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(54) **AUTOMATED HIGH-PRESSURE PUMP TESTING SYSTEM**

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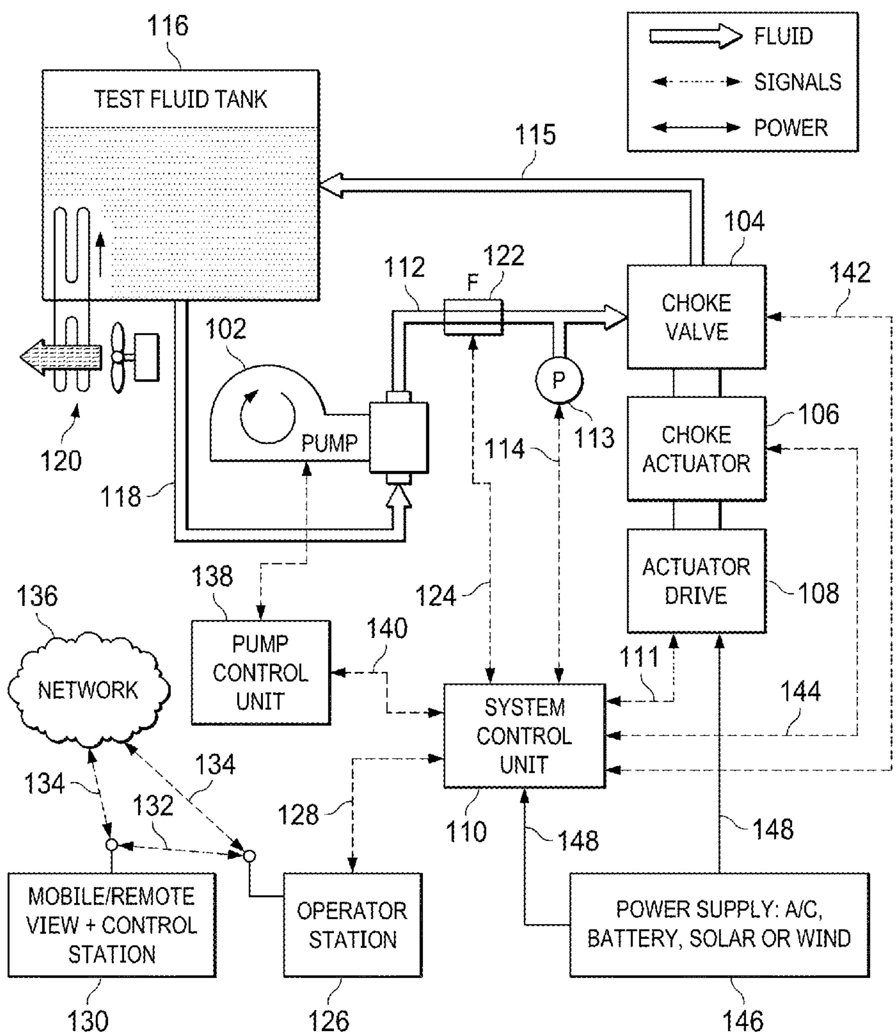
(57) **ABSTRACT**

A system for automated testing of a high-pressure pump comprises a choke valve, actuator and actuator drive for operating the choke in response to receiving control signals. A system control unit includes a processor unit, system memory, I/O interface, human-machine interface, and display device. A pressure sensor is connected to the pump outlet line for sensing and reporting outlet pressure to the control unit. The control unit can execute a test phase by causing the pump to run at a test speed and causing the actuator to change the restriction value of the choke until a predetermined pressure is sensed in the outlet line and reported to the control unit. The control unit can cause the actuator to maintain the predetermined pressure for a predetermined period of time. The control unit can cause the display device to show a result or print a report of one or more test phases.



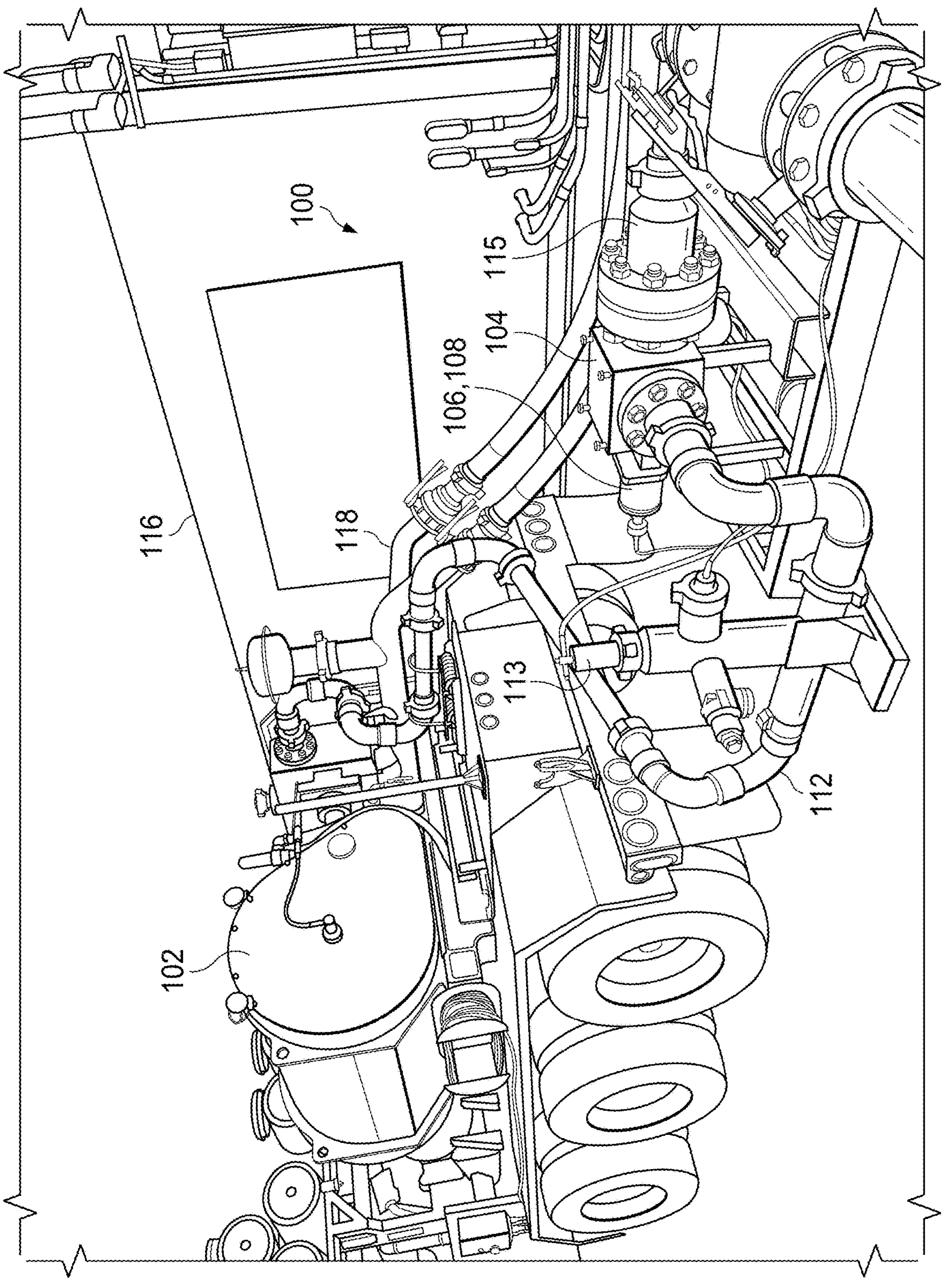
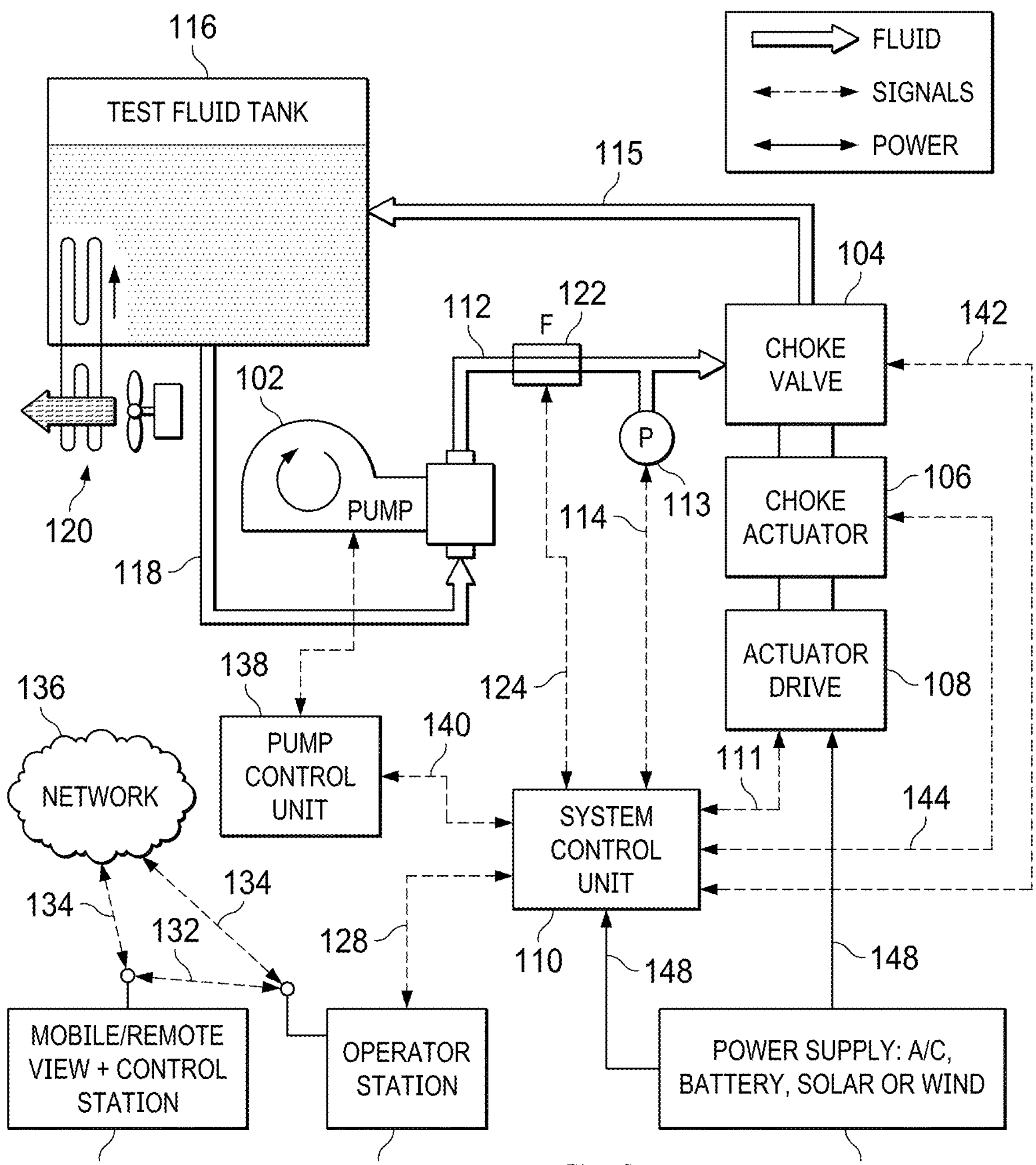
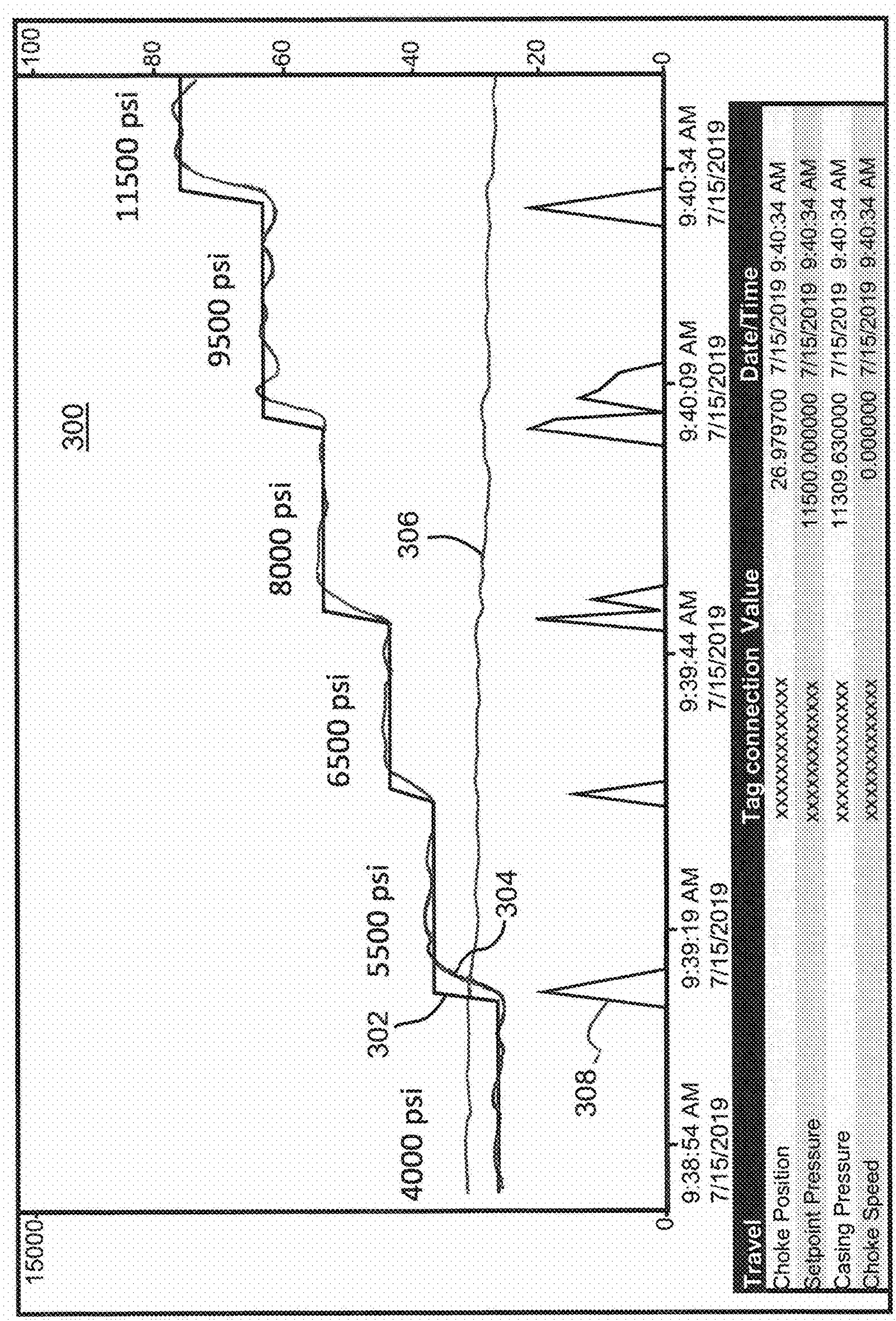


FIG. 1



FLUID
SIGNALS
POWER
116
TEST FLUID TANK
115
104
122
F
112
142
CHOKE VALVE
102
P
PUMP
113
106
CHOKE ACTUATOR
114
120
118
ACTUATOR DRIVE
108
138
124
136
NETWORK
PUMP CONTROL UNIT
140
111
SYSTEM CONTROL UNIT
144
134
134
132
128
110
148
148
MOBILE/REMOTE VIEW + CONTROL STATION
OPERATOR STATION
POWER SUPPLY: A/C, BATTERY, SOLAR OR WIND
130
126
146

FIG. 2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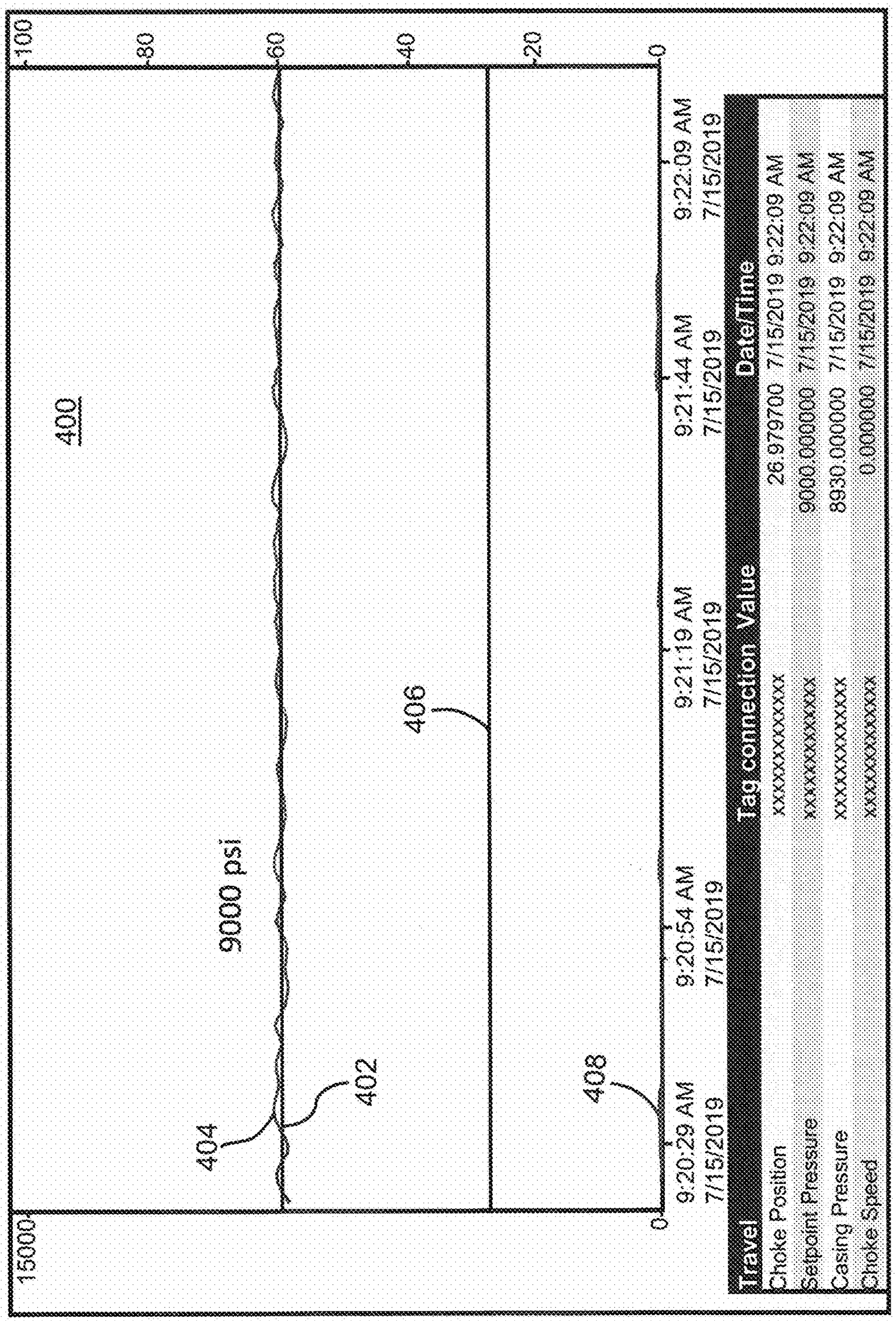
15000
100
80
60
40
20
0
0
4000 psi
5500 psi
6500 psi
8000 psi
9500 psi
11500 psi
302
304
306
308
9:38:54 AM 7/15/2019
9:39:19 AM 7/15/2019
9:39:44 AM 7/15/2019
9:40:09 AM 7/15/2019
9:40:34 AM 7/15/2019
Travel
Tag connection Value
Date/Time
Choke Position xxxxxxxxxxxxxx 26.979700 7/15/2019 9:40:34 AM
Setpoint Pressure xxxxxxxxxxxxxx 11500.000000 7/15/2019 9:40:34 AM
Casing Pressure xxxxxxxxxxxxxx 11309.630000 7/15/2019 9:40:34 AM
Choke Speed xxxxxxxxxxxxxx 0.000000 7/15/2019 9:40:34 AM

FIG. 3


400
9000 psi
402
404
406
408
15000
100
80
60
40
20
0
0
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9:21:44 AM 7/15/2019
9:22:09 AM 7/15/2019
Travel Tag connection Value Date/Time
Choke Position xxxxxxxxxxxxxx 26.979700 7/15/2019 9:22:09 AM
Setpoint Pressure xxxxxxxxxxxxxx 9000.000000 7/15/2019 9:22:09 AM
Casing Pressure xxxxxxxxxxxxxx 8930.000000 7/15/2019 9:22:09 AM
Choke Speed xxxxxxxxxxxxxx 0.000000 7/15/2019 9:22:09 AM

FIG. 4

AUTOMATED HIGH-PRESSURE PUMP TESTING SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims benefit of U.S. Provisional Application No. 63/070,998, filed Aug. 27, 2020, entitled SYSTEM AND METHOD FOR CHOKE VALVE OPERATION IN HIGH PRESSURE FRACKING SYSTEMS (Atty. Docket No. ADSS01-35137), the specification of which is incorporated by reference herein in its entirety.

TECHNICAL FIELD

[0002] This disclosure relates to apparatus and systems for automated testing of high-pressure pumps. In one application, the system can test high pressure fluid pumps used in hydraulic fracturing (i.e., fracking). In some embodiments, the system can automatically test the operation of a high-pressure pump to produce and maintain each in a series of predetermined pressures.

BACKGROUND

[0003] Pumps used for the oil and gas industry, such as fracking pumps, triplex mud pumps, etc., are operated at a high pressure to send fluid downstream a well bore for applications such as fracking and drilling. The manufacturers of said pumps perform factory acceptance tests to ensure that the pumps can generate high pressures for longer intervals which may be needed for particular operations. These high pressures can be 4,000 psi, 6,000 psi, 8,000 psi, and as high as 11,000-12,000 psi. The current practice is to use a choke valve (i.e., a "choke") downstream of the pump to create the needed high pressures. However, the choke valves are operated manually by means of a user adjusting the choke movement to result in needed pressure build up. There are several limitations to this set-up. For example, manual adjustment of the choke valve is slower than automated processes and risks the introduction of user error during operation. Further, at higher pressure requirements, the choke valve may operate in a sensitive area of the choke valve's flow coefficient (Cv) curve, thereby making precise pressure control using the choke valve difficult and resulting in frequent overshoot and/or undershoot of desired pressure values or ranges. In some cases, managed pressure drilling (MPD) systems may be used for pressure set point control, however, these MPD systems have only been used and/or proven for lower pressure operations with a max pressure of around 1,000 to 1,500 psi.

SUMMARY

[0004] In one aspect, a fracking system comprises a pump in fluid communication with a wellbore via a fluid supply line and a choke valve system. The choke valve system comprises a choke valve in fluid communication with the wellbore via a fluid return line and configured to receive a return fluid from the wellbore, the choke valve selectively positionable in a fully shut position, a fully open position, and a range of intermediate positions between the fully shut position and the fully open position. The choke valve system further comprises a motor connected to the choke valve with a worm gear and configured to selectively position the choke valve, the motor and the worm gear having a total gear ratio greater than or equal to 100.

[0005] In one embodiment, the motor and the worm gear have a total gear ratio greater than or equal to 300.

[0006] In another embodiment, the fracking system further comprises a controller in communication with the motor and configured to control one or both of a torque or a speed of the motor based on an intermediate position of the choke valve.

[0007] In still another embodiment, the controller causes the motor to apply a first torque with the choke valve between a first intermediate position and the fully open position and a second torque with the choke valve between the first intermediate position and a second intermediate position, wherein the second torque is greater than the first torque.

[0008] In yet another embodiment, the controller causes the motor to apply a third torque with the choke valve between the second intermediate position and the fully shut position, wherein the third torque is less than the second torque.

[0009] In a further embodiment, the first intermediate position corresponds to a position of the choke valve of about thirty percent open and the second intermediate position corresponds to a position of the choke valve of about 10 percent open.

[0010] In a still further embodiment, the controller causes the motor to operate at a first speed with the choke valve between the first intermediate position and the fully open position and a second speed with the choke valve between the first intermediate position and the fully shut position, wherein the second speed is less than the first speed.

[0011] In a yet further embodiment, the controller is configured to selectively position the choke valve based on a magnitude of a control error function.

[0012] In another embodiment, the control error function is based on a percentage difference between a current pressure of the return fluid and a desired hold pressure of the return fluid.

[0013] In another aspect, a method for controlling a choke valve of a fracking system comprises supplying a fluid to a wellbore with a pump via a fluid supply line. The method further comprise receiving fluid from the wellbore with a choke valve via a fluid return line, the choke valve being selectively positionable in a fully shut position, a fully open position, and a range of intermediate positions between the fully shut position and the fully open position. The method further comprises controlling the choke valve with a motor connected to the choke valve with a worm gear by applying a first torque with the choke valve between a first intermediate position and the fully open position and a second torque with the choke valve between the first intermediate position and a second intermediate position, wherein the second torque is greater than the first torque.

[0014] In one embodiment, controlling the choke valve further comprises applying a third torque with the choke valve between the second intermediate position and the fully shut position, wherein the third torque is less than the second torque.

[0015] In another embodiment, the first intermediate position corresponds to a position of the choke valve of about thirty percent open and the second intermediate position corresponds to a position of the choke valve of about 10 percent open.

[0016] In still another embodiment, controlling the choke valve further comprises operating the motor at a first speed with the choke valve between the first intermediate position and the fully open position and a second speed with the choke valve between the first intermediate position and the fully shut position, wherein the second speed is less than the first speed.

[0017] In yet another embodiment, controlling the choke valve further comprises selectively positioning the choke valve based on a magnitude of a control error function.

[0018] In a further embodiment, the control error function is based on a percentage difference between a current pressure of the fluid and a desired hold pressure of the fluid.

[0019] In a still further embodiment, controlling the choke valve further comprises determining that movement of the choke valve has stopped while operating the motor to selectively position the choke valve, with the choke valve between the second intermediate position and the fully open position; stopping the motor in response to determining that movement of the choke valve has stopped; and producing an error message.

[0020] In yet a further embodiment, the method further comprises determining that a pressure of the fluid is greater than a threshold safety pressure, and stopping the motor in response to determining that the pressure of the fluid is greater than the threshold safety pressure.

[0021] In yet another aspect, a system for automated testing of a high-pressure pump is provided, the high-pressure pump having a pump outlet line for carrying high-pressure fluid. The system comprises a choke valve defining a choke passage therethrough having an inlet at one end, an outlet at the other end and a gate positioned therebetween, wherein the gate is selectively movable along a path to change a fluid restriction value of the choke passage. The inlet of the choke is connectable to a pump outlet line of a high-pressure pump to be tested. A choke actuator has an input shaft and is operatively connected to the gate of the choke valve for moving the gate along the path in response to rotation of the input shaft. An actuator drive is operatively connected to the input shaft of the actuator for selectively rotating the input shaft in response to receiving actuator drive control signals. A system control unit includes a processor unit for executing program steps, a system memory for storing program steps and data, an input/output (I/O) interface for communicating between the processor unit and system memory, a human-machine interface (HMI) for accepting control inputs from a human user, and a display device for communicating at least one of a system status and a test result to the human user. A pressure sensor is connected to the pump outlet line for sensing the pressure of a fluid in the pump outlet line and communicating pump output pressure signals indicative of the fluid pressure within the pump outlet line to the system control unit. The system control unit can execute a first test phase by causing the pump to run at a first speed and causing the actuator drive to rotate the input shaft of the actuator to cause the actuator to move the gate of the choke valve to change the fluid restriction value of the choke path until a first predetermined pressure is sensed in the high-pressure line by the pressure sensor and reported to the system control unit via pump output pressure signals. The system control unit can further cause the actuator drive to rotate the input shaft of the actuator to cause the actuator to move the gate of the choke valve to change the fluid restriction of the choke path to maintain the first predetermined pressure for a first predetermined period of time. The system control unit can cause the display device to show a result of the first test phase or print a report showing the result of the first test phase.

[0022] In one embodiment, after executing a first test phase, the system control unit can execute a subsequent test phase by causing the pump to run at a subsequent speed and causing the actuator drive to rotate the input shaft of the actuator to cause the actuator to move the gate of the choke valve to change the fluid restriction value of the choke path until a subsequent predetermined pressure is sensed in the high-pressure line by the pressure sensor and reported to the system control unit via pump output pressure signals, causing the actuator drive to rotate the input shaft of the actuator to cause the actuator to move the gate of the choke valve to change the fluid restriction of the choke path to maintain the subsequent predetermined pressure for a subsequent predetermined period of time, and causing the display device to show a result of the subsequent test phase or print a report showing the result of the subsequent test phase.

[0023] In another embodiment, stored instructions in the system memory are executed by the system control unit to cause: while the actuator is commanded to move the choke gate to achieve to a new predetermined pressure, the system control unit monitors at least one of choke position signal and choke actuator speed signal; and when the system control unit detects, before the new predetermined pressure is attained, that either the monitored choke position signal has stopped changing or the monitored actuator speed signal is unexpectedly low, the system control unit stops any further movement of the choke gate and sends out an error message to the display device, whereby debris in the choke passage are detected during a test.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] For a more complete understanding, reference is now made to the following description taken in conjunction with the accompanying Drawings in which:

[0025] FIG. **1** shows an automated high-pressure pump testing system rigged up for testing a high-pressure pump;

[0026] FIG. **2** shows a schematic diagram of an automated high-pressure pump testing system in accordance with another embodiment;

[0027] FIG. **3** shows a printed result of a test conducted by an automated high-pressure pump testing system in accordance with another embodiment, in this case a 4000, 5500, 6500, 8000, 9500, 11500 psi auto pressure hold test; and

[0028] FIG. **4** shows a printed result of another test conducted by an automated high-pressure pump testing system in accordance with yet another embodiment, in this case a 9000 psi auto pressure hold test.

DETAILED DESCRIPTION

[0029] According to an aspect of the present disclosure, a choke valve system and method for operation is provided which incorporates hardware as well as improved control algorithms to solve the current problem associated with high pressure fracking and drilling operations. This introduction of hardware and control algorithms is a novel approach to accurately holding high-pressure output of pumps which may be more than 10 times greater than typical pressure hold requirements (e.g., 10,000 to 12,000 psi).

[0030] Operation of the choke valve during high-pressure operation may include increased torque and resolution at low speeds in some or all choke valve positions between a fully shut position and a fully open position, and especially at lower choke valve positions (e.g., the sensitive Cv area of the choke valve less than about thirty percent (30%) open) to be able to move slowly & trap the greater than 10,000 psi well fluid with automatic control. In various embodiments, this application may, therefore, include operation of the choke valve with a motor (e.g., an electric or hydraulic motor) and worm gear having a high gear ratio of the order of greater than 100 or, in various embodiments, greater than 300, where the motor torque is multiplied by that ratio. In various embodiments, the motor and choke valve may have a total gear ratio as high as 360 or higher, thereby providing more torque and resolution for this high-pressure pump control application.

[0031] In various embodiments, the choke valve system may include a controller configured to selectively position the choke valve in a fully shut position, a fully open position, and a range of intermediate positions between the fully shut position and the fully open position, as well as to control a torque and/or a speed of the motor. In various embodiments, the controller may be further configured to implement an algorithm which increases motor torque and/or reduces motor speed during choke valve travel in the sensitive Cv area of choke valve less than or equal to about thirty percent (30%) open. In various embodiments, the algorithm my further limit the motor torque when the choke valve is closing, thereby preventing damage to the choke trim. High torque values generated by an electric or hydraulic motor during operation of the choke valve may cause the choke valve gate to close against the choke valve seat, thereby damaging the internals of the choke valve. Accordingly, implementation of the algorithm by the controller may cause the controller to limit the motor torque at a choke valve position less than or equal to about ten percent (10%) open, when the choke valve is close to closing. The motor torque, limited in such a way, may also permit the user to be able to close the choke with no pressure within the choke valve so that the user is able to perform gate to seat tests to get a full seal as part of API pressure test requirement, hence not comprising that functionality.

[0032] Since the motor torque may be limited only from about ten percent (10%) to zero percent (0%, e.g., fully shut) choke open, in various embodiments another safety feature of the algorithm may be provided because of this relatively higher torque available between one hundred percent (100%, e.g., fully open) and ten percent (10%) choke open. In the event that debris is stuck within the choke valve at any point between one hundred percent (100%, e.g., fully open) and ten percent (10%) choke open, the gate of the choke valve may contact the debris which may, in turn, rub against or otherwise contact the seat of the choke valve, thereby mimicking a choke closed condition. Since the torque is not limited to the reduced torque values corresponding to the choke valve position below ten percent (10%) choke open, said debris can again damage the choke valve internals as a result of the higher motor torque. Hence, according to aspects of the present disclosure, if the algorithm detects the choke valve movement has stopped when trying to travel to trap higher pressure set point, the algorithm will immediately stop any further choke movement and will send out an error message for a user to perform an inspection or maintenance on the choke valve system. Additionally, in various embodiments, if the algorithm detects an increase in well bore fluid pressure greater than a safety threshold, the algorithm will immediately stop any further choke valve movement. For example, the algorithm may stop choke valve movement in response to user control of the choke valve which exceeds the safety threshold, thereby preventing damage to the choke valve, the fracking system, and/or the well.

[0033] In various embodiments, the controller may selectively position the choke valve based on a magnitude of a control error function. In conventional choke valve systems, control of the choke valve may be based on a control error function which is calculated based on a difference between a current pressure and a set point pressure of the well fluid. In high-pressure applications, this determination of control error may be ineffective as the difference between the current and the set point pressure can be as very high (e.g., 10,000-12,000 psi). As a result, the conventional auto control algorithm may determine the choke valve has a longer distance to travel in order to cause the well fluid to reach the needed set point pressure. In this case, the choke valve may move rapidly to traverse the determined longer distance, thereby overshooting and causing a relief valve in the choke valve line to lift, reducing well fluid pressure to 0 psi and causing operational down time.

[0034] Hence, in high pressure applications, aspects of the present disclosure provide an algorithm for auto choke control to hold backpressure which includes calculating a percentage difference between a current well fluid pressure to required pressure to hold rather than by a magnitude of pressure difference between the current well fluid pressure and the set point pressure. This implementation of the algorithm results in an error margin having a manageably smaller control error function in a form of a percentage value instead of a relatively large value associated with the magnitude of pressure difference between the currently well fluid pressure and the set point pressure. For example, the error margin may be represented by a difference between the set point pressure and the current well fluid pressure expressed as a percentage of the set point pressure.

[0035] The above-discussed hardware changes and improved algorithm-based choke valve control, alone or in combination, may provide automatic choke control of pumps in high-pressure fracking and drilling operations. Aspects of the present disclosure may be applicable for any pump operation (fracking, drilling etc.) as well as for manufacturers as part of pump factory acceptability testing.

[0036] Referring now to FIG. **1**, there is illustrated an automated high-pressure pump testing system **100** in accordance with one embodiment rigged up for testing a high-pressure pump **102**. The test system **100** comprises a choke valve **104** fitted with a choke actuator **106** having an actuator drive **108**. In some embodiments, the choke valve **104** defines a choke passage therethrough having an inlet at one end, an outlet at the other end at a gate positioned therebetween, wherein the gate is selectively movable along a path to change the fluid restriction value of the choke passage. The inlet of the choke **104** is connectable to a pump outlet line **112** of the pump **102** to be tested. In some embodiments, the choke actuator **106** has an input shaft and is operatively connected to the gate of the choke valve **104** for moving the gate along the path of the choke passage in response to rotation of the input shaft. In some embodiments, the actuator drive **108** is operatively connected to the input shaft of the actuator **106** for selectively rotating the input shaft in response to receiving actuator drive control signals.

[0037] The system **100** further includes a system control unit **110** (FIG. **2**) operably connected to the actuator drive **108** to send actuator drive control signals to the actuator drive. The pump **102** to be tested can be fluidly connected to the test system **100** using a high-pressure fluid line **112**, which leaves the pump discharge and is connected to the inlet of the choke **104**. A pressure sensor **113** is provided on the high-pressure line **112** and operatively connected to the system control unit **110** to provide pump output pressure signals **114** indicative of the pressure within the high-pressure line. A flow sensor **122** (FIG. **2**) can be provided on the high-pressure line **112** and operatively connected to the system control unit **110** to provide pump output flow signals **124** indicative of the rate of fluid flow within the high-pressure line. A low-pressure fluid line **115**, which is connected to the outlet of the choke **104**, can connect to a fluid storage tank **116**. Fluid from a fluid source can be supplied to the intake of the pump **104** via fluid intake line **118**. Preferably, the fluid source for the pump **104** is also the fluid storage tank **116** so that the test fluid can be recirculated through the tank, pump and choke during testing. In some embodiments, the fluid storage tank **116** may include a chiller unit **120** (FIG. **2**) to remove heat from the test fluid that can build up during pump testing.

[0038] Referring now also to FIG. **2**, there is shown a schematic diagram of an automated high-pressure pump testing system **100** illustrating additional aspects. The system control unit **110** can include a processor unit for executing program steps, a system memory for storing program steps and data, an input/output (I/O) interface for communicating between the processor unit, system memory, other elements of the system and external equipment, a human-machine interface (HMI) for accepting control inputs from a human user, and a display device for communicating system status and results to the human user. In some embodiments, the HMI for the system control unit **110** can be a keyboard, a button, a touchscreen, a joystick, a voice sensor and/or other apparatus for receiving human inputs and converting such inputs into machine-readable signals. In some embodiments, the display device can be a display screen, an indicator light, a speaker, a buzzer or other audio indicator, a printer and/or other apparatus for receiving machine-readable signals and converting such signals into human-readable information. The human-readable information can be transient information including, but not limited to, an active screen display, audio speech or sound, recorded information including, but not limited to, a video or data recording, and/or a permanent information including, but not limited to, a paper printout or a test report, all of the aforementioned indicating a least one of a status of the testing system **100** or a pump test result.

[0039] For safety reasons, it is preferable for a human operator to remain at a safe distance from the high-pressure pump **102** during testing. Therefore, in some embodiments of the automated test system **100**, the HMI and display device for the system control unit **110** can be disposed at the same location as the processor unit, system memory and other components of the control unit; however, in other embodiments, the HMI and display device may be located and/or duplicated at a second location remote from the pump **102** and from the processor unit and system memory. Accordingly, in some embodiments, the automated test system **100** further includes an operator station **126** including a HMI and display device operatively connected to the system control unit **110** with remote control lines **128**. Put another way, in some embodiments, the HMI and display device located at the operator station **126** will be the only HMI and display device for system **100**, whereas in other embodiments, the HMI and display device located at the operator station **126** will duplicate another HMI and/or another display device located at the system control unit **110**. The remote control lines **128** can be physical cables such as conventional multiple conductor wires, data communication cables such as Ethernet cables or local wireless communication links allowing data and/or control signals to be transferred between the system control unit **110** and the operator station **126**.

[0040] In some embodiments, the automated test system **100** further comprises a mobile station **130** that is wirelessly connected to the system control unit **110** and/or to the operator station **126**. In some embodiments, the mobile station **130** can be a dedicated apparatus duplicating the HMI and display device of the system control unit **110**. In other embodiments, the mobile station **130** can be a conventional mobile device such as a mobile phone, tablet, laptop or computer executing a program allowing the mobile device to emulate all or parts of the HMI and display device of the system control unit **110**. In some embodiments, the mobile station **130** can communicate data and control signals with the operator station **126** and/or system control unit **110** using a dedicated wireless link **132**, for example a dedicated radio control link. In other embodiments, the mobile station **130** can communicate data and control signals with the operator station **126** and/or system control unit **110** by a networked wireless link **134** carried by a public or private network **136** including, but not limited to, the internet. For purposes of illustration, in FIG. **2** the mobile station **130** is only connected to the operator station **126**, and is shown using both a dedicated link **132** and a networked link **134**, whereas only one type of link would typically be used.

[0041] Referring still to FIG. **2**, the high-pressure pump **102** can be controlled by a pump control unit **138**, which is typically part of the conventional pump system. In some embodiments, the system control unit **110** is operatively connected to the pump control unit **138** to communicate pump control signal signals **140** to allow the automated testing system **100** to control the operation of the pump **102** during a test. In other embodiments, the system control unit **110** can be operatively connected directly to the pump **102** (i.e., bypassing any pump control unit **138**) to allow the automated testing system **100** to communicate pump control signals **140** to the pump **102** to directly control the operation of the pump during the test. The system control unit **110** can further be operatively connected to the choke **104** to receive gate position signals **142** indicative of the position of the gate of the choke relative to the seat (e.g., an indication of choke percentage open). The system control unit **110** can further be operatively connected to the choke actuator **106** to receive actuator speed and/or revolution count signals **144** indicative of the movement speed of the actuator and/or of the cumulative travel of the actuator which can also indicate speed and/or cumulative travel of the choke gate.

[0042] Referring still to FIG. **2**, the system control unit **100** can further comprise a power supply unit **146** that is operatively connected via electrical lines **148** to the system control unit **110** and the actuator drive **108** for providing electrical power. In some embodiments, the power supply unit **146** can receive input power from alternating current (AC) mains or from a fuel-powered generator. In some embodiments, the power supply unit **146** can receive input power from batteries and/or solar (photovoltaic) cells and/or from a wind-powered generator.

[0043] In some embodiments, the automated test system **100** can automatically implement the testing of a high-pressure pump **102** using the processor unit to execute stored instructions on the system memory. The system anticipates that the inlet of the pump **102** is connected to a source of test fluid, e.g., tank **116**, and that the outlet of the pump is connected to the inlet of the choke **104**. When executing the stored instructions, the system control unit **110** can execute a first test phase by commanding the pump control unit **138** to drive the pump **102** at a first speed and commanding the actuator drive **108** to move the choke gate until a first predetermined pressure can be sensed in the high-pressure line **112** by the pressure sensor **113** and reported via pressure signals **114**. Optionally, the first associated fluid flow rate in the high-pressure line **112** can be sensed by the flow sensor **122** and reported to the system control unit **110** via pump flow signals **124**. Optionally, the first associated speed and revolution of the choke actuator **106** can be sensed and reported to the system control unit **110** via the actuator speed signals **144**. Optionally, the first associated gate position (e.g., percentage open) of the choke **104** can be sensed and reported to the system control unit **110** via the gate position signals **142**. Optionally, the system control unit **110** can command the pump control unit **138** (and thus the pump **102**) and choke actuator **108** to maintain the first predetermined pressure in the high-pressure line **112** for a first predetermined period of time. During the first phase pump test, the system control unit **110** can display the real-time parameters reported by the various sensors and actuators on the display device of the system control unit, operator station **126** and/or mobile station **130**. Optionally, the system **100** may cause the display device to record the system parameters in real-time or print a report showing the results of the test.

[0044] After the automated testing system **100** completes the first test phase, the processor unit may optionally continue executing stored instructions to execute a second test phase. The system control unit **110** can command the pump control unit **138** to change the speed of the pump **102** to a second speed and/or command the actuator drive **108** to move the choke gate until a second predetermined pressure can be sensed in the high-pressure line **112** by the pressure sensor **113** and reported via pressure signals **114**. The second predetermined pressure can be a higher pressure that the first predetermined pressure in order to incrementally test the safety and performance of the pump **102**. Optionally, the second associated fluid flow rate in the high-pressure line **112** can be sensed by the flow sensor **122** and reported to the system control unit **110** via pump flow signals **124**. Optionally, the second associated speed and revolution of the choke actuator **106** can be sensed and reported to the system control unit **110** via the actuator speed signals **144**. Optionally, the second associated gate position of the choke **104** can be sensed and reported to the system control unit **110** via the gate position signals **142**. Optionally, the system control unit **110** can command the pump control unit **138** and choke actuator **108** to maintain the second predetermined pressure in the high-pressure line **112** for a second predetermined period of time. During the second phase pump test, the system control unit **110** can continue to display the real-time parameters reported by the various sensors and actuators on the display device of the system control unit, operator station **126** and/or mobile station **130**. Optionally, the system **100** may cause the display device to continue recording the system parameters in real-time or print a report showing the results of the test.

[0045] After the automated testing system **100** completes the second test phase, the processor unit may optionally continue executing stored instructions to execute a further successive test phases. In some embodiments, for each successive test phase, the new predetermined pressure can be a higher pressure that the previous first predetermined pressure in order to continually incrementally test the safety and performance of the pump **102** until the maximum pressure required for acceptance of the pump is successfully achieved. In other embodiments, the predetermined pressure of the second and subsequent test phases can be any desired pressures, regardless of whether they are successively increasing.

[0046] FIG. **3** shows a printed result **300** of a high-pressure pump test conducted by an automated high-pressure pump testing system in accordance with another embodiment, in this case a 4000, 5500, 6500, 8000, 9500, 11500 psi auto pressure hold test. Thus, this test included six successive test phases. In the report **300**, the pressure setpoint commanded by the automated testing system **100** (i.e., the predetermined pressure) is shown by line **302** and the actual pressure measured by the system (e.g., by the pressure sensor **113**) is shown by line **304**. The associated fluid flow rate of the pump **102** measured by the system **100** (e.g., by the flow sensor **122**) is shown by line **306**. The associated actuator movement, e.g., speed and duration, measured by the system **100** (e.g., from the actuator speed signals **144**) is shown by line **308**.

[0047] FIG. **4** shows a printed result **400** of another high-pressure pump test conducted by an automated high-pressure pump testing system in accordance with yet another embodiment, in this case a 9000 psi auto pressure hold test. Thus, this test included only one test phase. In the report **400**, the pressure setpoint commanded by the automated testing system **100** (i.e., the predetermined pressure) is shown by line **402** and the actual pressure measured by the system (e.g., by the pressure sensor **113**) is shown by line **404**. The associated fluid flow rate of the pump **102** measured by the system **100** (e.g., by the flow sensor **122**) is shown by line **406**.

[0048] During the testing of high-pressure pumps, especially during acceptance testing after pump maintenance, there can sometimes be a failure of a newly replaced part and/or the dislodgment of tools, broken parts or other debris left within the pump during maintenance. As the pump testing proceeds, such debris can move through the pump **102** and into the choke **104**, where they can become jammed in the throat of the choke. Therefore, in some embodiments of the system **100**, the stored instructions in the system memory of the system control unit **110** can comprise an algorithm that detects the presence of debris in the choke **104** during testing. In one such embodiment, the stored instructions in the system memory of the system control unit **110** can comprise an algorithm that detects when choke gate movement has stopped or been impeded when trying to travel to higher pressure set point (i.e., when closing the gate). For example, the detection algorithm in the system control unit **110** can monitor the choke position signals **142** and/or the choke actuator speed signals **144** while the actuator **106** is commanded to move the choke gate to achieve to a new setpoint or predetermined pressure. If the detection algorithm in the system control unit **110** detects that the actuator **106** has stopped moving or the actuator speed as measured by signal **144** is unexpectedly low before the new predetermined pressure is attained, the algorithm can cause the system control unit to stop any further movement of the choke gate and can send out an error message to the display device on the system control unit, the operator station **126** and/or the mobile statin **130** for a user to perform an inspection or maintenance on the choke valve **104**.

[0049] It will be appreciated by those skilled in the art having the benefit of this disclosure that this automated high-pressure pump testing system provides many advantages in safety, speed and convenience compared to previous procedures for testing high-pressure pumps. It should be understood that the drawings and detailed description herein are to be regarded in an illustrative rather than a restrictive manner, and are not intended to be limiting to the particular forms and examples disclosed. On the contrary, included are any further modifications, changes, rearrangements, substitutions, alternatives, design choices, and embodiments apparent to those of ordinary skill in the art, without departing from the spirit and scope hereof, as defined by the following claims. Thus, it is intended that the following claims be interpreted to embrace all such further modifications, changes, rearrangements, substitutions, alternatives, design choices, and embodiments.

1. A fracking system comprising:

a pump in fluid communication with a wellbore via a fluid supply line; and

a choke valve system comprising:

a choke valve in fluid communication with the wellbore via a fluid return line and configured to receive a return fluid from the wellbore, the choke valve selectively positionable in a fully shut position, a fully open position, and a range of intermediate positions between the fully shut position and the fully open position; and

a motor connected to the choke valve with a worm gear and configured to selectively position the choke valve, the motor and the worm gear having a total gear ratio greater than or equal to 100.

2. The fracking system of claim **1**, wherein the motor and the worm gear have a total gear ratio greater than or equal to 300.

3. The fracking system of claim **1**, further comprising a controller in communication with the motor and configured to control one or both of a torque or a speed of the motor based on an intermediate position of the choke valve.

4. The fracking system of claim **3**, wherein the controller causes the motor to apply a first torque with the choke valve between a first intermediate position and the fully open position and a second torque with the choke valve between the first intermediate position and a second intermediate position, wherein the second torque is greater than the first torque.

5. The fracking system of claim **4**, wherein the controller causes the motor to apply a third torque with the choke valve between the second intermediate position and the fully shut position, wherein the third torque is less than the second torque.

6. The fracking system of claim **5**, wherein the first intermediate position corresponds to a position of the choke valve of about thirty percent open and the second intermediate position corresponds to a position of the choke valve of about 10 percent open.

7. The fracking system of claim **4**, wherein the controller causes the motor to operate at a first speed with the choke valve between the first intermediate position and the fully open position and a second speed with the choke valve between the first intermediate position and the fully shut position, wherein the second speed is less than the first speed.

8. The fracking system of claim **3**, wherein the controller is configured to selectively position the choke valve based on a magnitude of a control error function.

9. The fracking system of claim **8**, wherein the control error function is based on a percentage difference between a current pressure of the return fluid and a desired hold pressure of the return fluid.

10. A method for controlling a choke valve of a fracking system, the method comprising:

supplying a fluid to a wellbore with a pump via a fluid supply line;

receiving the fluid from the wellbore with a choke valve via a fluid return line, the choke valve selectively positionable in a fully shut position, a fully open position, and a range of intermediate positions between the fully shut position and the fully open position; and

controlling the choke valve with a motor connected to the choke valve with a worm gear by applying a first torque with the choke valve between a first intermediate position and the fully open position and a second torque with the choke valve between the first intermediate position and a second intermediate position, wherein the second torque is greater than the first torque.

11. The method of claim **10**, wherein controlling the choke valve further comprises applying a third torque with the choke valve between the second intermediate position and the fully shut position, wherein the third torque is less than the second torque.

12. The method of claim **11**, wherein the first intermediate position corresponds to a position of the choke valve of about thirty percent open and the second intermediate position corresponds to a position of the choke valve of about 10 percent open.

13. The method of claim **10**, wherein controlling the choke valve further comprises operating the motor at a first speed with the choke valve between the first intermediate position and the fully open position and a second speed with the choke valve between the first intermediate position and the fully shut position, wherein the second speed is less than the first speed.

14. The method of claim **10**, wherein controlling the choke valve further comprises selectively positioning the choke valve based on a magnitude of a control error function.

15. The method of claim **14**, wherein the control error function is based on a percentage difference between a current pressure of the fluid and a desired hold pressure of the fluid.

16. The method of claim **11**, wherein controlling the choke valve further comprises:

determining that movement of the choke valve has stopped while operating the motor to selectively position the choke valve, with the choke valve between the second intermediate position and the fully open position;

stopping the motor in response to determining that movement of the choke valve has stopped; and

producing an error message.

17. The method of claim **10**, further comprising:

determining that a pressure of the fluid is greater than a threshold safety pressure; and stopping the motor in response to determining that the pressure of the fluid is greater than the threshold safety pressure.

18. A system for automated testing of a high-pressure pump, the high-pressure pump having a pump outlet line for carrying high-pressure fluid, the system comprising:

a choke valve defining a choke passage therethrough having an inlet at one end, an outlet at the other end and a gate positioned therebetween, wherein the gate is selectively movable along a path to change a fluid restriction value of the choke passage;

wherein the inlet of the choke is connectable to a pump outlet line of a high-pressure pump to be tested;

a choke actuator having an input shaft and operatively connected to the gate of the choke valve for moving the gate along the path in response to rotation of the input shaft;

an actuator drive operatively connected to the input shaft of the actuator for selectively rotating the input shaft in response to receiving actuator drive control signals;

a system control unit including:

a processor unit for executing program steps;

a system memory for storing program steps and data;

an input/output (I/O) interface for communicating between the processor unit and system memory;

a human-machine interface (HMI) for accepting control inputs from a human user; and

a display device for communicating at least one of a system status and a test result to the human user;

a pressure sensor connected to the pump outlet line for sensing the pressure of a fluid in the pump outlet line and communicating pump output pressure signals indicative of the fluid pressure within the pump outlet line to the system control unit; and

wherein the system control unit can execute a first test phase by:

causing the pump to run at a first speed and causing the actuator drive to rotate the input shaft of the actuator to cause the actuator to move the gate of the choke valve to change the fluid restriction value of the choke path until a first predetermined pressure is sensed in the high-pressure line by the pressure sensor and reported to the system control unit via pump output pressure signals;

causing the actuator drive to rotate the input shaft of the actuator to cause the actuator to move the gate of the choke valve to change the fluid restriction of the choke path to maintain the first predetermined pressure for a first predetermined period of time; and

causing the display device to show a result of the first test phase or print a report showing the result of the first test phase.

19. The system for automated testing of claim **18**, further comprising:

wherein after executing a first test phase, the system control unit can execute a subsequent test phase by:

causing the pump to run at a subsequent speed and causing the actuator drive to rotate the input shaft of the actuator to cause the actuator to move the gate of the choke valve to change the fluid restriction value of the choke path until a subsequent predetermined pressure is sensed in the high-pressure line by the pressure sensor and reported to the system control unit via pump output pressure signals;

causing the actuator drive to rotate the input shaft of the actuator to cause the actuator to move the gate of the choke valve to change the fluid restriction of the choke path to maintain the subsequent predetermined pressure for a subsequent predetermined period of time; and

causing the display device to show a result of the subsequent test phase or print a report showing the result of the subsequent test phase.

20. The system for automated testing of claim **18**, wherein stored instructions in the system memory are executed by the system control unit to cause:

while the actuator is commanded to move the choke gate to achieve to a new predetermined pressure, the system control unit monitors at least one of choke position signal and choke actuator speed signal; and

when the system control unit detects, before the new predetermined pressure is attained, that either the monitored choke position signal has stopped changing or the monitored actuator speed signal is unexpectedly low, the system control unit:

stops any further movement of the choke gate; and

sends out an error message to the display device;

whereby debris in the choke passage are detected during a test.

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