Each planned task may comprise a plurality of operational sequences and may be performed by the well construction equipment to construct the planned well. A planned task may be or comprise drilling a predetermined portion or depth of the planned well, completing a predetermined portion or stage of drilling operations, drilling through a predetermined section of the subterranean formation, and performing a predetermined plurality of operational sequences, among other examples. Each operational sequence may comprise a plurality or sequence of physical (i.e., mechanical) operations (i.e., actions) performed by various pieces of well construction equipment. Example operational sequences may include operations of one or more pieces of the well construction equipment of the well construction system **100** described above in association with FIG. **1**.

The well construction plan **206** may further include planned operational parameters of the well construction equipment during each planned stage, portion, sequence, task, and/or operation of the well construction operations, such as WOB, RPM, and ROP as a function of wellbore depth. The well construction plan **206** may further include a planned electrical power demand profile (or schedule) indicative of electrical power demand for performing or otherwise associated with each planned stage, portion, sequence, task, and/or operation of the well construction operations contained in the well construction plan **206**. Thus, the planned electrical power demand profile may be or comprise a schedule (e.g., sequence or order) of expected electrical power demand levels for predetermined pieces of well construction equipment that are to be met to perform each planned stage, portion, sequence, task, and/or operation of the well construction operations. The planned electrical power demand profile may comprise information indicative of planned generation and/or distribution of electrical power generated by one or more pieces of electrical power generating equipment of the PS system **216** to the various well construction equipment of the well construction system **100**, including the well construction equipment of the subsystems **211-219**, such as to facilitate performance of the well construction operations pursuant to the well construction plan **206**.

The information forming or otherwise from the well construction plan **206** may originate or be delivered in a paper form, whereby the rig personnel manually input such information into the data storage device containing the well construction plan **206**. However, the information forming the well construction plan **206** may originate or be delivered in digital format, such that it can be directly loaded to or saved by the data storage device or plurality of data storage devices. The data storage device, or plurality of data storage devices, containing the well construction plan **206** may be communicatively connected to the central controller **192** such that the central controller **192** can receive and process (or analyze) the well construction plan **206**. The well construction plan **206** may be analyzed programmatically by the central controller **192** without human intervention. The data storage device storing the well construction plan **206** may be directly or indirectly (e.g., via the communication network **202**) communicatively connected with the central controller **192**. The data storage device storing the well construction plan **206** may instead be or form a portion of the central controller **192**. The central controller **192** may analyze the well construction plan **206** and generate or output control data to the local controllers **221-229** or directly to the actuators **241-249** to control the well construction equipment to cause, facilitate, or otherwise implement one or more aspects of methods and operations described herein.

The operational data sources **205** may comprise a processing device (e.g., a computer, a PLC, etc.) operable to receive and store machine-readable and executable program code instructions on a data storage device and then execute such program code instructions to run, operate, or perform an abnormal event detector **207** (e.g., an abnormal event detecting computer process), which may be operable to analyze or otherwise process the sensor data received from the sensors **231-239** and detect an abnormal event (e.g., status, condition, etc.) experienced by or otherwise associated with one or more pieces of well construction equipment, and/or an abnormal event experienced by or otherwise associated with a wellbore (e.g., the wellbore **102** shown in FIG. **1**). The abnormal event detector **207** may be operable to detect the abnormal events based on the sensor data and output abnormal event data indicative of the detected abnormal event. The processing device performing the abnormal event detector **207** may be directly or indirectly (e.g., via the communication network **202**) communicatively connected with the central controller **192** and operable to transmit the abnormal event data to the central controller **192** for analysis. The processing device performing the abnormal event detector **207** may instead be or form a portion of the central controller **192**. One or more of the local controllers **221-229** may also execute program code instructions to execute a corresponding abnormal event detector **207** to detect a local abnormal event. The local controllers **221-229** may then transmit local abnormal event data indicative of the local abnormal event to the central controller **192** for analysis.

The central controller **192** and/or the local controllers **221-229** may be operable to automate the well construction equipment to perform well construction operations and change such well construction operations as operational parameters of the well construction operations change and/or when an abnormal event (e.g., state, condition, etc.) is detected during the well construction operations. For example, the control process **204** of the central controller **192** may then re-plan well construction tasks, operational sequences, and other processes based on the well construction plan **206**, the detected abnormal events, and/or the condition of the well and/or the well construction equipment. The abnormal event detector **207** may be operable to detect an abnormal event based on the sensor data received from the sensors **231-239** and cause the predetermined operations to be performed or otherwise implemented to stop or mitigate the abnormal event or otherwise in response to the abnormal event, without manual control of the well construction equipment by the rig personnel via the control workstation **197**. For example, the central controller **192** may be operable to make decisions related to selection of actions or sequences of operations that are to be implemented during the well construction operations and/or the manner (e.g., speed, torque, mechanical power, electrical power, etc.) in which such selected operational sequences are to be implemented to stop or mitigate a detected abnormal event.

An abnormal event may be or comprise an abnormal operational surface event experienced by surface equipment (e.g., the surface equipment **110** shown in FIG. **1**) and/or an abnormal operational downhole event experienced by a drill string (e.g., the drill string **120** shown in FIG. **1**). An example abnormal operational downhole event may include stick-slip, axial vibrations, lateral vibrations, rotational vibrations, and stuck drill pipe. The abnormal event may instead be or comprise an abnormal downhole fluid event experienced by a downhole fluid, such as wellbore fluid (e.g., drilling fluid, formation fluid, fracturing fluid, etc.) within the wellbore, and/or formation fluid within a subterranean formation (e.g., the subterranean formation **106** shown in FIG. **1**) through which the wellbore extends. An abnormal downhole fluid event may comprise, for example, a sudden change (e.g., increase or decrease) in wellbore pressure and/or wellbore fluid volume. An example abnormal downhole fluid event may include underpressure of the formation fluid, overpressure of the formation fluid, influx of formation fluid, gains of the wellbore fluid, and losses of the wellbore fluid.

The operational data sources **205** may comprise a processing device (e.g., a computer, a PLC, etc.) operable to receive and store machine-readable and executable program code instructions on a data storage device and then execute such program code instructions to run, operate, or perform an operational state detector **208** (e.g., an operational state detecting computer process), which may be operable to analyze or otherwise process the sensor data received from the sensors **231-239** and detect a state (e.g., a status, a stage, etc.) of the well construction operations that the well construction system **100** is performing. The operational state detector **208** may then output operational state data indicative of the operational state of the well construction system **100**. The processing device performing the operational state detector **208** may be directly or indirectly (e.g., via the communication network **202**) communicatively connected with the central controller **192** and operable to transmit the operational state data to the central controller **192** for analysis. The processing device performing the operational state detector **208** may instead be or form a portion of the central controller **192**. One or more of the local controllers **221-229** may also execute program code instructions to execute a corresponding operational state detector **208** to detect a local operational state. The local controllers **221-229** may then transmit local operational state data indicative of the local operational state to the central controller **192** for analysis. Operational states of the well construction system **100** may comprise, for example, drilling, tripping, circulating, and reaming, among others.

The central controller **192** and/or the local controllers **221-229** may be operable to automate the well construction equipment to perform well construction operations and change such well construction operations as operational parameters of the well construction operations change and/or when a change in operational state (e.g., state, condition, etc.) is detected during the well construction operations. For example, the control process **204** of the central controller **192** may then re-plan well construction tasks, operational sequences, and other processes based on the well construction plan **206**, the detected operational state, and/or the condition of the well and/or the well construction equipment.

The operational data sources **205** may comprise a processing device (e.g., a computer, a PLC, etc.) operable to receive and store machine-readable and executable program code instructions on a data storage device and then execute such program code instructions to run, operate, or perform a pipe tally tracker **209** (e.g., a pipe tally tracking computer process). The pipe tally tracker **209** may be operable to track (i.e., determine and record) a pipe tally (i.e., a list or inventory) containing various attributes (e.g., physical characteristics or specifications) indicative of or otherwise associated with each tubular (e.g., drill pipe, drill collars, drill pipe stands, casing joints, etc.) stored, used, or otherwise located at the well construction system **100**, including tubulars that have been received on the rig floor **114** and/or stored in the fingerboard **164** of the pipe rack **162**. The processing device performing the pipe tally tracker **209** may be directly or indirectly (e.g., via the communication network **202**) communicatively connected with the central controller **192** and operable to transmit the pipe tally tracker **209** to the central controller **192** for analysis. The processing device performing the pipe tally tracker **209** may instead be or form a portion of the central controller **192**.

The pipe tally tracker **209** may track the pipe tally in preparation for drilling or running operations. The pipe tally may be updated as the tubulars are being retrieved from the wellbore **102**. For example, the pipe tally tracker **209** may track length of the drill string **120** based on the pipe tally. The pipe tally tracker **209** may be operable to track position (e.g., depth, height, stickup height, etc.) of each tubular and/or connection joint connecting adjacent tubulars. The pipe tally tracker **209** may simultaneously update service records, length of the drill string **120**, and/or position of each tubular and/or connection joint. The pipe tally tracker **209** may be operable to receive and record block position measurements indicative of the height of the travelling block **113** as the DSH system **212** moves the drill string **120** upward and/or downward into and/or out of the wellbore **102**. The pipe tally tracker **209** may be further operable to keep track of location and physical characteristics (e.g., a measured length) of each tubular and/or connection joint that is deployed downhole as part of the drill string **120**, retrieved to the wellsite surface **104** from the wellbore **102**, and/or stored in a fingerboard **164**. The pipe tally tracker **209** may be further operable to determine the stickup height of the drill string **120** based on the height of the travelling block **113** and the pipe tally. The stickup height may be or comprise a height that the stickup portion of the drill string **120** extends above the rig floor **114**. The stickup portion may be or comprise a portion of a tubular of the drill string **120** that is gripped by the slips **119** that extends above the rig floor **114**.

The pipe tally may comprise an identifier (e.g., an identification number, a serial number, an assigned number, etc.) of each tubular in association with various attributes of that tubular, such as location on the fingerboard **164**, weight, diameter, length, type, and historical use, among other examples. The pipe tally tracker **209** may automatically record the identifier of each tubular as it is deployed into and withdrawn from the wellbore **102** to record the order in which each tubular is deployed into and withdrawn from the wellbore **102**. Tallying of the tubulars may be facilitated by a reader (not shown) operable to read the identifier off of a tag (e.g., a radio frequency tag, a magnetic tag, a bar code, a label, etc.) (not shown) associated with each tubular, such as when each tubular is received on the rig floor **114** and/or when being deployed into and withdrawn from the wellbore **102**. The identifier may then be received and stored by the pipe tally tracker **209** to form or update the pipe tally. The tallying of the tubulars may instead be facilitated by sensors (e.g., weight and/or length sensors) (not shown) operable to track location attributes of each tubular, including information indicating when each tubular is received on the rig floor **114** and/or when each tubular is deployed into and withdrawn from the wellbore **102**. The tracked attributes may then be received and stored by the pipe tally tracker **209** in association with an identifier assigned to that tubular, to form or update the pipe tally.

The operational data sources **205** may comprise a processing device (e.g., a computer, a PLC, etc.) operable to receive and store machine-readable and executable program code instructions on a data storage device and then execute such program code instructions to run, operate, or perform an equipment health monitor **210** (e.g., an equipment health monitoring computer process). The health monitor **210** may be operable to receive and record sensor data indicative of operational status of various well construction equipment and predict, calculate, or otherwise determine operational health (e.g., operational condition, maintenance condition, remaining operational life, etc.) of such well construction equipment based on the sensor data. The processing device performing the health monitor **210** may be communicatively connected with the local controllers **221-229** of the subsystems **211-219** via the communication network **202** and the local communication networks **251-252**, such as may permit the health monitor **210** to receive sensor data from the sensors **231-239** of the various equipment of the subsystems **211-219**. The processing device performing the health monitor **210** may be directly or indirectly (e.g., via the communication network **202**) communicatively connected with the central controller **192** and operable to transmit the determined operational health to the central controller **192** for further analysis and/or to the control workstation **197** to be viewed by the rig personnel. The processing device performing the health monitor **210** may instead be or form a portion of the central controller **192**.

The health monitor **210** may be operable to determine operational health of various well construction equipment based on sensor data output by sensors **231-239** associated with such well construction equipment. The health monitor **210** may be operable to determine operational health of the well construction equipment by using or otherwise based on one or more operational health monitoring analytics (or theories).

For example, the health monitor **210** may be operable to determine (current) operational health of well construction equipment based on an operational quantity (or amount) of an operational parameter indicated by sensor data. The operational quantity may be tracked (i.e., recorded and determined) and continuously compared to a historical (i.e., past, recorded, or otherwise known) operational quantity baseline (or threshold) that is associated with a historical operational health. The operational quantity may also or instead be tracked and continuously compared to a historical operational quantity trend (or curve) that associates a progressively changing historical operational health with a progressively changing historical operational quantity. Both the historical operational quantity baseline and the historical operational quantity trend may be determined based on historical operational quantity records. Thus, operational health may be determined by comparing a current operational quantity to a historical operational quantity baseline or to a historical operational quantity trend and then estimating (e.g., interpolating, extrapolating, etc.) the operational health based on such comparison. For example, operational health may be determined based on a relative difference between the historical operational quantity baseline and the current operational quantity. The operational health may also or instead be determined by assuming that the operational health is the same as (or equal to) the historical operational health along the historical operational quantity trend that is associated with the historical operational quantity that is the same as the current operational quantity. Operational quantities may include, for example, a quantity (i.e., number) of hours a piece of equipment has been operating, a quantity of operational cycles (e.g., movements, rises, closures, rotations, etc.) that piece of equipment has performed, a cumulative (or total) distance that a piece of equipment has moved, and a cumulative distance that a piece of equipment has moved an object (e.g., a tubular, a drill string, a travelling block, etc.).

The health monitor **210** may also or instead be operable to determine operational health of well construction equipment based on performance based condition monitoring, which utilizes sensor data indicative of actions performed or otherwise caused by actuators **241-249** of a piece of equipment to generate or otherwise output performance based condition indicators. Such performance based condition indicators may then be utilized as a basis for determining operational health of the piece of equipment. Performance based condition indicators may be indicative of condition of each actuator **241-249** and/or other components facilitating each action performed by the piece of equipment. Performance based condition indicators may be utilized as a basis for predicting developing faults (i.e., operational problems, breakdowns, failures) before such faults have manifested themselves through visual and/or physical detection by rig personnel or a full stop (i.e., failure) of the well construction equipment. When a fault has progressed to a point at which it is detectable via audible noise or excessive temperature (e.g., too hot to touch), the equipment is approaching point of failure.

Performance based condition monitoring may utilize a bottom-up approach, which focuses on sensor data indicative of detailed operational states (e.g., physical states) of individual actuators **241-249** or other components causing or otherwise associated with each action performed by a piece of equipment. The health monitor **210** may utilize sensor data to predict or determine the condition of the piece of well construction equipment. For example, performance based condition monitoring may include recording sensor data for each sensor **231-239**, actuator **241-249**, and/or action of a piece of equipment, and analyzing or otherwise processing such sensor data to output performance based condition indicators to predict or determine condition of the piece of equipment. The health monitor **210** may determine (i.e., calculate, generate, etc.) the performance based condition indicators based on sensor data indicative of physical states during each action caused, performed, or otherwise facilitated by a corresponding actuator **241-249** or other part of a piece of well construction equipment. Sensor data may be further indicative of different points of measurement of the action performed. Sensor data may include, for example, position of a hydraulic cylinder or motor, hydraulic fluid pressure, pressure within an accumulator, flow generated by a pump, force generated by an actuator **241-249**, and temperature of hydraulic fluid.

The health monitor **210** may determine the performance based condition indicators based further on control commands (e.g., control signals, sequence steps, control functions, etc.) generated or output by equipment controllers to the individual actuators **241-249** of the well construction equipment triggering or causing the intended actions. The use of control commands highlights performance of the actuators **241-249** in the overall process efficiency, thereby treating the actuator **241-249** performance independently of process parameters. The sensor data may be compared to the control commands to determine differences in performance between an action that has been intended, as indicated by the control commend, and an action that has been actually executed, as indicated by the sensor data. Control commands may initiate the action. Control commands may include, for example, control signals that are transmitted by an equipment controller (e.g., central controller devices **192** and local controllers **221-229**) to a mechanical controller, such as a hydraulic valve, to operate a hydraulic actuator, or an electrical controller, such as a relay or VFD, to operate an electrical actuator.

The performance based condition indicators may be recorded. Current and historical performance based condition indicators may be analyzed systematically or in real-time over a period of time by the health monitor **210** to recognize changes or trends in performance (e.g., performance quality degradation) of individual actuators **241-249** or components. Such trends may be indicative of developing or potential faults, which may be repaired or otherwise addressed before failure or large reductions in performance can manifest. When at least one of the performance based condition indicators falls below a predetermined threshold, the health monitor **210** may then generate or output health condition information indicative of operational health of the piece of equipment and transmit such health condition information to one or more output devices (e.g., workstations **151**, **197**) for viewing by rig personnel, who may then implement maintenance operations to improve the operational health of such piece of equipment.

The operational data sources **205** may comprise a processing device (e.g., a computer, a PLC, etc.) operable to receive and store machine-readable and executable program code instructions on a data storage device and then execute such program code instructions to run, operate, or perform a communication network and sensor health monitor **203** (e.g., a communication network and sensor health monitoring computer process). The health monitor **203** may be operable to receive data (e.g., sensor data, control commands, etc.) transmitted via various communication networks (e.g., communication networks **202**, **251-259**, etc.) and monitor such data to predict, calculate, or otherwise determine operational health of the communication networks and sensors (e.g., sensors **231-239**) connected to such communication networks. The processing device performing the health monitor **203** may be communicatively connected with the local controllers **221-229** of the subsystems **211-219** via the communication network **202** and the local communication networks **251-259**, such as may permit the health monitor **210** to receive sensor data from the sensors **231-239** of the various equipment of the subsystems **211-219**. The processing device performing the health monitor **203** may be directly or indirectly (e.g., via the communication network **202**) communicatively connected with the central controller **192** and operable to transmit the determined operational health to the central controller **192** for further analysis and/or to the control workstation **197** to be viewed by the rig personnel. The processing device performing the health monitor **203** may instead be or form a portion of the central controller **192**.

The communication network and sensor health monitor **203** may therefore be or comprise a fail-safe watchdog system operable to monitor the status of the communication networks **202**, **251-259** (and other communication systems) and sensors **231-239** of the well construction system **100**. For example, the health monitor **203** may be operable to determine operational health of sensors **237-239** and/or the communication networks **257-259** of one or more of the safety systems **217-219**. The health monitor **203** may monitor quality of signals output by the sensors **231-239**, including sensor activity, status, and/or data consistency to determine operational health of the sensors **231-239** and communication networks **202**, **251-259**. The health monitor **203** continuously checks operational health of the sensors **231-239** and the communication networks **202**, **251-259** within the scope of the present disclosure and may be operable to facilitate alarms indicative of loss of operational health and/or stop operation of equipment of one or more of the subsystems **211-219** when loss of operational health is detected. The health monitor **203** may also permit safe restarting of equipment of one or more of the subsystems **211-219** after loss of operational health is remedied.

FIG. **3** is a schematic view of at least a portion of an example implementation of a processing device (or system) **300** according to one or more aspects of the present disclosure. The processing device **300** may be or form at least a portion of one or more equipment controllers and/or other electronic devices shown in one or more of the FIGS. **1** and **2**. For example, the processing device **300** may be or form at least a portion of one or more of the central controller **192**, the local controllers **221-229**, the control workstations **151**, **197**, the drilling plan **206**, the abnormal event detector **207**, the operational state detector **208**, the pipe tally tracker **209**, and the health monitor **210**. Accordingly, the following description refers to FIGS. **1-3**, collectively.

The processing device **300** may be or comprise, for example, one or more processors, controllers, special-purpose computing devices, PCs (e.g., desktop, laptop, and/or tablet computers), personal digital assistants, smartphones, IPCs, PLCs, servers, internet appliances, and/or other types of computing devices. Although it is possible that the entirety of the processing device **300** is implemented within one device, it is also contemplated that one or more components or functions of the processing device **300** may be implemented across multiple devices, some or an entirety of which may be at the wellsite and/or remote from the wellsite.

The processing device **300** may comprise a processor **312**, such as a general-purpose programmable processor. The processor **312** may comprise a local memory **314**, and may execute machine-readable and executable program code instructions **332** (i.e., computer program code) present in the local memory **314** and/or other memory device. The processor **312** may be, comprise, or be implemented by one or more processors of various types suitable to the local application environment, and may include one or more of general-purpose computers, special-purpose computers, microprocessors, digital signal processors (DSPs), field-programmable gate arrays (FPGAs), application-specific integrated circuits (ASICs), and processors based on a multi-core processor architecture, as non-limiting examples. Examples of the processor **312** include one or more INTEL microprocessors, microcontrollers from the ARM and/or PICO families of microcontrollers, embedded soft/hard processors in one or more FPGAs.

The processor **312** may execute, among other things, the program code instructions **332** and/or other instructions and/or programs to implement the example methods and/or operations described herein. For example, the program code instructions **332**, when executed by the processor **312** of the processing device **300**, may cause the processor **312** to receive and process (e.g., compare, analyze, etc.) sensor data (e.g., sensor measurements). The program code instructions **332**, when executed by the processor **312** of the processing device **300**, may also or instead output control data (i.e., control commands) to cause one or more portions or pieces of well construction equipment of a well construction system to perform the example methods and/or operations described herein. The program code instructions **332**, when executed by the processor **312** of the processing device **300**, may also or instead output information indicative of an event (e.g., abnormal event), a status (e.g., operational state, operational position, operational health, etc.), or a characteristic (e.g., size, length, height, etc.) of an object (e.g., a tubular), a piece of equipment, a well construction system, or otherwise at a wellsite to an output device (e.g., control workstation **197**) for viewing by rig personnel.

The processor **312** may be in communication with a main memory **316**, such as may include a volatile memory **318** and a non-volatile memory **320**, perhaps via a bus **322** and/or other communication means. The volatile memory **318** may be, comprise, or be implemented by random-access memory (RAM), static RAM (SRAM), dynamic RAM (DRAM), synchronous DRAM (SDRAM), RAMBUS DRAM (RDRAM), and/or other types of RAM devices. The non-volatile memory **320** may be, comprise, or be implemented by read-only memory, flash memory, and/or other types of memory devices. One or more memory controllers (not shown) may control access to the volatile memory **318** and/or non-volatile memory **320**.

The processing device **300** may also comprise an interface circuit **324**, which is in communication with the processor

312, such as via the bus 322. The interface circuit 324 may be, comprise, or be implemented by various types of standard interfaces, such as an Ethernet interface, a universal serial bus (USB), a third generation input/output (3GIO) interface, a wireless interface, a cellular interface, and/or a satellite interface, among others. The interface circuit 324 may comprise a graphics driver card. The interface circuit 324 may comprise a communication device, such as a modem or network interface card to facilitate exchange of data with external computing devices via a network (e.g., Ethernet connection, digital subscriber line (DSL), telephone line, coaxial cable, cellular telephone system, satellite, etc.).

The processing device 300 may be in communication with various sensors, video cameras, actuators, processing devices, equipment controllers, and other devices of the well construction system via the interface circuit 324. The interface circuit 324 can facilitate communications between the processing device 300 and one or more devices by utilizing one or more communication protocols, such as an Ethernet-based network protocol (such as ProfiNET, OPC, OPC/UA, Modbus TCP/IP, EtherCAT, UDP multicast, Siemens S7 communication, or the like), a proprietary communication protocol, and/or other communication protocol.

One or more input devices 326 may also be connected to the interface circuit 324. The input devices 326 may permit a human user to enter the program code instructions 332, which may be or comprise control data, operational parameters, operational set-points, a well construction plan, and/or a database of operational sequences. The program code instructions 332 may further comprise modeling or predictive routines, equations, algorithms, processes, applications, and/or other programs operable to perform example methods and/or operations described herein. The input devices 326 may be, comprise, or be implemented by a keyboard, a mouse, a joystick, a touchscreen, a track-pad, a trackball, an isopoint, and/or a voice recognition system, among other examples. One or more output devices 328 may also be connected to the interface circuit 324. The output devices 328 may permit visualization or other sensory perception of various data, such as sensor data, status data, and/or other example data. The output devices 328 may be, comprise, or be implemented by video output devices (e.g., a liquid crystal display (LCD), a light-emitting diode (LED) display, a cathode ray tube (CRT) display, a touchscreen, etc.), printers, and/or speakers, among other examples. The one or more input devices 326 and the one or more output devices 328 connected to the interface circuit 324 may, at least in part, facilitate the HMIs described herein.

The processing device 300 may comprise a mass storage device 330 for storing data and program code instructions 332. The mass storage device 330 may be connected to the processor 312, such as via the bus 322. The mass storage device 330 may be or comprise a tangible, non-transitory storage medium, such as a floppy disk drive, a hard disk drive, a compact disk (CD) drive, and/or digital versatile disk (DVD) drive, among other examples. The processing device 300 may be communicatively connected with an external storage medium 334 via the interface circuit 324. The external storage medium 334 may be or comprise a removable storage medium (e.g., a CD or DVD), such as may be operable to store data and program code instructions 332.

As described above, the program code instructions 332 may be stored in the mass storage device 330, the main memory 316, the local memory 314, and/or the removable storage medium 334. Thus, the processing device 300 may be implemented in accordance with hardware (perhaps implemented in one or more chips including an integrated circuit, such as an ASIC), or may be implemented as software or firmware for execution by the processor 312. In the case of firmware or software, the implementation may be provided as a computer program product including a non-transitory, computer-readable medium or storage structure embodying computer program code instructions 332 (i.e., software or firmware) thereon for execution by the processor 312. The program code instructions 332 may include program instructions or computer program code that, when executed by the processor 312, may perform and/or cause performance of example methods, processes, and/or operations described herein.

The present disclosure is further directed to systems and methods (e.g., operations and/or processes) for communicating with (e.g., monitoring, controlling, etc.) a BOP control system operable to monitor and control operation of BOP equipment at a wellsite. The systems of the present disclosure may comprise one or more instances of the apparatus (e.g., controllers 192, 221-229, workstations 151, 197, rig equipment 241-246, safety equipment 247-249, equipment systems or subsystems 211-219, etc.) shown in one or more of FIGS. 1-3, and/or otherwise within the scope of the present disclosure. Similarly, the methods of the present disclosure may be performed by utilizing (or otherwise in conjunction with) at least a portion of one or more implementations of one or more instances of the apparatus shown in one or more of FIGS. 1-3, and/or otherwise within the scope of the present disclosure. The methods may be caused to be performed, at least partially, by a controller (e.g., the control device 300, the central controller 192, the BOP controller 153, etc.) executing computer program code according to one or more aspects of the present disclosure. Thus, the present disclosure is also directed to a non-transitory, computer-readable medium comprising computer program code that, when executed by the controller, may cause such controller to perform the example methods described herein. The methods may also or instead be caused to be performed, at least partially, by rig personnel utilizing one or more instances of the apparatus shown in one or more of FIGS. 1-3, and/or otherwise within the scope of the present disclosure. Thus, the following description of example systems and/or methods refer to apparatus shown in one or more of FIGS. 1-3. However, the methods may also be performed in conjunction with implementations of apparatus other than those depicted in FIGS. 1-3 that are also within the scope of the present disclosure.

An example system for communicating with a BOP control system according to one or more aspects of the present disclosure may comprise the rig control system 200 for monitoring and controlling the rig equipment 241-246 operable to perform or otherwise facilitate drilling operations to drill the wellbore 201 at the wellsite 104. An example system for communicating with a BOP control system according to one or more aspects of the present disclosure may also or instead comprise a pressure control system for monitoring and controlling safety equipment (e.g., one or more of the pressure control manifolds 152, 156) fluidly connected with the wellbore 102.

The rig control system 200 may comprise the equipment controllers 192, 221-226 for controlling the rig equipment 241-246 and the sensors 231-236 operable to output rig data indicative of operational status of the rig equipment 241-246. For example, rig data may include position of the travelling block 113, which may be indicative of or otherwise used by the rig control system 200 to determine, for example, position (or height) of the drill string **120** within the wellbore **102**, within the BOP equipment **130**, **132**, and above the rig floor **114**, position of various portions (e.g., connection joints) of the drill string **120** within the wellbore **102**, within the BOP equipment **130**, **132**, and above the rig floor **114**, and length of the drill string **120** conveyed within the wellbore **102**. As described above, the rig control system **200** may comprise the pipe tally tracker **209** or the rig control system **200** may instead be communicatively connected with the pipe tally tracker **209**. Thus, the rig control system **200** may be operable to receive from the pipe tally tracker **209** pipe data indicative of the position of the drill string **120** within the wellbore **102**, within the BOP equipment **130**, **132**, and above the rig floor **114**, the position of various portions of the drill string **120** within the wellbore **102**, within the BOP equipment **130**, **132**, and above the rig floor **114**, and the length of the drill string **120** conveyed within the wellbore **102**. The rig control system **200** may also or instead use the pipe data stored on the pipe tally tracker **209**, including characteristics of the individual drill pipe **111**, to determine the position of the drill string **120** within the wellbore **102**, within the BOP equipment **130**, **132**, and above the rig floor **114**, the position of various portions of the drill string **120** within the wellbore **102**, within the BOP equipment **130**, **132**, and above the rig floor **114**, and the length of the drill string **120** conveyed within the wellbore **102**.

The pressure control system may comprise at least a portion of one or more of the MPD system **217** and the CPC system **219**. For example, the pressure control system may be an MPD control system operable to control the MPD manifold **152**. Such pressure control system may comprise the MPD controller **227** for controlling the MPD manifold **152** and the MPD sensors **237** operable to output pressure data associated with the MPD manifold **152** and indicative of wellbore pressure. The pressure control system may also or instead be a choke pressure control system operable to control the CK manifold **156**. Such pressure control system may comprise the CK controller **227** for controlling the CK manifold **156** and the CK sensors **239** operable to output pressure data associated with the CK manifold **156** and indicative of the wellbore pressure. The pressure data may also or instead be indicative of hydraulic pressure applied to an actuator of the BOP equipment **130**, **132** to close the BOP equipment **130**, **132**. For example, the pressure data may be indicative of hydraulic pressure generated by the power unit **137** and applied to the rams of the BOP stack **130** to actuate the rams to a closed position against the drill string **120** or applied to the annular packer of the annular preventer **132** to inflate the annular packer to a closed position against the drill string **120**. Pressure data may also or instead be output by the abnormal event detector **207** and may include pressure data indicative of an impending or current abnormal surface or downhole event that can cause or has caused abnormal wellbore pressure. The sensors (e.g., the sensors **237** and/or the sensors **239**) of a pressure control system (e.g., the MPD control system **217** and/or the CPC system **219**) may be further operable to output flow rate data indicative of flow rate of wellbore fluid (e.g., drilling fluid, formation fluid, etc.) flowing uphole and out of the wellbore **102** to the wellbore surface **104**.

The BOP control system within the scope of the present disclosure may be operable to monitor and control the BOP equipment **130**, **132**. The BOP control system may comprise at least a portion of the WC system **218**. For example, the BOP control system may comprise the BOP controller **228** for controlling the BOP equipment **130**, **132** and the BOP sensors **238** operable to output BOP data indicative of operational status of the BOP equipment **130**, **132**. The BOP control system may further comprise a BOP HMI (e.g., the BOP control workstation **151**) usable by a human user to monitor and control the BOP equipment **130**, **132**. The BOP data may be indicative of closure status of the BOP equipment **130**, **132**, including whether one or more of the sets of rams of the BOP stack **130** or the annular packer of the annular preventer **132** are open or closed. Such closure status BOP data may be based on operator pressure data output by the BOP sensors **238** (e.g., pressure sensors) disposed in association with one or more of the BOP control unit **137** and the BOP equipment **130**, **132**. The operator pressure data may be indicative of hydraulic pressure generated by the power unit **137** and applied to the rams of the BOP stack **130** to actuate the rams to a closed position against the drill string **120** or applied to the annular packer of the annular preventer **132** to inflate the annular packer to a closed position against the drill string **120**. The closure status BOP data may also or instead be based on ram position data output by the BOP sensors **238** (e.g., position sensors, proximity switches, Hall effect switches, etc.) disposed in association with one or more of the BOP control unit **137** and the BOP equipment **130**, **132**.

The BOP control system may be communicatively connected with the rig control system **200** and/or the pressure control system to thereby facilitate communication between the BOP control system, the rig control system **200**, and the pressure control system. The BOP control system may be operable to receive the rig data and/or the pressure data from a corresponding one of the rig control system **200** and the pressure control system and display on the BOP HMI information based on the rig data and/or the pressure data. A human user viewing the information on the BOP HMI may then implement a course of action based on such information. For example, the human user may use the rig control workstation **197** to operate one or more of the rig equipment **241**-**247** in response to the viewed information. The human user may also or instead use the BOP HMI to control one or more of the BOP equipment **130**, **132** in response to the viewed information.

The rig control system **200**, the pressure control system, and/or the BOP control system may be operable to perform or otherwise facilitate alarm operations according to one or more aspects of the present disclosure, such as to alarm the human user (e.g., the driller or other rig personnel) of the BOP HMI of predetermined conditions and/or events. As described above, the rig control system **200** may comprise one or more of the sensors **231**-**236** operable to output rig data indicative of operational status of the rig equipment **241**-**246**, the pressure control system may comprise one or more of the sensors **237**, **239** operable to output pressure data indicative of wellbore pressure, and the BOP control system may comprise one or more of the sensors **238** operable to output BOP data indicative of operational status of the BOP equipment **130**, **132**. For example, when the pressure data indicates that the wellbore pressure is above a predetermined threshold and the BOP data indicates that BOP equipment **130**, **132** is closed, the BOP control system may be operable to display on the BOP HMI information (e.g., an alarm, a warning, etc.) indicative of the wellbore pressure being above a predetermined threshold. Also, when the pressure data indicates that the wellbore pressure is above a predetermined threshold and the rig data indicates that a connection joint of the drill string **120** for performing the drilling operations is located between a set of rams of the BOP equipment **130**, **132**, the BOP control system may be operable to display on the BOP HMI information (e.g., an alarm, a warning, etc.) indicative of the wellbore pressure being above the predetermined threshold and/or display on the BOP HMI information indicative of the connection joint of the drill string **120** being located between the rams of the BOP equipment **130**, **132**.

The rig control system **200** and the BOP control system may also or instead be collectively operable to perform or otherwise facilitate alarm and interlock operations according to one or more aspects of the present disclosure, such as to prevent the human user of the rig control workstation **197** to cause performance of predetermined operations when predetermined conditions and/or events are taking place. For example, when the BOP data indicates that a set of rams of the BOP stack **130** is closed, the rig control system **200** may be operable to display on the rig control workstation **197** information indicative of the set of rams of the BOP stack **130** being closed and/or prevent the rig control workstation **197** from being used by the human user to operate the drawworks **118** to lift the drill string **120**.

The rig control system **200** and the BOP control system may also or instead be collectively operable to perform or otherwise facilitate alarm and interlock operations according to one or more aspects of the present disclosure, such as to limit control of predetermined rig equipment by the human user via the rig control workstation **197** when predetermined conditions and/or events are taking place. For example, when the BOP data indicates that the annular preventer **132** is closed, the rig control system **200** may be operable to display on the rig control workstation **197** information indicative of the annular preventer **132** being closed and/or limit the use of the rig control workstation **197** by the human user to control the drawworks **118** to convey (e.g., raise or lower) the drill string **120** within the wellbore **102**. For example, when the BOP data indicates that the annular preventer **132** is closed, the rig control system **200** may be operable to limit the rate (or speed) at which the drill string **120** is conveyed (or moved) by the drawworks **118**, regardless of whether the human user of the control workstation **197** is attempting to convey the drill string **120** at a faster rate. Thus, during stripping operations when the drill string **120** is conveyed within the wellbore **102** while the annular preventer **132** is closed, a controller (e.g., the central controller, the local controller **222**) of the rig control system **200** may limit the speed of the drawworks **118** to limit the rate at which the drill string **120** is conveyed within the wellbore, such as to reduce wear that is caused to the annular packer of the annular preventer **132**.

The rig control system **200**, the pressure control system, and the BOP control system may also or instead be collectively operable to perform or otherwise facilitate alarm and interlock operations according to one or more aspects of the present disclosure, such as to prevent the human user of the BOP HMI to cause performance of predetermined operations when predetermined conditions and/or events are taking place. For example, when the pressure data indicates that the wellbore pressure is above a predetermined threshold and the BOP data indicates that BOP equipment **130**, **132** is closed, the BOP control system may be operable to display on the BOP HMI information indicative of the wellbore pressure being above the predetermined threshold and prevent the BOP HMI from being used by the human user to open the BOP equipment **130**, **132**. Furthermore, when the pressure data indicates that the wellbore pressure is above the predetermined threshold and the rig data indicates that a connection joint of the drill string **120** is located between a set of rams of the BOP equipment **130**, **132**, the BOP control system may be operable to: display on the BOP HMI information (e.g., an alarm, a warning, etc.) indicative of the wellbore pressure being above the predetermined threshold; display on the BOP HMI information indicative of the connection joint of the drill string **120** being located between the rams of the BOP equipment **130**, **132**; and prevent the BOP HMI from being used by the human user to open the rams of the BOP equipment **130**, **132**.

The rig control system **200**, the pressure control system, and the BOP control system may also or instead be collectively operable to perform or otherwise facilitate alarm and interlock operations and request operation confirmation according to one or more aspects of the present disclosure, such as to prevent the human user of the BOP HMI from manually causing unintended performance of predetermined operations when predetermined conditions and/or events are taking place. For example, when the pressure data indicates that the wellbore pressure is above a predetermined threshold and the BOP data indicates that BOP equipment **130**, **132** is closed, the BOP control system may be operable to: display on the BOP HMI information (e.g., an alarm, a warning, etc.) indicative of the wellbore pressure being above the predetermined threshold, prevent the BOP HMI from being used by the human user to open the BOP equipment **130**, **132**; display on the BOP HMI a request that the human user confirm via the BOP HMI that the wellbore pressure is above the predetermined threshold; and permit the BOP HMI to be used by the human user to open the BOP equipment **130**, **132** after the human user has confirmed via the BOP HMI that the wellbore pressure is above the predetermined threshold. Such operations of the BOP control system may be performed during the drilling operations, such as when high wellbore pressure is caused by influx of formation fluid, and during BOP equipment testing operations, such as when the wellbore **102** is artificially pressurized and the BOP equipment **130**, **132** is tested for intended functionality and fluid leaks.

The rig data may be further indicative of the size of drill pipe **111** of the drill string **120** used to perform the drilling operations and the BOP data may be further indicative of the size of each set of rams of the BOP equipment **130**, **132**. Such rig data and BOP data may be manually entered to a controller (e.g., central controller **192**) of the rig control system **200** and/or a controller (e.g., local controller **228**) of the BOP control system by a human user prior to drilling operations. Such rig data and BOP data may also or instead be output from the well construction plan **206** and/or the pipe tally tracker **209** and automatically pushed to and received by the controllers **192**, **153** of the rig control system **200** and/or the BOP control system.

In an example implementation, when the pressure data indicates that the wellbore pressure is above a predetermined threshold, the BOP control system may be further operable to: display on the BOP HMI information (e.g., an alarm, a warning, etc.) indicative of the wellbore pressure being above the predetermined threshold; display on the BOP HMI a request that the human user select one of the sets of scaling rams of the BOP stack **130** to close; receive from the BOP HMI ram data indicative of the selected one of the sets of rams of the BOP stack **130** to close; and compare the size of the selected one of the sets of rams of the BOP stack **130** and the size of the drill pipe **111**. When the size of the selected one of the sets of rams and the size of the drill pipe **111** match, the BOP control system may be further operable to cause the selected one of the sets of rams to close to seal the wellbore **102**. However, when the size of the selected one of the sets of rams and the size of the drill pipe **111** do not match, the BOP control system may be further operable to display on the BOP HMI information indicative of the size of the selected one of the sets of rams not matching the size of the drill pipe **111**. Also, when the size of the selected one of the sets of rams and the size of the drill pipe **111** do not match, the BOP control system may be operable to: display on the BOP HMI a request that the human user confirm via the BOP HMI that the size of the selected one of the sets of rams and the size of the drill pipe **111** match; and cause the selected one of the sets of rams to close after the human user has confirmed via the BOP HMI that the size of the selected one of the sets of rams and the size of the drill pipe **111** match. When the size of the selected one of the sets of rams and the size of the drill pipe **111** do not match, the BOP control system may also or instead be operable to: display on the BOP HMI a request that the human user enter ram data indicative of another one of the sets of rams to close; receive from the BOP HMI ram data indicative of the another one of the sets of rams to close; compare the size of the another one of the sets of rams and the size of the drill pipe **111**; and, when the size of the another one of the sets of rams and the size of the drill pipe **111** match, cause the another one of the sets of rams to close to seal the wellbore **102**.

In another example implementation, when the pressure data indicates that the wellbore pressure is above a predetermined threshold, the BOP control system may be further operable to: display on the BOP HMI information (e.g., an alarm, a warning, etc.) indicative of the wellbore pressure being above the predetermined threshold; display on the BOP HMI a request that the human user select a set of shear rams of the BOP stack **130** to close; receive from the BOP HMI shear ram data indicative of the selected set of shear rams of the BOP stack **130** to close; and compare the size of the selected set of shear rams of the BOP stack **130** and the size of the drill pipe **111**. When the size of the selected set of shear rams and the size of the drill pipe **111** match, the BOP control system may be further operable to cause the selected set of shear rams to close to therefore shear (or cut) the drill string **120**. However, when the size of the selected set of shear rams and the size of the drill pipe **111** do not match, the BOP control system may be further operable to display on the BOP HMI information indicative of the size of the selected set of shear rams not matching the size of the drill pipe **111**. Also, when the size of the selected set of shear rams and the size of the drill pipe **111** do not match, the BOP control system may be operable to: display on the BOP HMI a request that the human user confirm via the BOP HMI that the size of the selected set of shear rams and the size of the drill pipe **111** match; and cause the selected set of shear rams to close after the human user has confirmed via the BOP HMI that the size of the selected set of shear rams and the size of the drill pipe **111** match. When the size of the selected set of shear rams and the size of the drill pipe **111** do not match, the BOP control system may also or instead be operable to: display on the BOP HMI a request that the human user enter ram data indicative of another set of shear rams to close; receive from the BOP HMI ram data indicative of the another set of shear rams to close; compare the size of the another set of shear rams and the size of the drill pipe **111**; and, when the size of the another set of shear rams and the size of the drill pipe **111** match, cause the another set of shear rams to close to shear the drill string **120**.

The rig control system **200**, the pressure control system, and the BOP control system may also or instead be collectively operable to perform or otherwise facilitate alarm and interlock operations and request operation confirmation according to one or more aspects of the present disclosure, such as to prevent the BOP control system to automatically cause unintended performance of predetermined operations when predetermined conditions and/or events are taking place.

In an example implementation, when the pressure data indicates that the wellbore pressure is above a predetermined threshold, the BOP control system may be operable to: display on the BOP HMI information (e.g., an alarm, a warning, etc.) indicative of the wellbore pressure being above the predetermined threshold; select one of the sets of scaling rams of the BOP stack **130** to close; and compare the size of the selected one of the sets of rams and the size of the drill pipe **111**. When the size of the selected one of the sets of rams and the size of the drill pipe **111** match, the BOP control system may cause the selected one of the sets of rams to close to seal the wellbore **102**; and, when the size of the selected one of the sets of rams and the size of the drill pipe **111** do not match, the BOP control system may display on the BOP HMI information indicative of the size of the selected one of the sets of rams not matching the size of the drill pipe **111**. Also, when the size of the selected one of the sets of rams and the size of the drill pipe **111** do not match, the BOP control system may be operable to: display on the BOP HMI a request that the human user confirm via the BOP HMI that the size of the selected one of the sets of rams and the size of the drill pipe **111** match; and cause the selected one of the sets of rams to close after the human user has confirmed via the BOP HMI that the size of the selected one of the sets of rams and the size of the drill pipe **111** match. When the size of the selected one of the sets of rams and the size of the drill pipe **111** do not match, the BOP control system may be operable to: display on the BOP HMI a request that the human user enter ram data indicative of another one of the sets of rams to close; receive from the BOP HMI ram data indicative of the another one of the sets of rams to close; compare the size of the another one of the sets of rams and the size of the drill pipe **111**; and, when the size of the another one of the sets of rams and the size of the drill pipe **111** match, cause the another one of the sets of rams to close to seal the wellbore **102**.

In another example implementation, when the pressure data indicates that the wellbore pressure is above a predetermined threshold, the BOP control system may be operable to: display on the BOP HMI information (e.g., an alarm, a warning, etc.) indicative of the wellbore pressure being above the predetermined threshold; select a set of shear rams of the BOP stack **130** to close; and compare the size of the selected set of shear rams and the size of the drill pipe **111**. When the size of the selected set of shear rams and the size of the drill pipe **111** match, the BOP control system may cause the selected set of shear rams to close to shear (or cut) the drill string **120**. When the size of the selected set of shear rams and the size of the drill pipe **111** do not match, the BOP control system may display on the BOP HMI information indicative of the size of the selected set of shear rams not matching the size of the drill pipe **111**. Also, when the size of the selected set of shear rams and the size of the drill pipe **111** do not match, the BOP control system may be operable to: display on the BOP HMI a request that the human user confirm via the BOP HMI that the size of the selected set of shear rams and the size of the drill pipe **111** match; and cause the selected set of shear rams to close after the human user has confirmed via the BOP HMI that the size of the selected set of shear rams and the size of the drill pipe **111** match. When the size of the selected set of shear rams and the size of the drill pipe **111** do not match, the BOP control system may be operable to: display on the BOP HMI a request that the human user enter ram data indicative of another set of shear rams to close; receive from the BOP HMI ram data indicative of the another set of shear rams to close; compare the size of the another set of shear rams and the size of the drill pipe **111**; and, when the size of the another set of shear rams and the size of the drill pipe **111** match, cause the another set of shear rams to close to shear the drill string **120**.

In another example implementation, when the pressure data indicates that the wellbore pressure is above the predetermined threshold, the BOP data indicates that the rams of the BOP stack **130** are open, and the rig data indicates that a connection joint of the drill string **120** is located between a set of rams of the BOP stack **130**, the BOP control system may be operable to: display on the BOP HMI information (e.g., an alarm, a warning, etc.) indicative of the wellbore pressure being above the predetermined threshold; display on the BOP HMI information indicative of the connection joint of the drill string **120** being located between the rams of the BOP stack **130**; prevent the BOP HMI to be used by the human user to close the rams of the BOP stack **130**; display on the BOP HMI a request that the human user cause the drawworks **118** to move (e.g., raise or lower) the drill string **120** to a position in which the connection joint of the drill string **120** is located away from (e.g., above or below) the rams of the BOP stack **130**, such that the rams can close about a body portion of the drill string **120**; display on the BOP HMI a request that the human user confirm via the BOP HMI that the drill string **120** has been repositioned such that the rams can close about the body portion of the drill string **120**; and permit the BOP HMI to be used by the human user to close the rams of the BOP stack **130** after the human user has confirmed via the BOP HMI that the drill string **120** has been repositioned. However, the BOP control system may be operable to automatically cause the drawworks **118** to move the drill string **120** (e.g., via the rig control system) to a position in which the connection joint of the drill string **120** is located away from the rams of the BOP stack **130**. The BOP control system may also or instead be operable to automatically cause the rams of the BOP stack **130** to close based on rig data that indicates that the drill string **120** has been repositioned and/or after the human user has confirmed via the BOP HMI that the drill string **120** has been repositioned.

In another example implementation, when the pressure data and/or the flow rate data is indicative of an influx of formation fluid into the wellbore **102** and the BOP data is indicative of the BOP equipment **130**, **132** being open, the BOP control system may be operable to: display on the BOP HMI information (e.g., an alarm, a warning, etc.) indicative of the wellbore pressure and/or the uphole flow rate of the wellbore fluid being indicative of an influx of formation fluid; cause the annular preventer **132** to close about the drill string **120** automatically or after the human user has caused, via the BOP HMI, the annular preventer **132** to close about the drill string **120**. The BOP control system may be operable to: receive rig data indicative of the size (e.g., diameter) of the drill string **120** and, based on programing and the size of the drill string **120**, determine operator pressure (e.g., hydraulic pressure) generated by the power unit **137** that is to be applied to the annular packer of the annular preventer **132** to inflate the annular packer to the closed position against the drill string **120**. For example, a smaller sized drill string **120** may result in a higher operator pressure to be applied to the annular packer to seal the wellbore **102** and a larger sized drill string **120** may result in a lower operator pressure to be applied to the annular packer to seal the wellbore **102**. Furthermore, during stripping operations, the BOP control system may be operable to: receive rig data indicative of the size of the drill string **120** and, based on programing and the size of the drill string **120**, change the operator pressure generated by the power unit **137** that is to be applied to the annular packer of the annular preventer **132** as the size of the drill string **120** changes to seal the wellbore **102**.

In still another example implementation, when the pressure data and/or the flow rate data is indicative of an influx of formation fluid into the wellbore **102**, the MPD system **217** is operating (e.g., the RCD **138** is closed and the wellbore fluid is flowing through the MPD manifold **152**), and the BOP data indicates that the BOP equipment **130**, **132** is open, the BOP control system may be operable to: display on the BOP HMI information (e.g., an alarm, a warning, etc.) indicative of the wellbore pressure and/or the uphole flow rate of the wellbore fluid being indicative of an influx of formation fluid and cause the MPD system **217** to initiate MPD control to increase wellbore pressure (e.g., by restricting flow through the MPD manifold **152**). The BOP control system may monitor the uphole flow rate of the wellbore fluid (e.g., flow through the MPD manifold **152**) until influx of the formation fluid is suppressed (e.g., flow rate decreases below a predetermined threshold) or a predetermined maximum wellbore pressure threshold is reached. The BOP control system may then be operable to display on the BOP HMI information (e.g., an alarm, a warning, etc.) indicative of the wellbore pressure having reached the predetermined maximum wellbore pressure threshold and initiate closure of the BOP equipment **130**, **132**. The BOP control system may then be operable to: display on the BOP HMI a request that the human user confirm via the BOP HMI that the size of the selected one of the sets of rams and the size of the drill pipe **111** match; and cause the selected one of the sets of rams to close after the human user has confirmed via the BOP HMI that the size of the selected one of the sets of rams and the size of the drill pipe **111** match. However, the BOP control system may instead automatically confirm that the size of the selected one of the sets of rams and the size of the drill pipe **111** match. The BOP control system may then be operable to initiate standpipe pressure control operations and cause the CPC system **219** to circulate the influx through the choke and kill lines of the CK manifold **156**.

The BOP control system may be programmed with a logic path (i.e., an algorithm) that, when executed by the BOP control system, may cause the BOP control system to perform predetermined operations. An example logic path may include defining a predetermined pressure threshold indicative of high wellbore pressure. Then, when the BOP equipment **130**, **132** is operated (manually or automatically) to an open position and the wellbore pressure exceeds the predetermined pressure threshold by a predetermined amount (e.g., percent), the BOP control system may activate (e.g., display on the BOP HMI) an alarm (e.g., displayed information) indicative of high wellbore pressure. If no action (manual or automatic) is taken by the human user or by the BOP control system, the BOP control system may activate interlock operations to prevent opening (manual or automatic) of the BOP equipment **130**, **132**. However, if the wellbore pressure is vented (manually or automatically) such that the wellbore pressure is below the predetermined pressure threshold by a predetermined amount, the BOP control system may request that the human user confirm opening of the BOP equipment **130**, **132**. After the human user has confirmed the opening of the BOP equipment **130**, **132**, the BOP control system may cause the BOP equipment **130**, **132** to open.

Other example logic path may include defining a predetermined pressure threshold indicative of high wellbore pressure, receiving by the BOP control system information indicative of configuration of the BOP equipment **130**, **132**, such as sizes of the rams of the BOP stack **130**, and receiving from the rig control system **200** information indicative of the size of the drill pipe **111** forming the drill string **120**. Then, when the BOP equipment **130**, **132** is operated (manually or automatically) to a closed position and if the wellbore pressure exceeds the predetermined pressure threshold, the BOP control system may activate (e.g., display on the BOP HMI) an alarm (e.g., displayed information) indicative of the high wellbore pressure. The human user may manually select or the BOP control system may automatically select a set of rams of the BOP stack **130** to close. The BOP control system may then compare (or validate) the size of the drill pipe **111** to the size of the set of rams that are being operated (manually or automatically) to the closed position. If the size of the drill pipe **111** does not match the size of the selected set of rams that are being operated to the closed position, the BOP control system may activate (e.g., display on the BOP HMI) an alarm indicating to the human user that the size of the drill pipe **111** does not match the size of the selected set of rams. The BOP control system may then request via the BOP HMI that the human user confirm (or validate) that the sizes match or operate another set of rams that match the size of the drill pipe **111**. However, if the size of the drill pipe **111** matches the size of the selected set of rams that are being operated to the closed position, the BOP control system may operate the selected set of rams to the closed position.

The BOP control system may also or instead be communicatively connected with a health monitoring system (e.g., the health monitor **210**) to thereby facilitate communication between the BOP control system and the health monitoring system. The health monitoring system may be operable to receive the BOP data, record the BOP data to a memory, and determine operational health of the BOP equipment **130**, **132** based on the BOP data. The health monitoring system may be communicatively connected to the rig control system **200** or the health monitoring system may be or form at least a portion of the rig control system **200**. Thus, the health monitoring system may be communicatively connected with the BOP control system via the rig control system **200**.

The health monitoring system may be operable to determine (current) operational health of the BOP equipment **130**, **132** based on an operational quantity (or amount) of an operational parameter indicated by the BOP data in a manner described above with respect to the health monitor **210**. As described above, the BOP data may be indicative of closure status of the BOP equipment **130**, **132**, including whether one or more of the sets of rams of the BOP stack **130** or the annular packer of the annular preventer **132** are open or closed. The quantity of closures may be tracked and continuously compared to a historical baseline or a historical trend (or curve). Thus, operational health may be determined by comparing a current number of closures to the historical baseline or the historical trend and then estimating (e.g., interpolating, extrapolating, etc.) the operational health based on such comparison. The operational health of the BOP equipment **130**, **132** may also or instead be determined based on performance based condition monitoring of the BOP data in a manner described above with respect to the health monitor **210**.

The health monitoring system may be further operable to transmit BOP health data indicative of the determined operational health of the BOP equipment **130**, **132** to the BOP control system and the BOP control system may be further operable to display on the BOP HMI health information based on the BOP health data. The health information displayed on the BOP HMI may be indicative of low operational health, including operational health that is approaching or is below a predetermined threshold. A human user viewing the health information on the BOP HMI may then implement a course of action based on such health information. For example, the human user may use the control workstation **197** to operate one or more of the rig equipment **241**-**247** in response to the viewed health information. The human user may also or instead use the BOP HMI to operate one or more of the BOP equipment **130**, **132** in response to the viewed health information. The human user may also or instead schedule or implement maintenance operations to mitigate or otherwise improve the low operational health of the BOP equipment **130**, **132**.

As described above, the BOP control system may also be communicatively connected with the rig control system **200** to thereby facilitate communication between the BOP control system and the rig control system **200**, and one or more sensors **231**-**236** of the rig control system **200** may be operable to output rig data indicative of operational status of the rig equipment **241**-**246**. The health monitoring system may be operable to receive the rig data, record the rig data to a memory, and determine operational health of the BOP equipment **130**, **132** based on the rig data.

The health monitoring system may be operable to determine operational health of the BOP equipment **130**, **132** based on an operational quantity of an operational parameter indicated by the rig data and BOP data in a manner described above with respect to the health monitor **210**. The operational health of the BOP equipment **130**, **132** may also or instead be determined based on performance based condition monitoring of the rig data and BOP data in a manner described above with respect to the health monitor **210**. As described above, the rig data may be indicative of length of a drill pipe **111** conveyed within the wellbore **102** and BOP data may be indicative of closure status of the BOP equipment **130**, **132**. The health monitoring system may thus be operable to: record the rig data to the memory, determine the length of drill pipe **111** conveyed within the wellbore **102** while the annular preventer **132** is closed based on the BOP data and the rig data; and determine operational health of the annular preventer **132** based on the determined length of drill pipe **111** that is stripped within the wellbore **102** (i.e., conveyed within the wellbore **102** while the annular preventer **132** is closed). During such stripping operations, the annular packer of the annular preventer is experiencing wear. Length (or footage) of the drill string **120** stripped or the quantity of connection joints stripped may be tracked and continuously compared to a historical baseline or a historical trend by the health monitoring system. Thus, operational health (i.e., amount of wear) of the annular packer may be determined by comparing a current length of the drill string stripped or a current quantity of connection joints stripped to the historical baseline or the historical trend and then estimating the operational health based on such comparison.

As described above, the BOP control system may be communicatively connected with the pressure control system to thereby facilitate communication between the BOP control system and the pressure control system, and one or more sensors **237**, **239** of the pressure control system may be operable to output pressure data indicative of the wellbore pressure. The health monitoring system may be operable to receive the pressure data and BOP data, record the pressure data and the BOP data to a memory, and determine operational health of the BOP equipment **130**, **132** based on the pressure data and BOP data.

The health monitoring system may be operable to determine operational health of the BOP equipment **130**, **132** based on an operational quantity of an operational parameter indicated by the pressure data and BOP data in a manner described above with respect to the health monitor **210**. The operational health of the BOP equipment **130**, **132** may also or instead be determined based on performance based condition monitoring of the pressure data and BOP data in a manner described above with respect to the health monitor **210**. As described above, the pressure data may be indicative of wellbore pressure and the BOP data may be indicative of closure status of the BOP equipment **130**, **132**. The health monitoring system may thus be operable to: record the pressure data to the memory, determine wellbore pressure while the BOP equipment **130**, **132** is closed based on the pressure data and BOP data; and determine operational health of the annular preventer **132** based on amount of time or instances when the BOP equipment **130**, **132** has been closed and the wellbore pressure has been high. When the BOP equipment **130**, **132** is closed and the wellbore pressure is high, ram packers (or bonnet seals) of the BOP stack **130** and an annular packer (or seal) of the annular preventer **132** are stressed and, thus, experience wear. The amount of time or instances when the BOP equipment **130**, **132** has been closed and the wellbore pressure has been high may be tracked and continuously compared to a historical baseline or a historical trend by the health monitoring system. Thus, operational health (i.e., amount of wear) of the ram packers and the annular packer may be determined by comparing a current amount of time or instances when the BOP equipment **130**, **132** has been closed and the wellbore pressure has been high to the historical baseline or the historical trend and then estimating the operational health based on such comparison.

FIG. **4** is an example implementation of a display screen **402** that may be generated by a processing device (e.g., the processing device **300**, the BOP controller **153**, etc.) and displayed by a video output device (e.g., a display monitor, a touchscreen, etc.) of a BOP HMI **400** (e.g., the BOP control workstation **151**) for monitoring and controlling the BOP equipment **130**, **132**. The BOP HMI **400** may be part of the BOP control system communicatively connected with the rig control system **200** and/or the pressure control system. The following description refers to FIGS. **1**-**4**, collectively.

The BOP control system may be operable to receive pressure data from the pressure control system and display on the BOP HMI **400** pressure information based on the pressure data. For example, the display screen **402** may comprise a pressure status area (or window) **404** displaying pressure information **406** indicative of wellbore pressure. The pressure information **406** indicative of wellbore pressure may be based on pressure data output by one or more of the MPD sensors **237** and CK sensors **239**. The pressure status area **404** may also or instead display pressure information **406** indicative of operator (e.g., hydraulic) pressure output by the BOP control unit **137** for operating (or actuating) the BOP equipment **130**, **132**. The pressure information **406** indicative of operator pressure may be based on pressure data output by BOP sensors **238** disposed in association with one or more of the BOP control unit **137** and the BOP equipment **130**, **132**. The pressure information **406** may comprise or be displayed in the form of numerical values, tables, graphs, bars, gauges, lights, and/or schematics, among other examples. The pressure status area **404** may also display location information **408** displayed in association with the pressure information **406** and describing the location of the pressure sensor facilitating the corresponding pressure information **406** or otherwise describing the source of the corresponding pressure information **406**. The pressure status area **404** may also display alarm (or event) information **410** displayed in association with the pressure information **406** and indicating presence of an abnormal (e.g., high) pressure. The alarm information **410** may activate (e.g., light up, change color, appear, etc.) based on the pressure data output by one or more of the pressure sensors **237**, **238**, **239**, such as when wellbore pressure and/or operator pressure is above or below a predetermined threshold. The alarm information **410** may also or instead activate based on information output by the abnormal event detector **207**, including information indicative of an impending or current abnormal surface or downhole event that can cause or has caused abnormal wellbore pressure.

The display screen **402** displayed on the BOP HMI **400** may comprise an operational status area (or window) **412** displaying BOP information based on BOP data and indicative of operational status of the BOP equipment **130**, **132**. For example, the BOP information displayed in the operational status area **412** may comprise virtual (or software) BOP equipment **414** representing the BOP equipment **130**, **132** of the well construction system **100**. The virtual BOP equipment **414** may indicate the physical configuration of the BOP equipment **130**, **132**. For example, the virtual BOP equipment **414** may include a virtual annular preventer **416**, virtual rams **418**, and virtual CK valves **420** representing corresponding portions of the BOP equipment **130**, **132**. The BOP information displayed in the operational status area **412** may also comprise BOP characteristics information **422** indicative of physical characteristics (e.g., model, size, etc.) of the BOP equipment **130**, **132**, including the annular preventer **416**, the rams **418**, and CK valves **420**. The BOP characteristics information **422** may comprise or be displayed in textual and/or numerical form and in association with a corresponding portion of the virtual BOP equipment **414**, such as to indicate the physical characteristics of the BOP equipment **130**, **132**. The virtual BOP equipment **414** and the BOP characteristics information **422** may therefore collectively indicate physical characteristics of the BOP equipment **130**, **132** and the relative position of the annular preventer **132**, the rams of the BOP stack **130**, and the CK valves (e.g., connected with the ported adapter **136**).

The BOP control system may be operable to receive rig data from the rig control system **200** and display on the BOP HMI **400** rig information based on the rig data and indicative of operational status of predetermined rig equipment **241**-**246**. Such rig information may be displayed in the operational status area **412**. For example, the rig information displayed in the operational status area **412** may comprise conveyance status information **424** indicative of whether the drill string **120** extends through the BOP equipment **130**, **132**. The rig information may also or instead comprise connection joint status information **426** indicative of whether a connection joint of the drill string **120** is positioned between one of the rams of the BOP stack **130** or within the annular preventer **132**. The rig information displayed in the operational status area **412** may comprise a virtual (or software) drill string **424** representing the drill string **120** of the well construction system **100**. The virtual drill string **424** may indicate the physical configuration of the drill string **120**. For example, the virtual drill string **424** may include virtual portions of the drill string **120**, including a virtual connection joint **426** representing a connection joint of the drill string **120**. The virtual drill string **424** may be shown positioned with respect to the virtual BOP equipment **414** in a manner that reflects the position of the drill string **120** with respect to the BOP equipment **130**, **132**. For example, the virtual connection joint **426** may be shown positioned with respect to the virtual annular preventer **416**, the virtual rams **418**, and/or the virtual CK valves **420** in a manner that reflects the position of a connection joint of the drill string **120** with respect to the same portion of the BOP equipment **130**, **132**. Thus, the virtual BOP equipment **414** and the virtual drill string **424** may indicate if the drill string **120** extends through the BOP equipment **130**, **132** and whether a connection joint of the drill string **120** is positioned between a set of rams of the BOP stack **130** or within the annular preventer **132**. The rig information displayed in the operational status area **412** may also comprise drill string characteristics information **428** indicative of physical characteristics (e.g., model, outside diameter, length, etc.) of a portion (or drill pipe) of the drill string **120** located within the BOP equipment **130**, **132**. The drill string characteristics information **428** may comprise or be displayed in textual and/or numerical form and in association with a corresponding portion of the virtual drill string **424**, such as to indicate the physical characteristics of a corresponding portion of the drill string **120** located within the BOP equipment **130**, **132**. The virtual drill string **424** and the drill string characteristics information **428** may therefore collectively indicate physical characteristics of the drill string **120** and the relative position of the drill string **120** with respect to the annular preventer **132**, the rams of the BOP stack **130**, and the CK valves.

The BOP information displayed in the operational status area **412** may further comprise closure status information **430** indicative of closure status (i.e., open or closed) of the BOP equipment **130**, **132**. The closure status information **430** may comprise or be displayed in textual and/or numerical form and in association with a corresponding portion of the virtual BOP equipment **414**, such as to indicate the closure status of a corresponding portion (e.g., set of rams) of the BOP equipment **130**, **132**. Each instance of the closure status information **430** may activate (e.g., appear, light up, change color, etc.) to indicate whether the rams of the BOP stack **130**, the annular preventer **132**, and/or the CK valves **420** are in the open position or in the closed position. Each instance of the closure status information **430** may operate as a virtual (or software) button, which may be operated (e.g., touched, clicked on, etc.) by the human user to cause the HMI **400** to output (or transmit) a control command to the BOP controller **153** and/or the BOP control unit **137** to cause the annular preventer **132**, a corresponding set of rams of the BOP stack **130**, and a corresponding one of the CK valves **420** to either close or open. Each instance of the closure status information **430** may activate to visually confirm or otherwise indicate to the human user the current position of the annular preventer **132**, the current position of the rams of the BOP stack **130**, and the current position of the CK valves **420**. The operational status area **412** may also display location information **432** displayed in association with the closure status information **430** and describing the portion of the BOP equipment **130**, **132** corresponding to the closure status information **430**. The operational status area **412** may also display alarm (or event) information **434** displayed in association with the closure status information **430** and indicating presence of an abnormal condition. For example, the alarm information **434** may activate (e.g., light up, change color, appear, etc.) when a connection joint of the drill string **120** is positioned between a set of rams of the BOP stack **130** and that set of rams is attempted to be closed automatically by the BOP controller **153** or manually by the human user of the BOP HMI **400**.

The display screen **402** may comprise a health status area (or window) **436** displaying health information **438** indicative of operational health of the BOP equipment **130**, **132**, including one or more of operational condition, maintenance condition, and remaining operational life of the BOP equipment **130**, **132**. For example, the health information **438** may comprise one or more of current total (or cumulative) runtime (or operating time) with respect to a predetermined threshold runtime, remaining runtime until maintenance is planned to be performed, and projected remaining operational life of a corresponding component or portion of the BOP equipment **130**, **132**. Components or portions of the BOP equipment **130**, **132** may include, for example, the annular packer of the annular preventer **132** and the ram packers of the BOP ram stack **130**. The health information **438** may be based on BOP health data output by the health monitoring system (e.g., the health monitor **210**). The health information **438** may comprise or be displayed in the form of numerical values, tables, graphs, bars, gauges, lights, and/or schematics, among other examples. The health status area **436** may also display location information **440** displayed in association with the health information **438** describing the name and/or location of the monitored component or portion of the BOP equipment **130**, **132**. For example, the location information **440** may indicate or refer to a specific set of rams of the BOP stack **130** or a portion of the annular preventer **132**. The health status area **436** may also display alarm (or event) information **442** displayed in association with the health information **438**. The alarm information **442** may activate (e.g., light up, change color, appear, etc.) to indicate to the human user that operational health of a corresponding component or portion of the BOP equipment **130**, **132** comprises low operational health or is approaching low operational health. The alarm information **442** may also or instead activate based on information output by the abnormal event detector **207**, such as information indicative of an impending or current abnormal surface or downhole event that can cause or has caused low operational health of the BOP equipment **130**, **132**.

The display screen **402** may comprise an alarm (or event) description area (or window) **444** displaying alarm information **446** describing active (or triggered) alarms related to the BOP equipment **130**, **132**, as described above. For example, the alarm information **446** may describe that a connection joint of the tool string **120** is located between a set of rams of the BOP stack **130** that the human user or the BOP controller **153** is attempting to close. The alarm information **446** may describe that pressure at the upper end (i.e., under the BOP equipment **130**, **132**) of the wellbore **102** is high. The alarm information **446** may describe which component or portion if the BOP equipment **130**, **132** is experiencing low operational health. The alarm description area **444** may display confirmation information **448** requesting that the human user confirm that the human user is aware of the conditions that activated the alarm and/or that the human user wants to proceed with subsequent operations of the BOP equipment in spite of the conditions that activated the alarm or after such conditions have been mitigated. The display screen **402** may comprise a virtual (or software) button **450** in association with the confirmation information **448**. The virtual button **450** may be operated (e.g., touched, clicked on, etc.) by the human user to confirm that the human user is aware of the alarm and/or that the human user wants to proceed with subsequent operations of the BOP equipment. For example, the confirmation information **448** may indicate to the human user a request to confirm that the human user is aware of high wellbore pressure and/or that the human user wishes to proceed with opening of the BOP equipment **130**, **132** in spite of such high pressure or after such high pressure has been mitigated. The confirmation information **448** may indicate to the human user a request to confirm that the human user is aware of the low operational health of the BOP equipment **130**, **132** and/or that the human user wishes to proceed with opening of the BOP equipment **130**, **132** despite such low operational health or after such low operational health has been mitigated. The alarm description area **444** may further display mitigation information **452** describing counteractive measures (i.e., corrective actions or operations) that may be performed or otherwise implemented by rig personnel (e.g., the human user of the BOP HMI) that may mitigate the conditions that activated the alarm. Such mitigating actions may include operating a specified piece of equipment, including a specific portion (e.g., a ram, a valve, etc.) of the BOP equipment or perform maintenance to the BOP equipment **103**, **132** associated with the alarm. For example, the mitigation information **452** may suggest that the rig personnel (e.g., the driller) first bleed off the high wellbore pressure before opening the BOP equipment **130**, **132**. The mitigation information **452** may suggest that the rig personnel (e.g., the driller) first raise the drill string **120** before closing a set of rams of the BOP stack **130**.

In view of the entirety of the present disclosure, including the figures and the claims, a person having ordinary skill in the art will readily recognize that the present disclosure introduces a system comprising: a pressure control system for controlling a pressure control manifold fluidly connected with a wellbore, wherein the pressure control system comprises a sensor operable to output pressure data indicative of wellbore pressure; and a BOP control system for controlling BOP equipment. The BOP control system comprises: a sensor operable to output BOP data indicative of operational status of the BOP equipment; and a BOP HMI usable by a human user to monitor and control the BOP equipment. The BOP control system: is communicatively connected with the pressure control system; receives the pressure data; and displays, on the BOP HMI, information based on the pressure data.

The pressure control system may comprise at least one of: a CK pressure control system for controlling a CK manifold; and an MPD control system for controlling an MPD manifold.

In response to the pressure data being indicative of the wellbore pressure being above a predetermined threshold and the BOP data being indicative of the BOP equipment being closed, the BOP control system may display, on the BOP HMI, information indicating that the wellbore pressure is above the predetermined threshold.

In response to the pressure data being indicative of the wellbore pressure being above a predetermined threshold and the BOP data being indicative of the BOP equipment being closed, the BOP control system may: display, on the BOP HMI, information indicating that the wellbore pressure is above the predetermined threshold; and prevent the BOP HMI from being used by the human user to open the BOP equipment.

In response to the pressure data being indicative of the wellbore pressure being above a predetermined threshold and the BOP data being indicative of the BOP equipment being closed, the BOP control system may: display, on the BOP HMI, information indicating that the wellbore pressure is above the predetermined threshold; prevent the BOP HMI from being used by the human user to open the BOP equipment; display, on the BOP HMI, a request that the human user confirm that the wellbore pressure is above the predetermined threshold; and permit the BOP HMI to be used by the human user to open the BOP equipment after the human user has confirmed, via the BOP HMI, that the wellbore pressure is above the predetermined threshold.

The present disclosure also introduces a system comprising: a rig control system for controlling rig equipment operable to perform drilling operations to drill a wellbore at a wellsite, wherein the rig control system comprises a plurality of sensors operable to output rig data indicative of operational status of the rig equipment; a pressure control system for controlling a pressure control manifold fluidly connected with the wellbore, wherein the pressure control system comprises a sensor operable to output pressure data indicative of wellbore pressure; and a BOP control system for controlling BOP equipment. The BOP control system comprises: a sensor operable to output BOP data indicative of operational status of the BOP equipment; and a BOP HMI usable by a human user to monitor and control the BOP equipment. The BOP control system: is communicatively connected with the rig control system and the pressure control system; receives the rig data and the pressure data; and displays, on the BOP HMI, information based on the rig data and the pressure data.

The pressure control system may comprise at least one of: a CK pressure control system for controlling a CK manifold; and an MPD control system for controlling an MPD manifold.

In response to the pressure data being indicative of the wellbore pressure being above a predetermined threshold and the BOP data being indicative of the BOP equipment being closed, the BOP control system may display, on the BOP HMI, information indicating that the wellbore pressure is above the predetermined threshold.

In response to the pressure data being indicative of the wellbore pressure being above a predetermined threshold and the BOP data being indicative of the BOP equipment being closed, the BOP control system may: display, on the BOP HMI, information indicating that the wellbore pressure is above the predetermined threshold; and prevent the BOP HMI from being used by the human user to open the BOP equipment.

In response to the pressure data being indicative of the wellbore pressure being above a predetermined threshold and the rig data being indicative of a connection joint of a drill string for performing the drilling operations being located between rams of the BOP equipment, the BOP control system may display on the BOP HMI: information indicating that the wellbore pressure is above the predetermined threshold; and information indicating that the drill string connection joint is located between the rams of the BOP equipment.

In response to the pressure data being indicative of the wellbore pressure being above a predetermined threshold and the rig data being indicative of a connection joint of a drill string for performing the drilling operations being located between rams of the BOP equipment, the BOP control system may: display, on the BOP HMI, information indicating that the wellbore pressure is above the predetermined threshold; display, on the BOP HMI, information indicating that the drill string connection joint is located between the rams of the BOP equipment; and prevent the BOP HMI from being used by the human user to open the rams of the BOP equipment.

The rig data may be further indicative of a size of drill pipe forming a drill string for performing the drilling operations, the BOP data may be further indicative of a size of each set of rams of the BOP equipment, and, in response to the pressure data being indicative of the wellbore pressure being above a predetermined threshold, the BOP control system may: display, on the BOP HMI, information indicating that the wellbore pressure is above the predetermined threshold; select one of the sets of rams to close; compare the size of the selected set of rams and the drill pipe size; in response to the size of the selected set of rams matching the drill pipe size, cause the selected set of rams to close; and in response to the size of the selected set of rams not matching drill pipe size, display on the BOP HMI information indicating that the size of the selected set of rams does not match the drill pipe size.

The rig data may be further indicative of a size of drill pipe forming a drill string for performing the drilling operations, whereas the BOP data may be further indicative of a size of each set of rams of the BOP equipment. In response to the pressure data being indicative of the wellbore pressure being above a predetermined threshold, the BOP control system may: display, on the BOP HMI, information indicating that the wellbore pressure is above the predetermined threshold; display, on the BOP HMI, a request that the human user select one of the sets of rams to close; receive, from the BOP HMI, ram data indicative of the user-selected set of rams to close; compare the size of the selected set of rams and the drill pipe size; in response to the size of the selected set of rams matching the drill pipe size, cause the selected set of rams to close; and in response to the size of the selected set of rams not matching the drill pipe size, display on the BOP HMI information indicating that the size of the selected set of rams and the drill pipe size do not match.

The present disclosure also introduces a system comprising: a BOP control system for controlling BOP equipment at a wellsite, wherein the BOP control system comprises a sensor operable to output BOP data indicative of operational status of the BOP equipment; and a health monitoring system communicatively connected with the BOP control system. The health monitoring system: records the BOP data to a memory; and determines operational health of the BOP equipment based on the BOP data.

The BOP control system may comprise a BOP HMI usable by a human user to monitor and control the BOP equipment, the health monitoring system may transmit BOP health data indicative of the determined operational health of the BOP equipment to the BOP control system, and the BOP control system may display, on the BOP HMI, information based on the BOP health data.

The BOP data may be indicative of closure status of the BOP equipment.

The system may comprise a rig control system for controlling rig equipment operable to perform drilling operations to drill a wellbore at the wellsite, wherein the rig control system may comprise a sensor operable to output rig data indicative of operational status of the rig equipment, the BOP data may be indicative of closure status of an annular preventer of the BOP equipment, the rig data may be indicative of a length of drill string conveyed within the wellbore, and the health monitoring system may be further operable to: record the rig data to the memory; determine the length of drill string conveyed within the wellbore while the annular preventer is closed based on the BOP data and the rig data; and determine operational health of the annular preventer based on the determined drill string length conveyed within the wellbore while the annular preventer is closed.

The system may comprise a pressure control system for controlling a pressure control manifold fluidly connected with the wellbore. The pressure control system may comprise a sensor operable to output pressure data indicative of wellbore pressure, the BOP data may be indicative of closure status of the BOP equipment, and the health monitoring system may be operable to: while the BOP equipment is closed, record the pressure data to the memory; and determine operational health of the BOP equipment based further on the recorded pressure data. The pressure control system may comprise at least one of: a CK pressure control system for controlling a CK manifold; and an MPD control system for controlling an MPD manifold.

The BOP data may be indicative of at least one of: closure status of the BOP equipment; and/or hydraulic pressure applied to an actuator portion of the BOP equipment to close the BOP equipment.

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

The Abstract at the end of this disclosure is provided to permit the reader to quickly ascertain the nature of the technical disclosure. It is submitted with the understanding that it will not be used to interpret or limit the scope or meaning of the claims.

What is claimed is:

1. A system comprising:

a rig control system for controlling rig equipment operable to perform drilling operations to drill a wellbore at a wellsite, wherein the rig equipment comprises a drawworks for raising or lowering a drill string, and wherein the rig control system comprises at least one sensor operable to output rig data related to the rig equipment;

a pressure control system for controlling a pressure control manifold fluidly connected with the wellbore, wherein the pressure control system comprises: a first sensor operative to output pressure data indicative of wellbore pressure; and a second sensor operative to output flow rate data indicative of a flow rate of wellbore fluid flowing uphole and out of the wellbore; and

a blowout preventer (BOP) control system for controlling BOP equipment, the BOP equipment comprising an annular preventer, wherein the BOP control system comprises:

at least one sensor operable to output BOP data indicative of operational status of the BOP equipment; and

a BOP human-machine interface (HMI) usable by a human user to monitor and control the BOP equipment, and

wherein the BOP control system:

is communicatively connected with the rig control system and the pressure control system;

receives the rig data, the pressure data, and the flow rate data;

displays, on the BOP HMI, information indicative of an influx of formation fluid based on at least one of pressure data and the flow rate data; and

causes the annular preventer to close about the drill string,

wherein the rig data received by the BOP control system is indicative of a diameter of the drill string, and wherein the BOP control system determines an operator pressure to be applied to an annular packer of the annular preventer to seal the wellbore based on the rig data.

2. The system of claim **1**, wherein the pressure control system further comprises a managed pressure drilling (MPD) control system for controlling an MPD manifold.

3. The system of claim **2**, wherein the BOP control system further causes the MPD control system to initiate MPD control to increase wellbore pressure by restricting flow through the MPD manifold.

4. The system of claim **2**, wherein the pressure control system further comprises a choke and kill (CK) pressure control system for controlling a CK manifold.

5. The system of claim **4**, wherein the BOP control system further causes circulation of the influx of formation fluid through the CK manifold.

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