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(54) SAND SEPERATION CONTROL SYSTEM AND METHOD

(71) Applicant: **ENERCORP ENGINEERED SOLUTIONS INC.**, Calgary (CA)

(72) Inventors: **Rory Nagge**, Calgary (CA); **Brent James William Coombe**, Calgary (CA)

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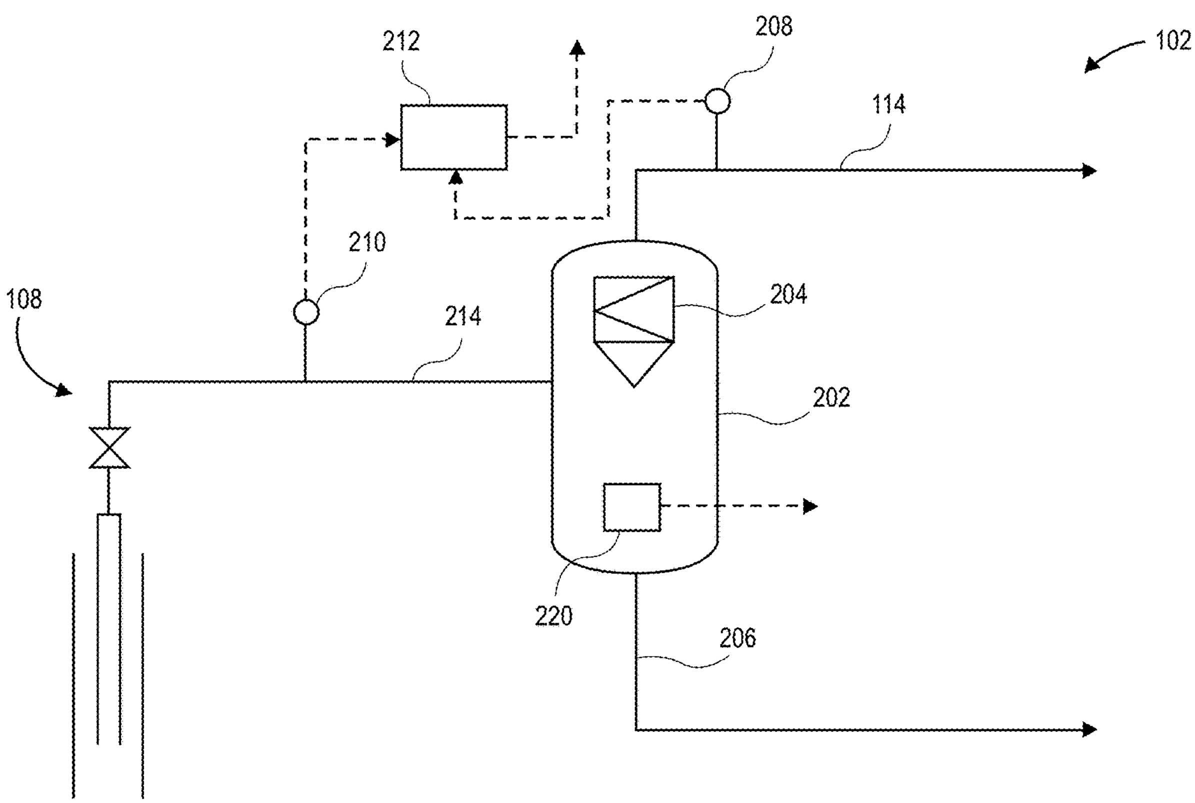
G01M 3/28	(2006.01)

(52) **U.S. Cl.**
CPC ***B01D 21/302*** (2013.01); ***B01D 21/245*** (2013.01); ***B01D 21/267*** (2013.01); ***E21B 43/35*** (2020.05); ***G01F 23/0007*** (2013.01); ***G01G 19/00*** (2013.01); ***G01M 3/2876*** (2013.01); *E21B 43/267* (2013.01)

(57) **ABSTRACT**

A sand separation system includes one or more separators configured to receive a mixed fluid from one or more wells or wellheads and to separate solids from the mixed fluid to produce the solids and a separated fluid. The system also includes one or more chokes downstream from and in fluid communication with the one or more separators. Each of the one or more chokes is configured to receive the separated fluid from a corresponding one of the one or more separators and to control a flow rate of the separated fluid therethrough. The system also includes one or more multiphase meters downstream from and in fluid communication with the one or more chokes. Each of the multiphase meters is configured to measure one or more first properties of the separated fluid and to adjust the one or more chokes in response to the one or more first properties.



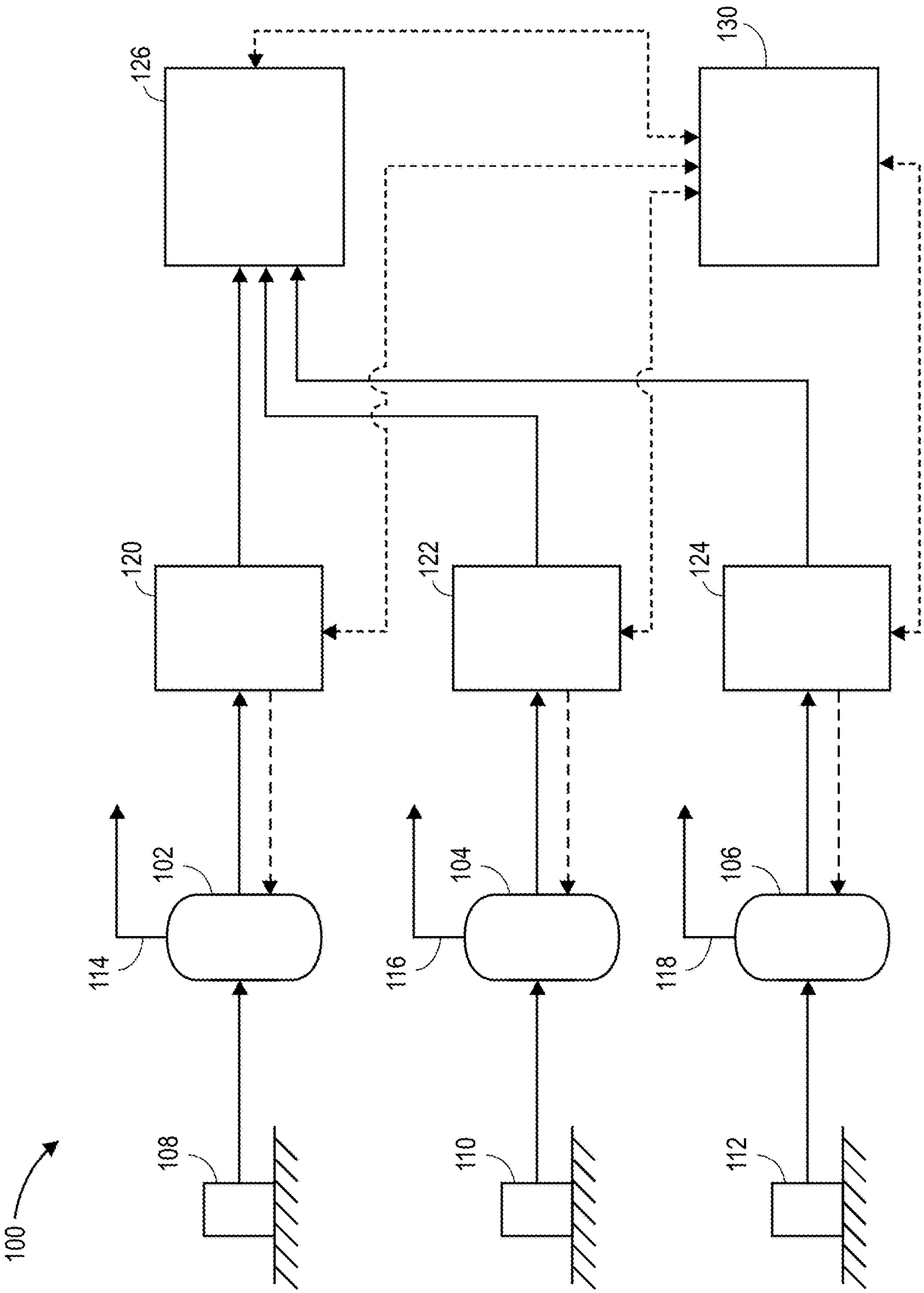


FIG. 1

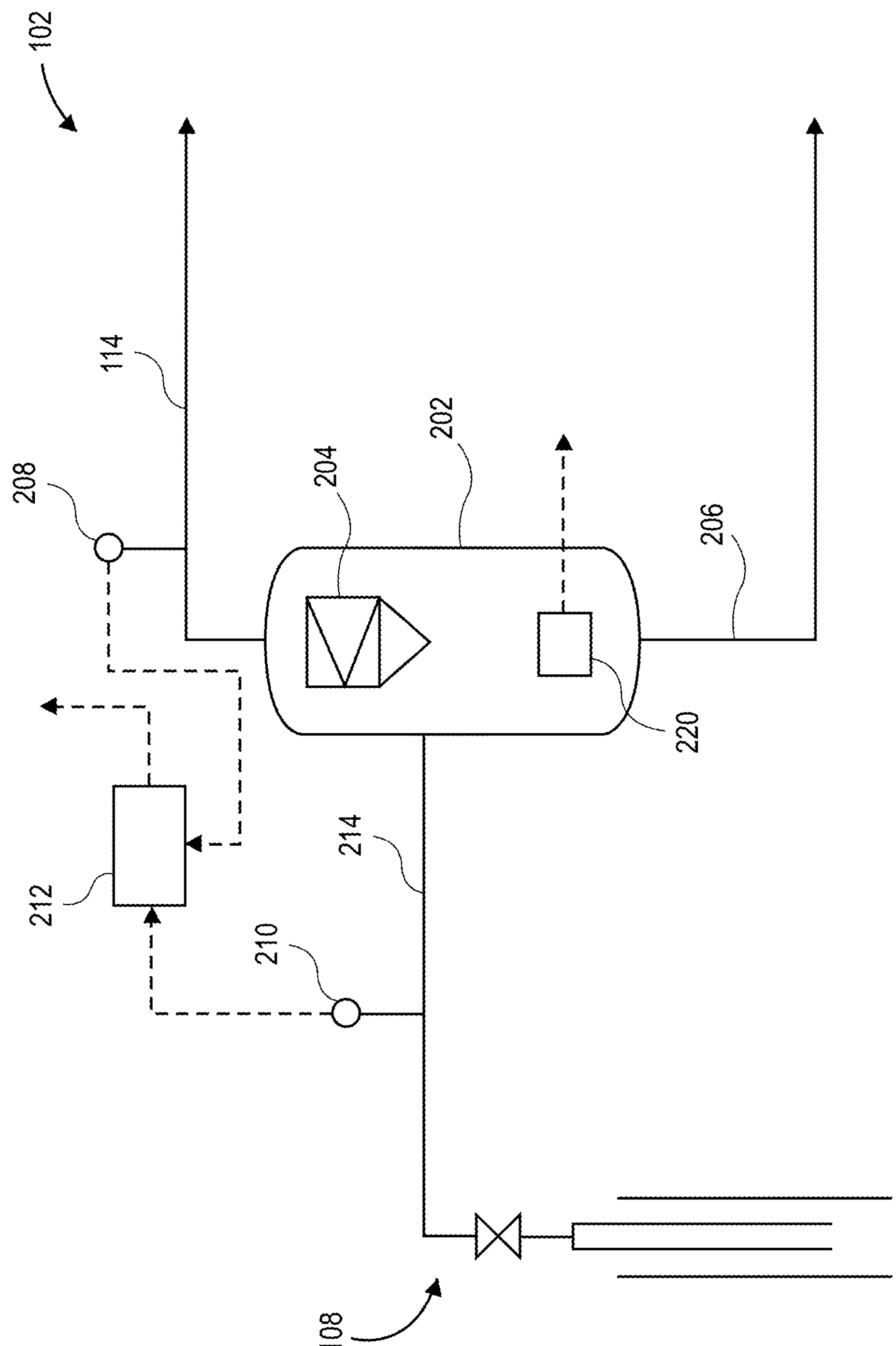


FIG. 2

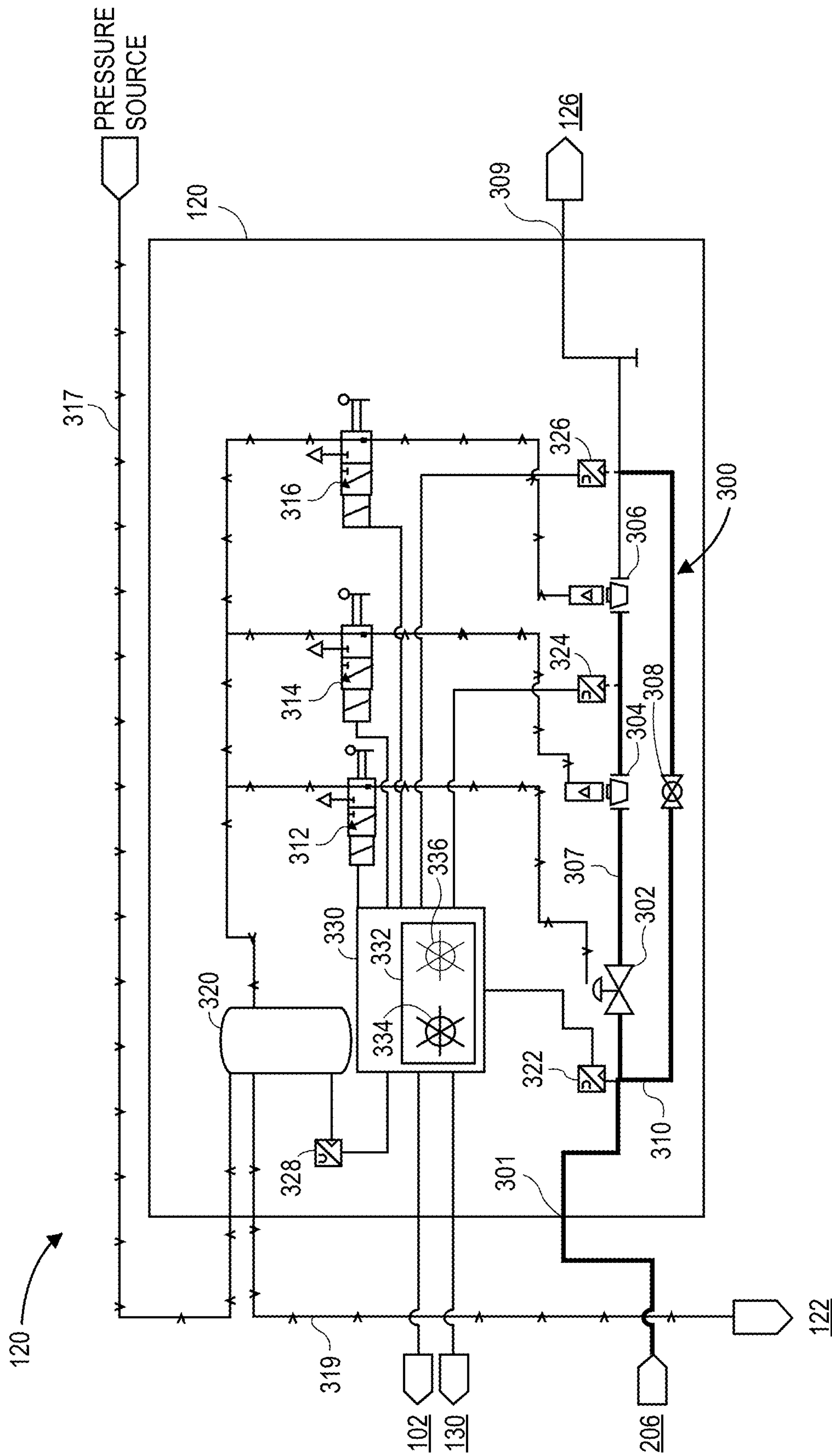
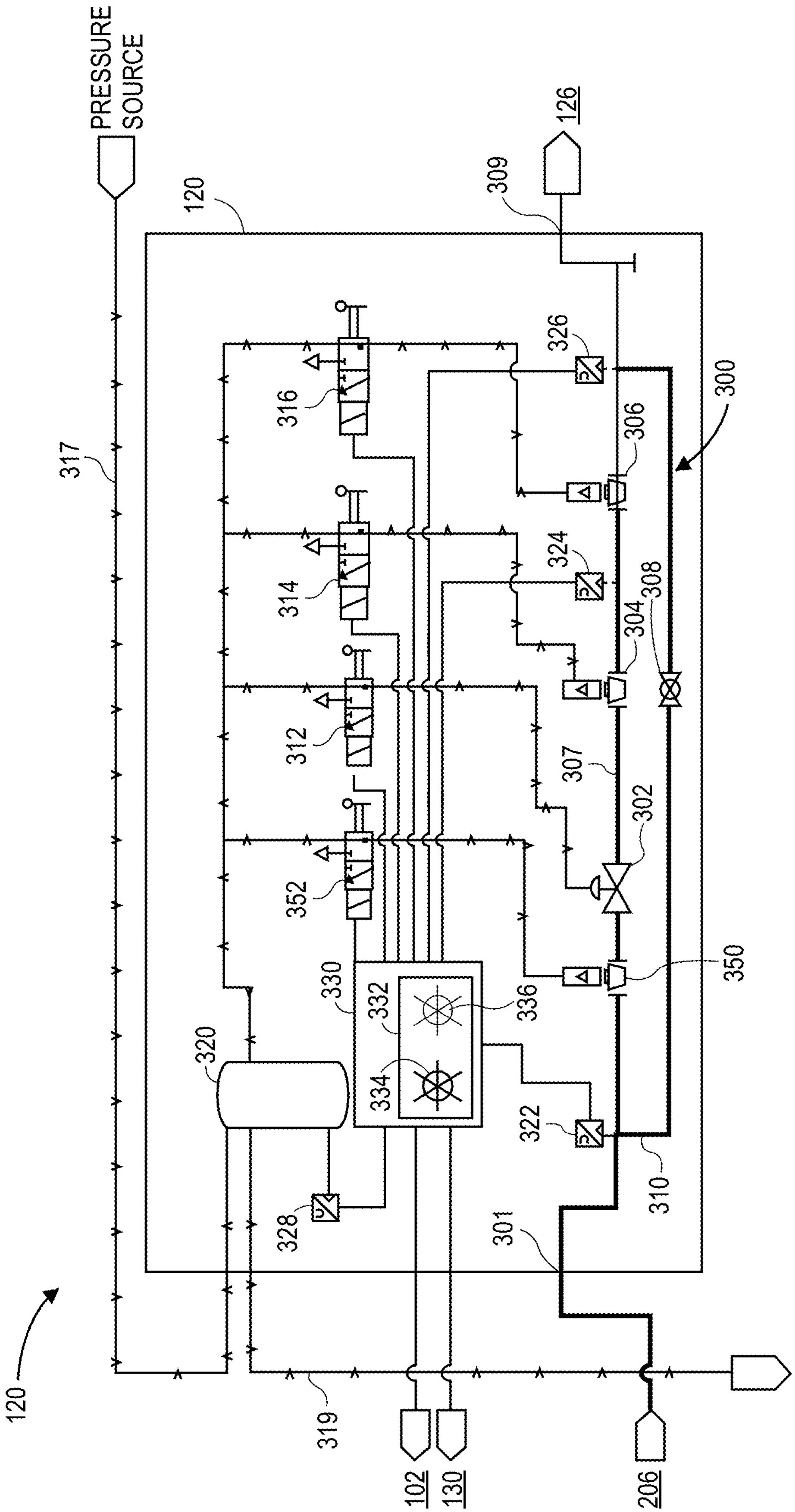

PRESSURE SOURCE
120
120
317
309
126
300
316
314
312
326
324
306
304
308
307
302
336
330
332
334
320
322
310
328
301
319
102
130
206
122

FIG. 3A



PRESSURE SOURCE
120
317
309
126
300
301
302
304
306
307
308
310
312
314
316
319
320
322
324
326
328
330
332
334
336
350
352
102
130
206
122

FIG. 3B

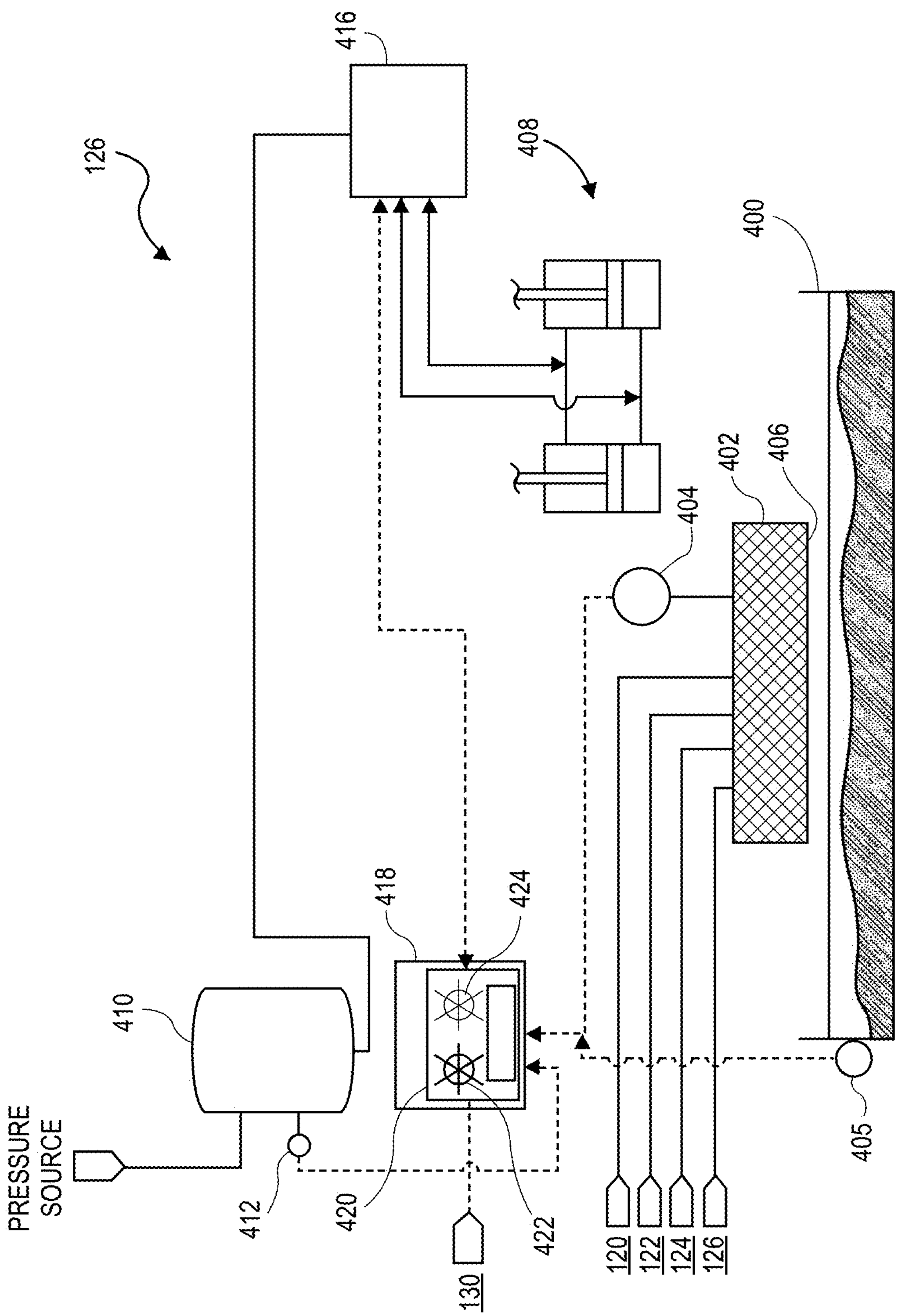

126
416
408
400
402
406
404
418
424
410
PRESSURE
SOURCE
412
420
422
130
120
122
124
126
405

FIG. 4

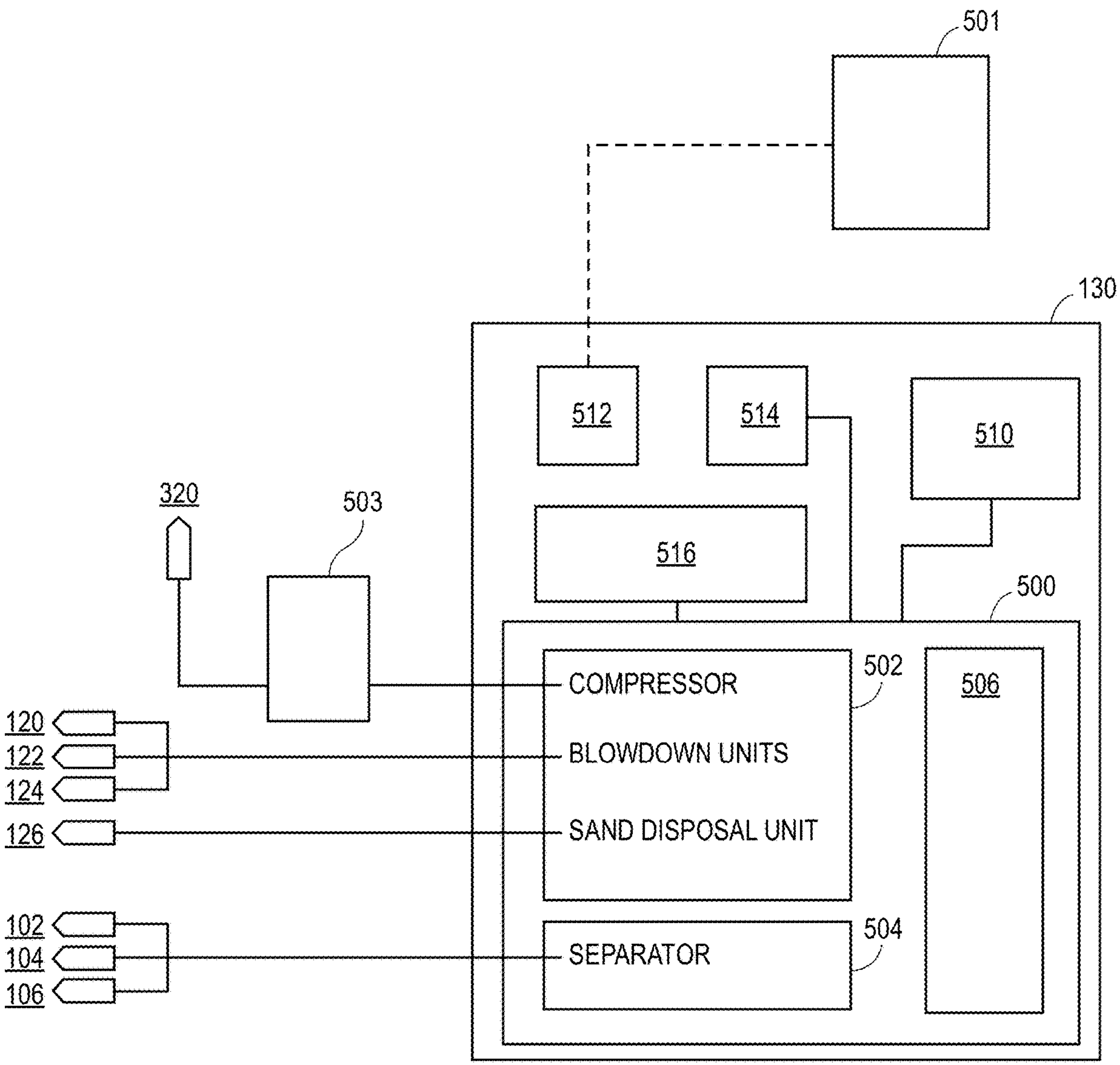

501
130
512
514
510
320
503
516
500
COMPRESSOR
502
506
120
122
124
BLOWDOWN UNITS
126
SAND DISPOSAL UNIT
102
104
106
SEPARATOR
504

FIG. 5

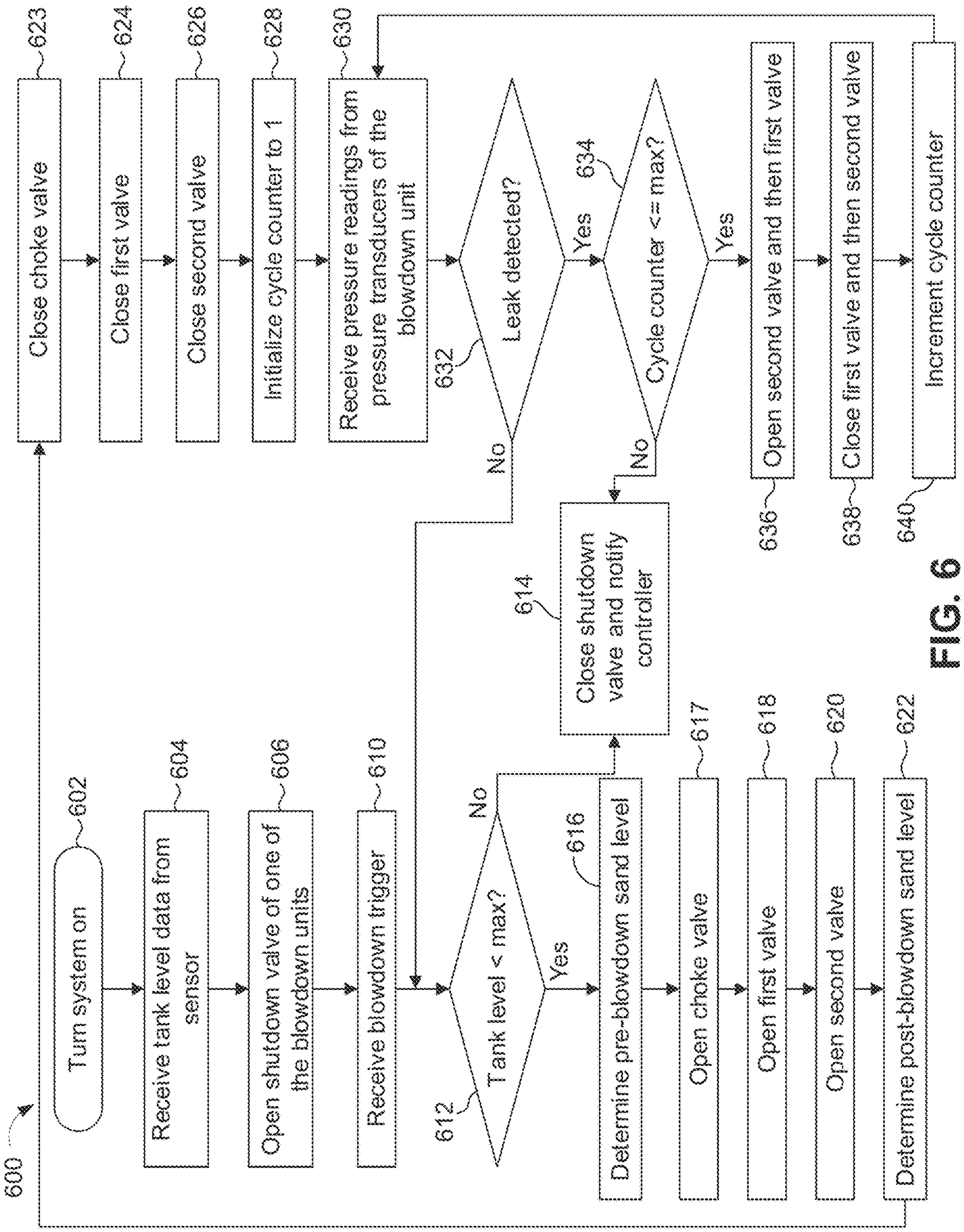

600
Turn system on
602
Receive tank level data from sensor
604
Open shutdown valve of one of the blowdown units
606
Receive blowdown trigger
610
Tank level < max?
612
Yes
No
Determine pre-blowdown sand level
616
Open choke valve
617
Open first valve
618
Open second valve
620
Determine post-blowdown sand level
622
Close shutdown valve and notify controller
614
Close choke valve
623
Close first valve
624
Close second valve
626
Initialize cycle counter to 1
628
Receive pressure readings from pressure transducers of the blowdown unit
630
Leak detected?
632
Cycle counter <= max?
634
Open second valve and then first valve
636
Close first valve and then second valve
638
Increment cycle counter
640

FIG. 6

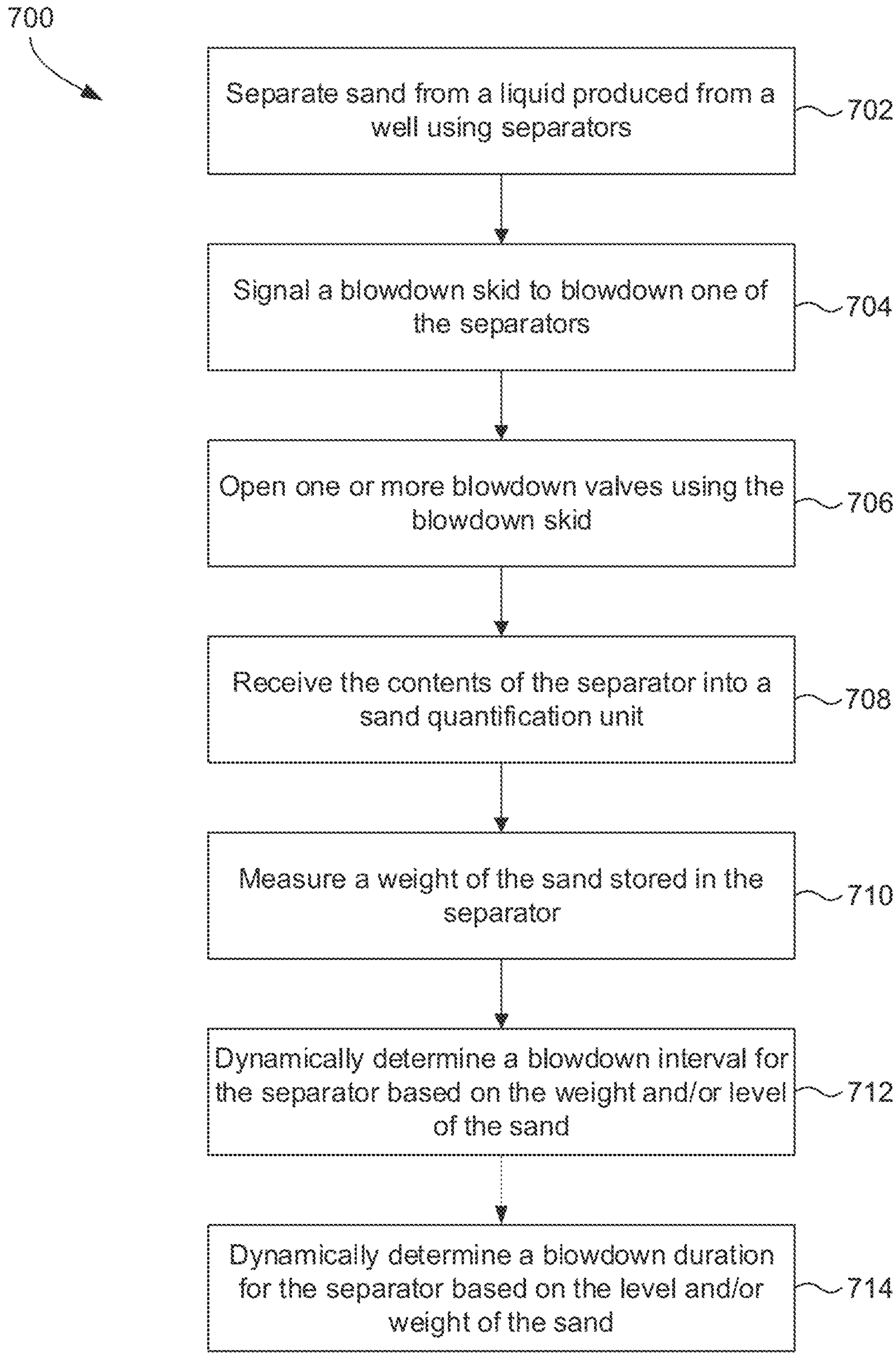

700
Separate sand from a liquid produced from a well using separators
702
Signal a blowdown skid to blowdown one of the separators
704
Open one or more blowdown valves using the blowdown skid
706
Receive the contents of the separator into a sand quantification unit
708
Measure a weight of the sand stored in the separator
710
Dynamically determine a blowdown interval for the separator based on the weight and/or level of the sand
712
Dynamically determine a blowdown duration for the separator based on the level and/or weight of the sand
714

FIG. 7

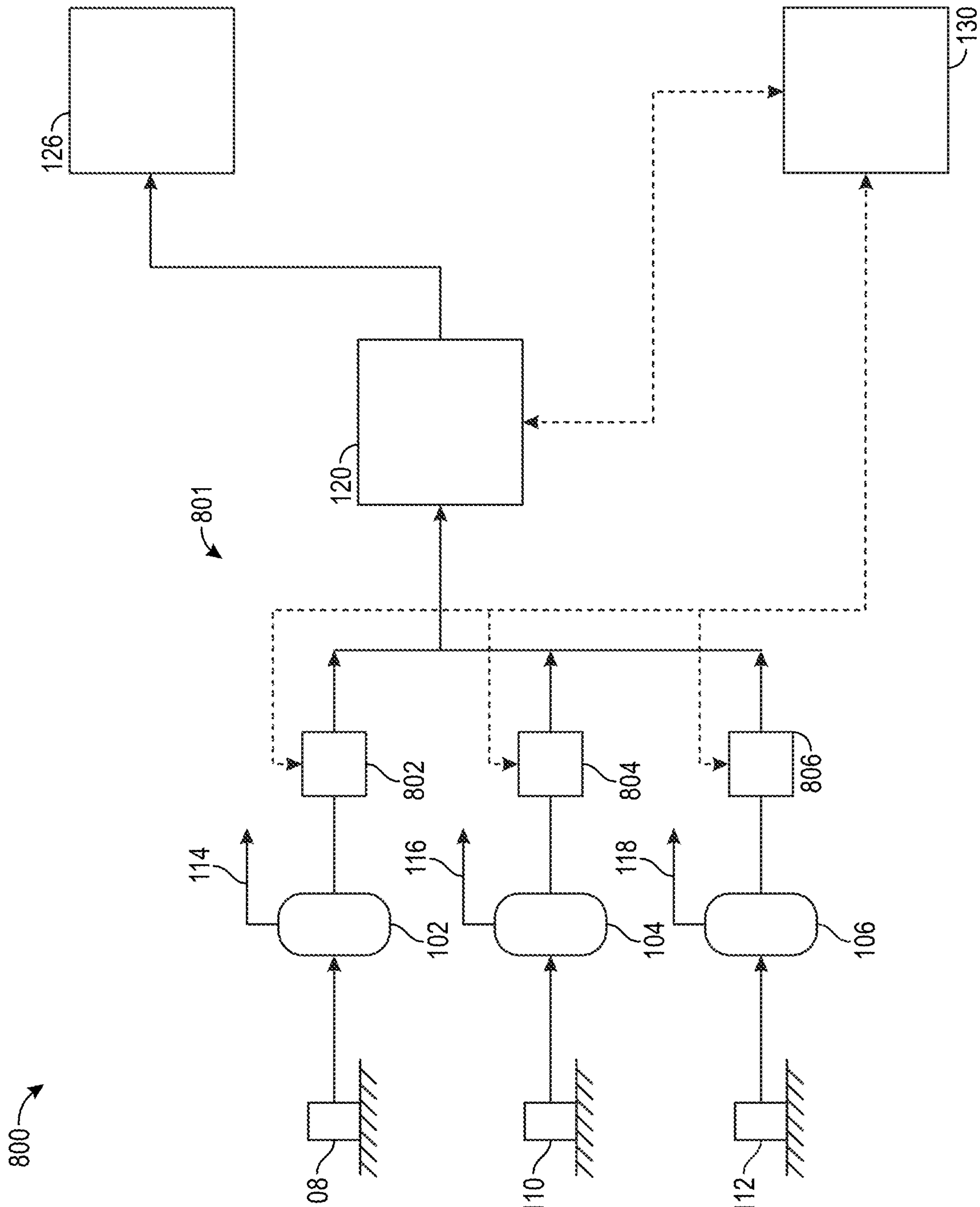

800
801
102
104
106
108
110
112
114
116
118
120
126
130
802
804
806

FIG. 8

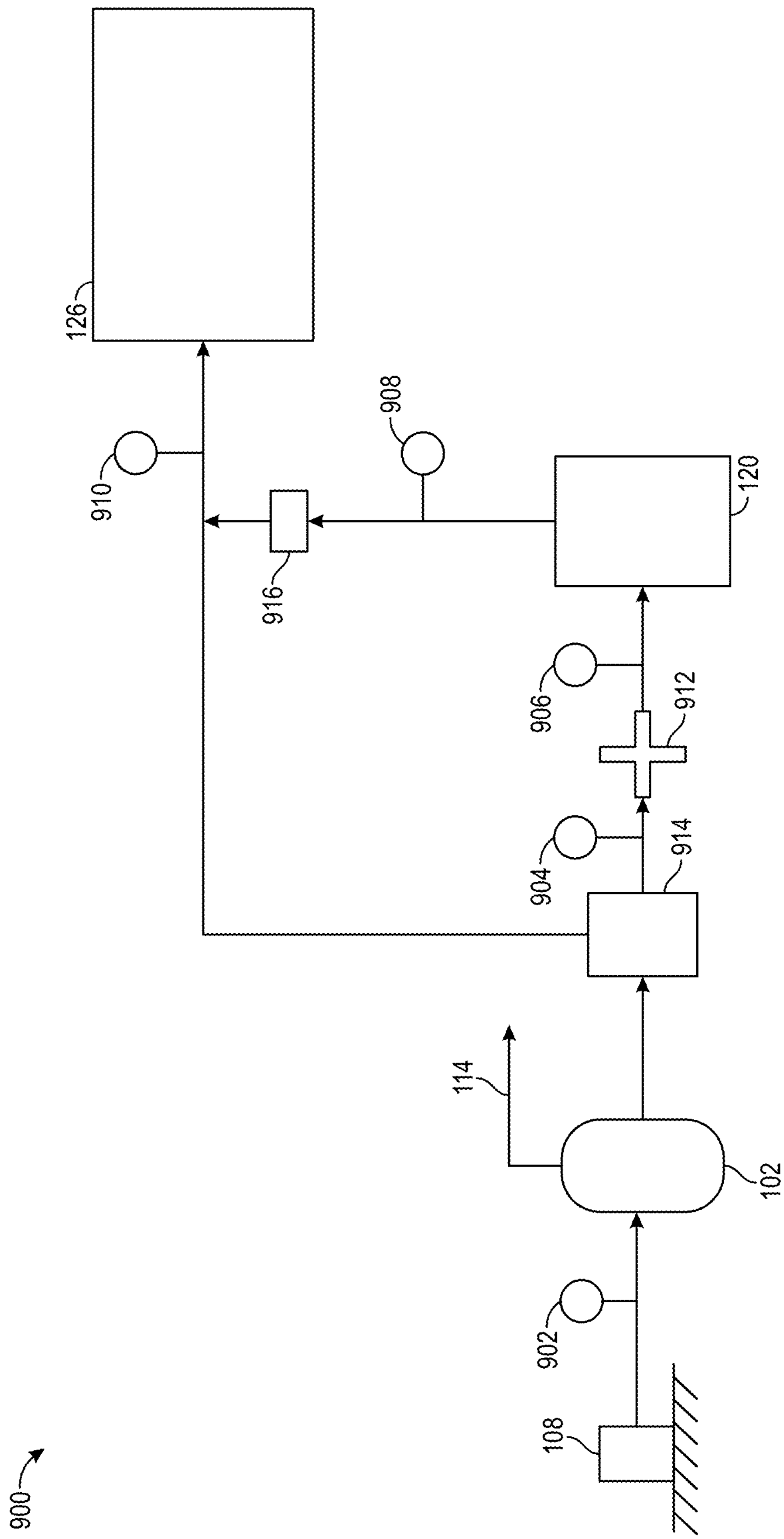


FIG. 9

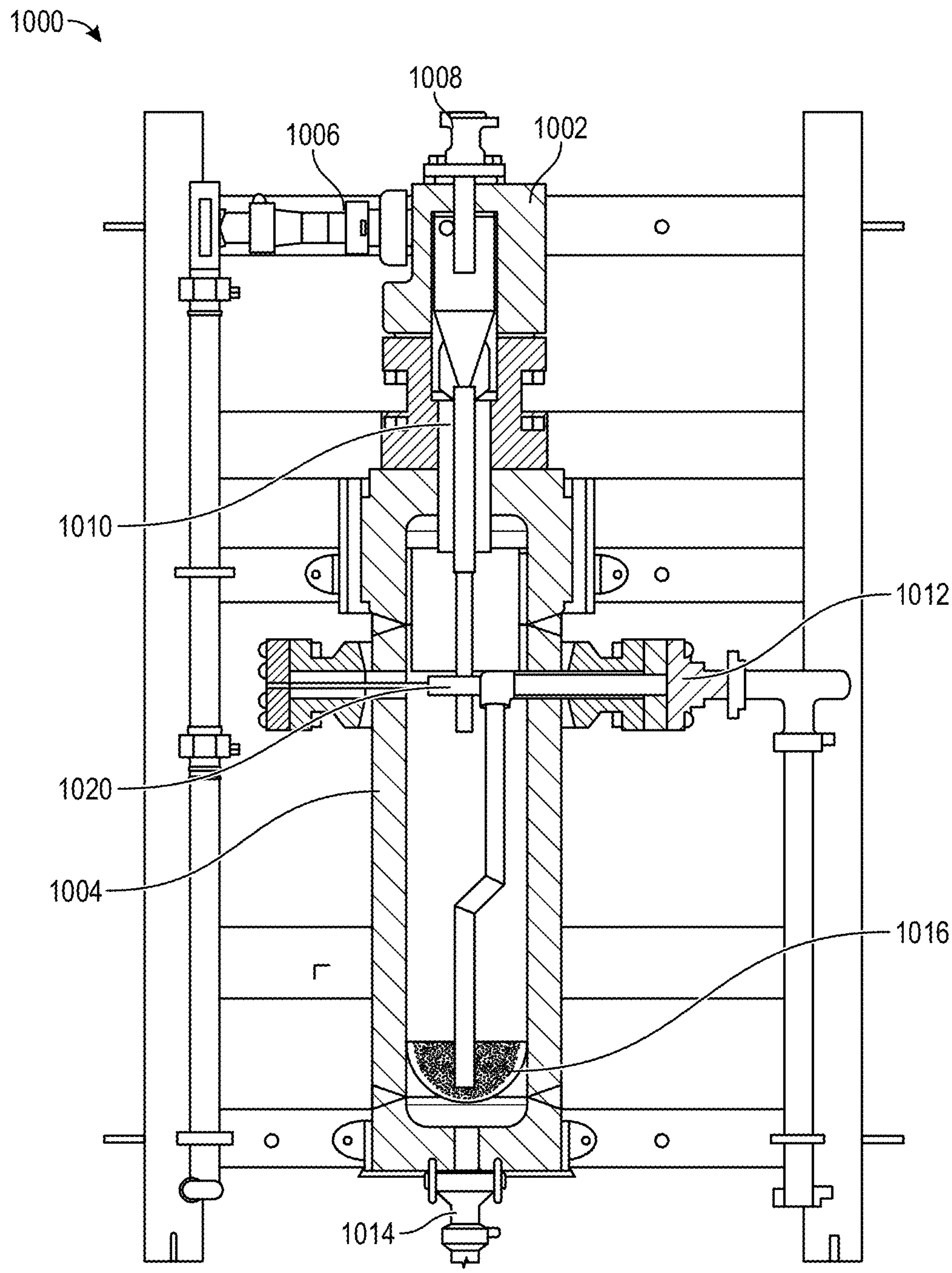


FIG. 10

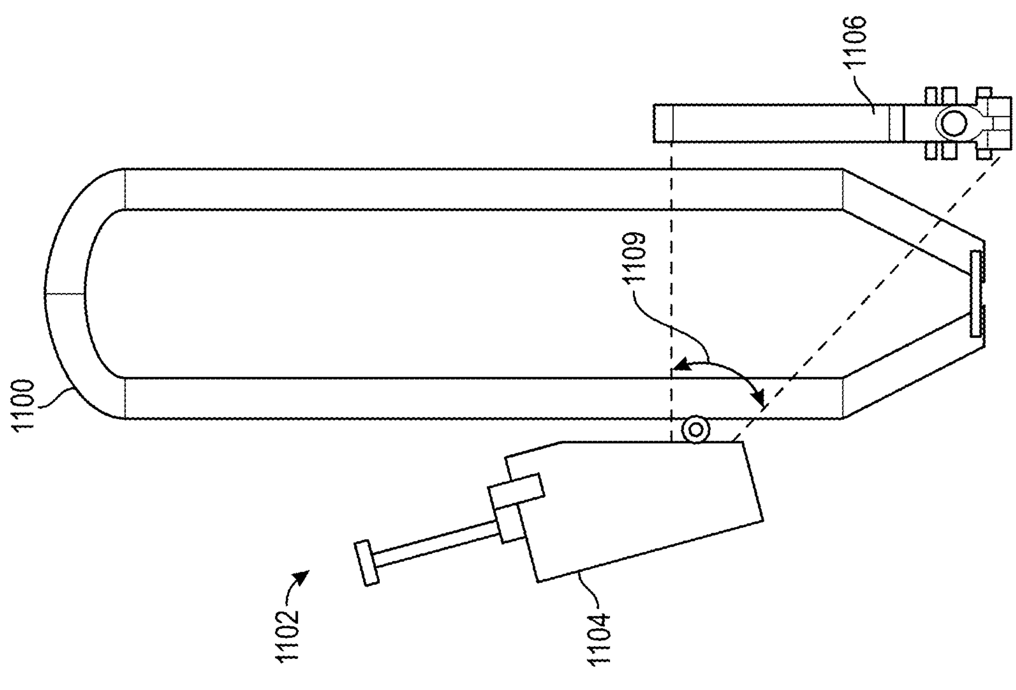


FIG. 11A

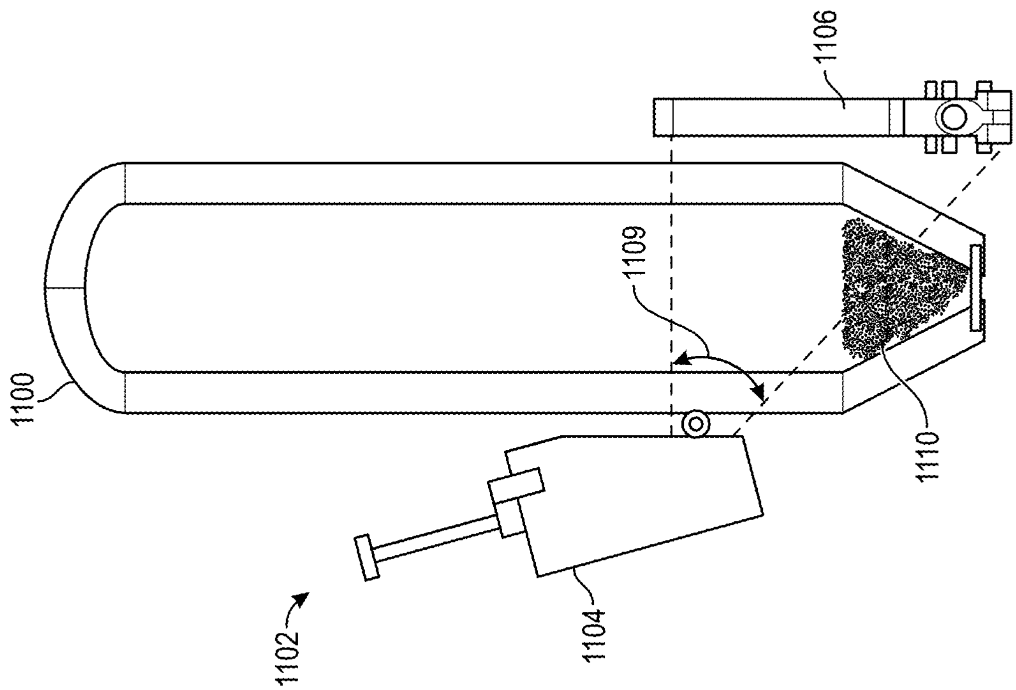


FIG. 11B

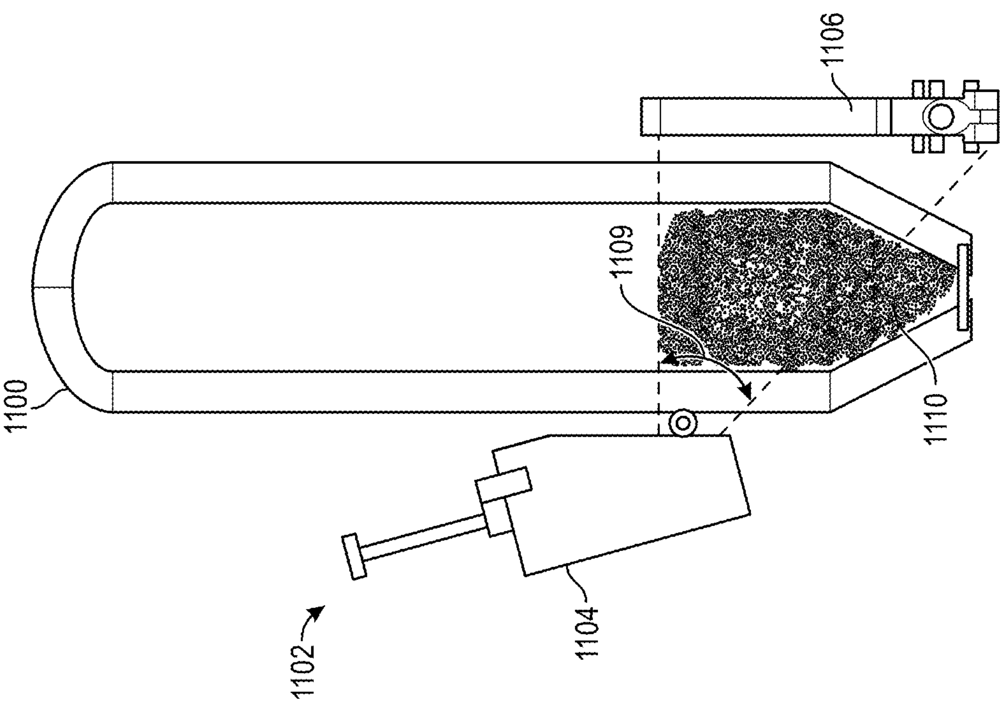


FIG. 11D

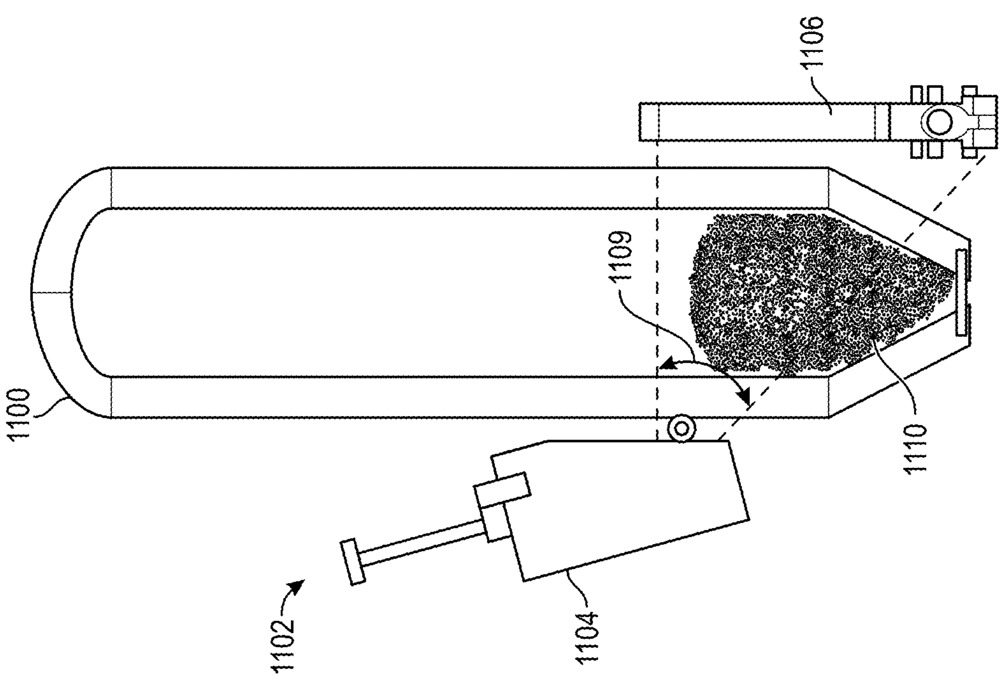


FIG. 11C

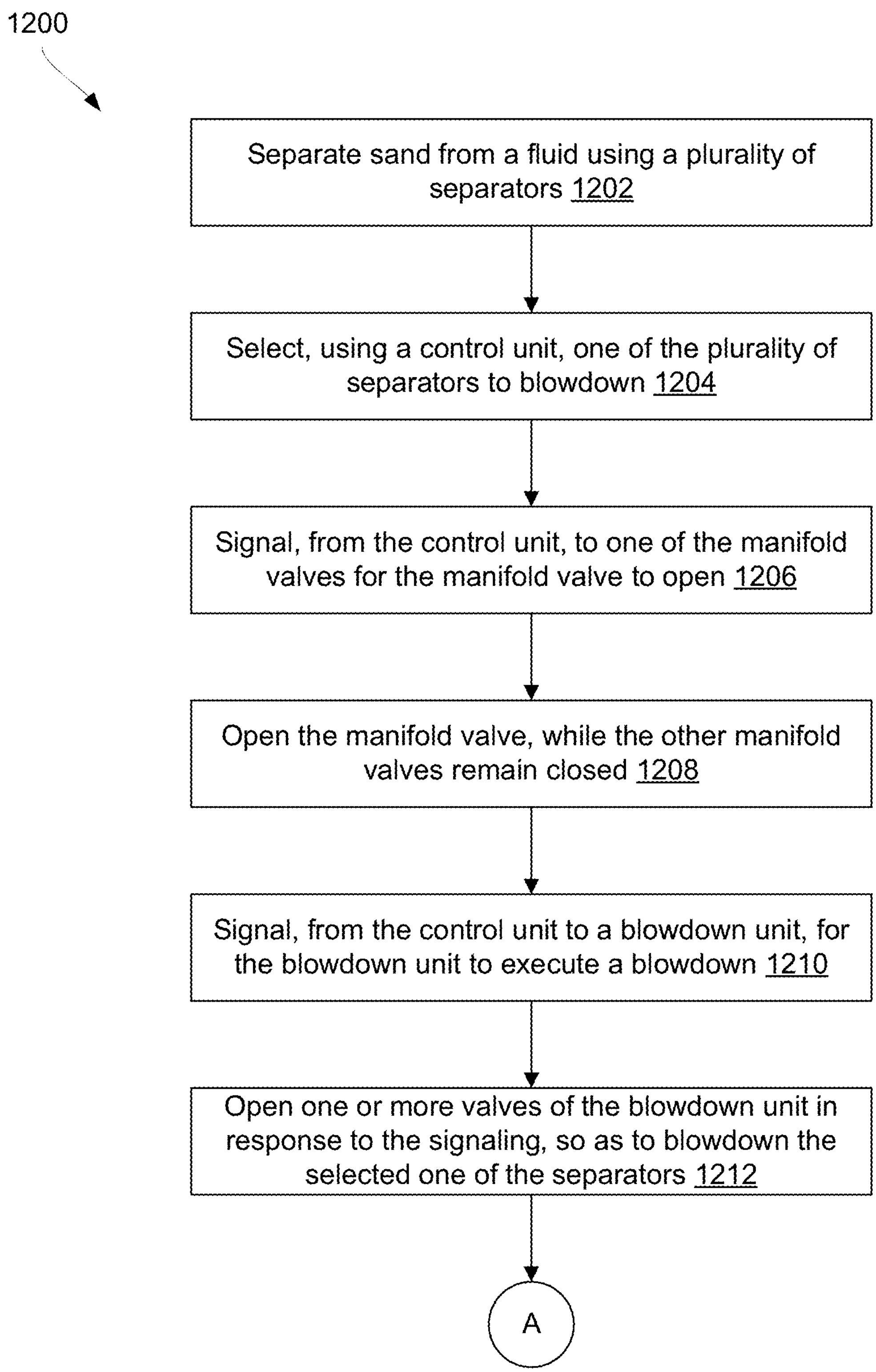

1200
Separate sand from a fluid using a plurality of separators 1202
Select, using a control unit, one of the plurality of separators to blowdown 1204
Signal, from the control unit, to one of the manifold valves for the manifold valve to open 1206
Open the manifold valve, while the other manifold valves remain closed 1208
Signal, from the control unit to a blowdown unit, for the blowdown unit to execute a blowdown 1210
Open one or more valves of the blowdown unit in response to the signaling, so as to blowdown the selected one of the separators 1212
A

FIG. 12A

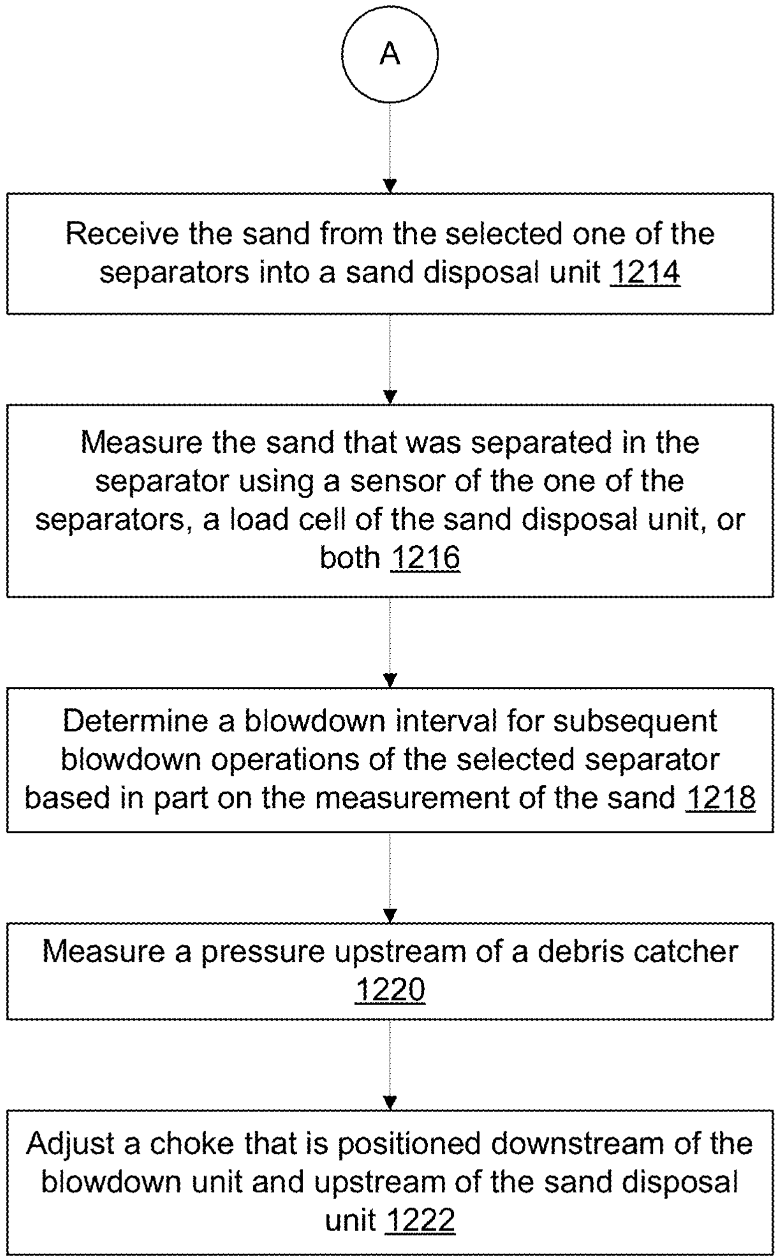

A
Receive the sand from the selected one of the separators into a sand disposal unit 1214
Measure the sand that was separated in the separator using a sensor of the one of the separators, a load cell of the sand disposal unit, or both 1216
Determine a blowdown interval for subsequent blowdown operations of the selected separator based in part on the measurement of the sand 1218
Measure a pressure upstream of a debris catcher 1220
Adjust a choke that is positioned downstream of the blowdown unit and upstream of the sand disposal unit 1222

FIG. 12B

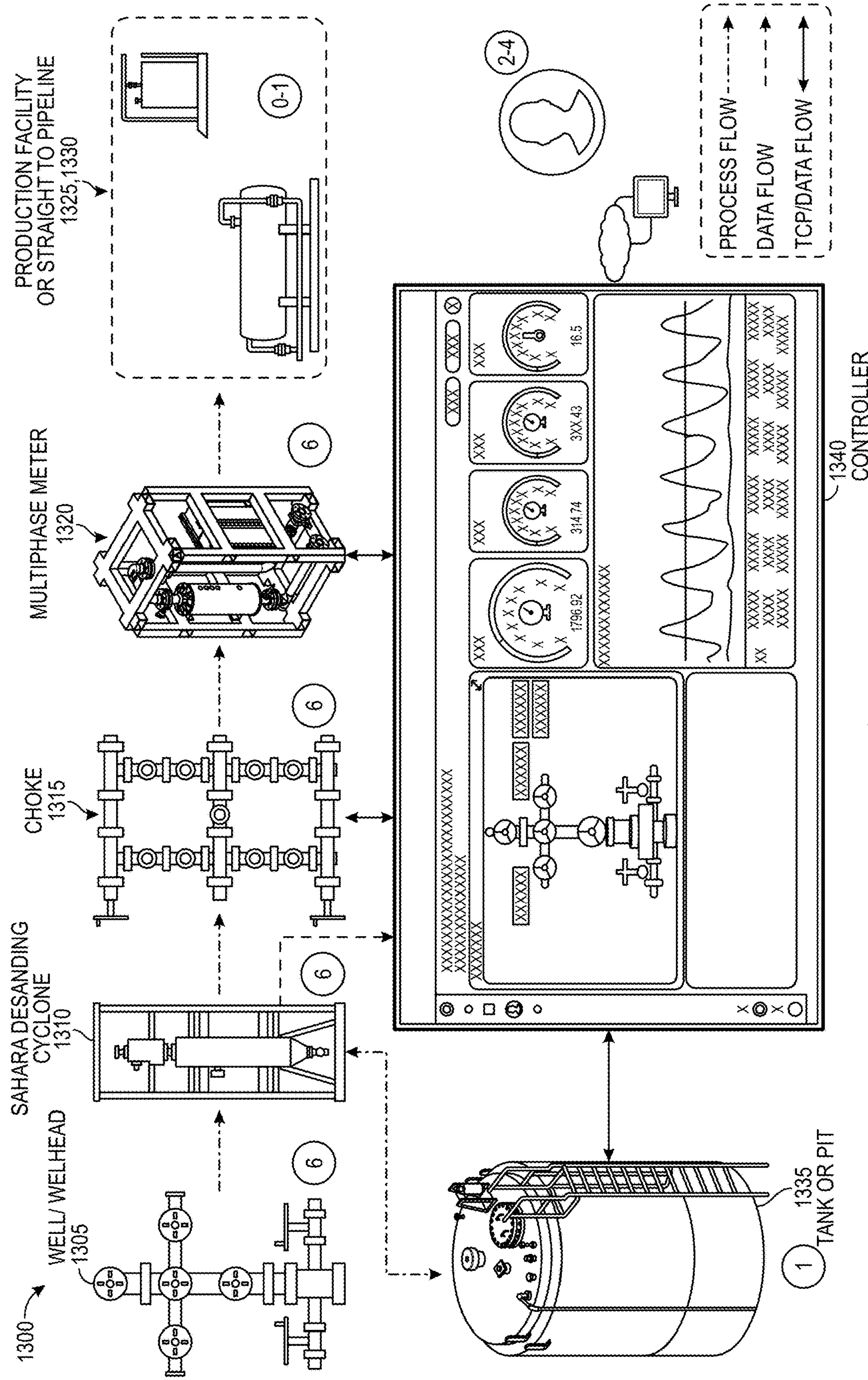

1300
WELL/ WELHEAD
1305
SAHARA DESANDING
CYCLONE
1310
CHOKE
1315
MULTIPHASE METER
1320
PRODUCTION FACILITY
OR STRAIGHT TO PIPELINE
1325,1330
6
6
6
6
0-1
2-4
1
1335
TANK OR PIT
1340
CONTROLLER
1796.92
314.74
3XX.43
16.5
PROCESS FLOW
DATA FLOW
TCP/DATA FLOW

FIG. 13

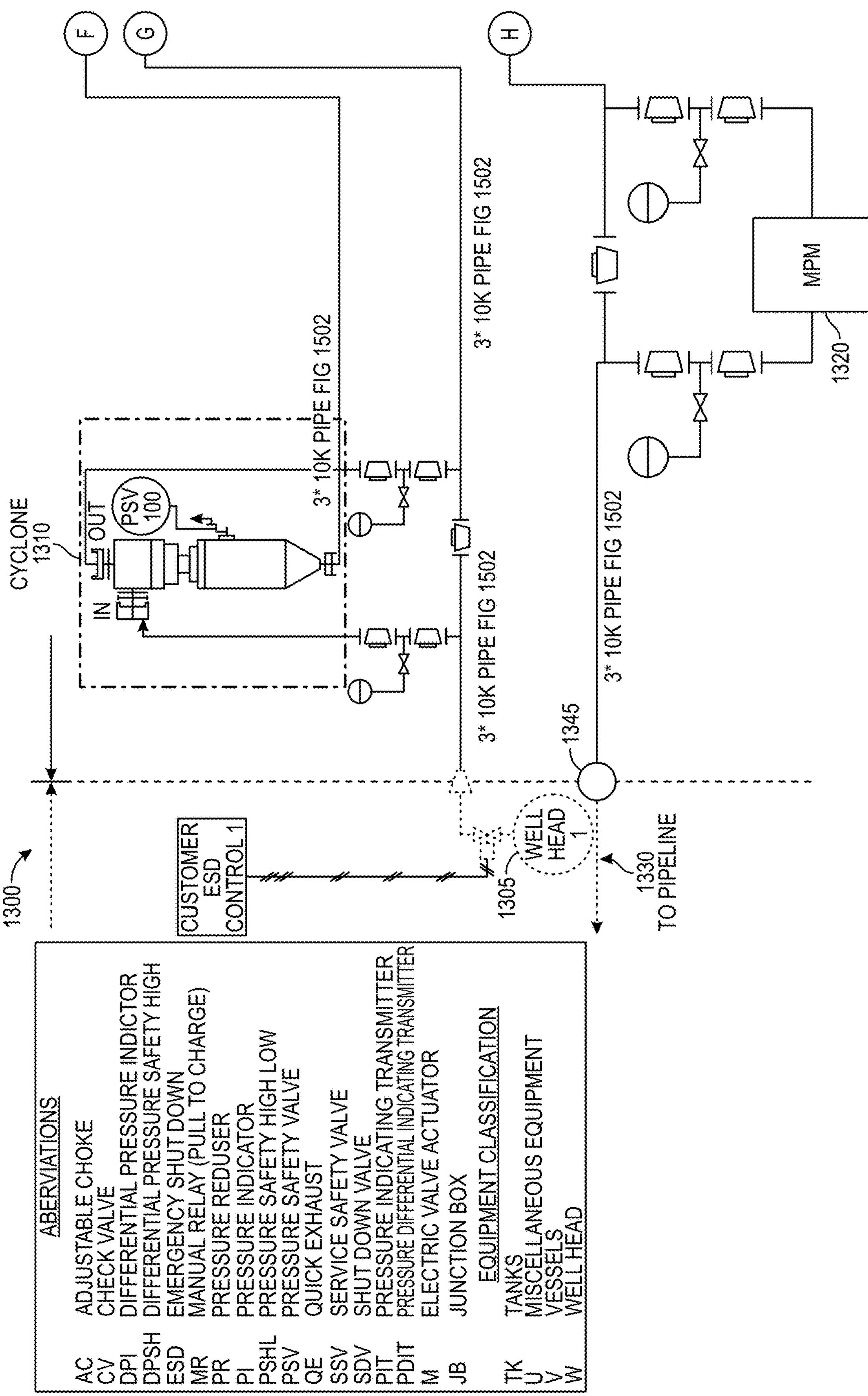

F
G
H
CYCLONE
1310
OUT
IN
PSV
100
3* 10K PIPE FIG 1502
3* 10K PIPE FIG 1502
3* 10K PIPE FIG 1502
3* 10K PIPE FIG 1502
3* 10K PIPE FIG 1502
MPM
1320
1345
1300
CUSTOMER
ESD
CONTROL 1
WELL
HEAD
1
1305
1330
TO PIPELINE
ABERVIATIONS
AC ADJUSTABLE CHOKE
CV CHECK VALVE
DPI DIFFERENTIAL PRESSURE INDICTOR
DPSH DIFFERENTIAL PRESSURE SAFETY HIGH
ESD EMERGENCY SHUT DOWN
MR MANUAL RELAY (PULL TO CHARGE)
PR PRESSURE REDUSER
PI PRESSURE INDICATOR
PSHL PRESSURE SAFETY HIGH LOW
PSV PRESSURE SAFETY VALVE
QE QUICK EXHAUST
SSV SERVICE SAFETY VALVE
SDV SHUT DOWN VALVE
PIT PRESSURE INDICATING TRANSMITTER
PDIT PRESSURE DIFFERENTIAL INDICATING TRANSMITTER
M ELECTRIC VALVE ACTUATOR
JB JUNCTION BOX
EQUIPMENT CLASSIFICATION
TK TANKS
U MISCELLANEOUS EQUIPMENT
V VESSELS
W WELL HEAD

FIG. 14A

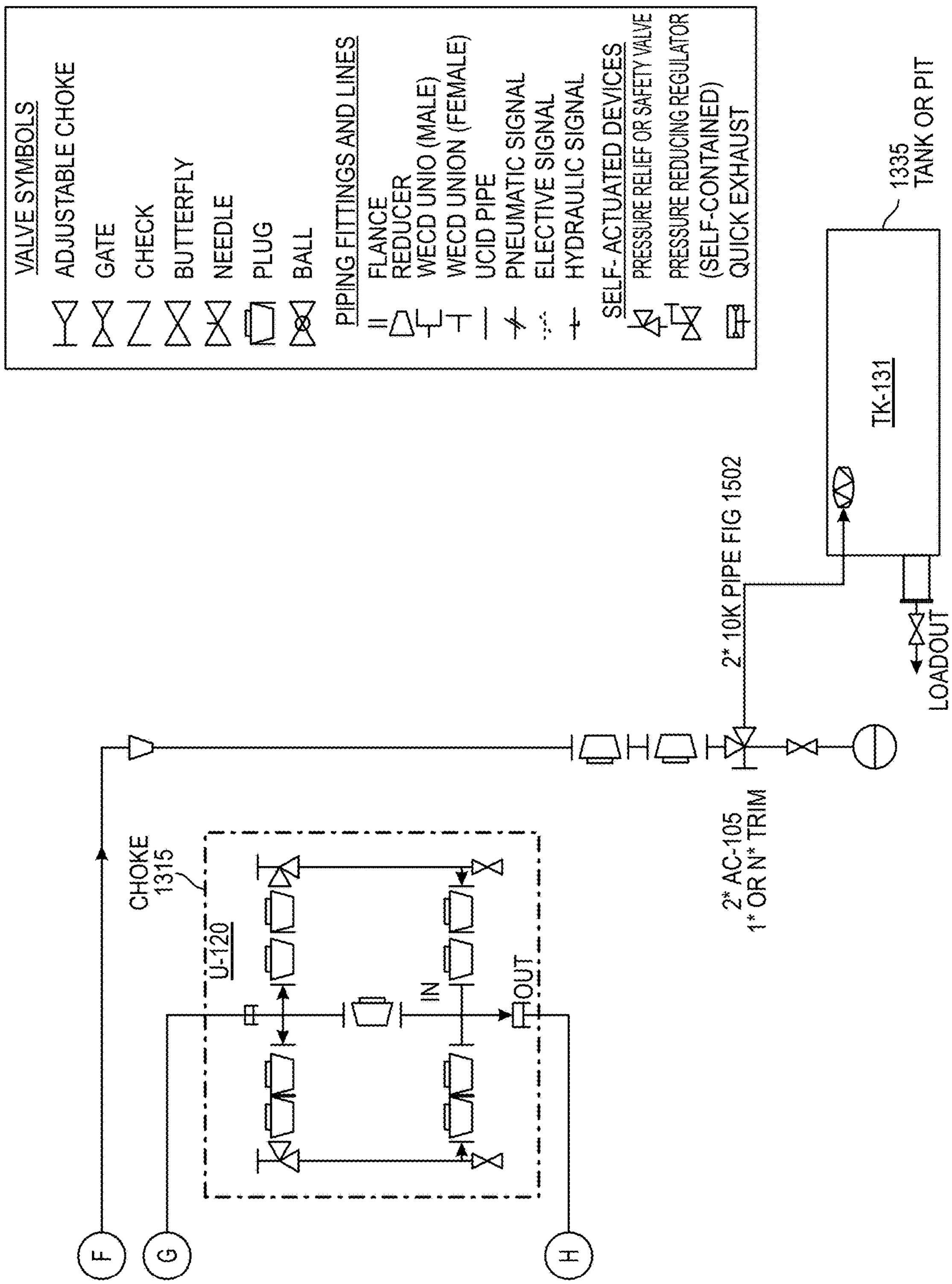

VALVE SYMBOLS
ADJUSTABLE CHOKE
GATE
CHECK
BUTTERFLY
NEEDLE
PLUG
BALL
PIPING FITTINGS AND LINES
FLANCE
REDUCER
WECD UNIO (MALE)
WECD UNION (FEMALE)
UCID PIPE
PNEUMATIC SIGNAL
ELECTIVE SIGNAL
HYDRAULIC SIGNAL
SELF- ACTUATED DEVICES
PRESSURE RELIEF OR SAFETY VALVE
PRESSURE REDUCING REGULATOR
(SELF-CONTAINED)
QUICK EXHAUST
1335
TANK OR PIT
TK-131
2* 10K PIPE FIG 1502
LOADOUT
2* AC-105
1* OR N* TRIM
CHOKE
1315
U-120
IN
OUT
F
G
H

FIG. 14B

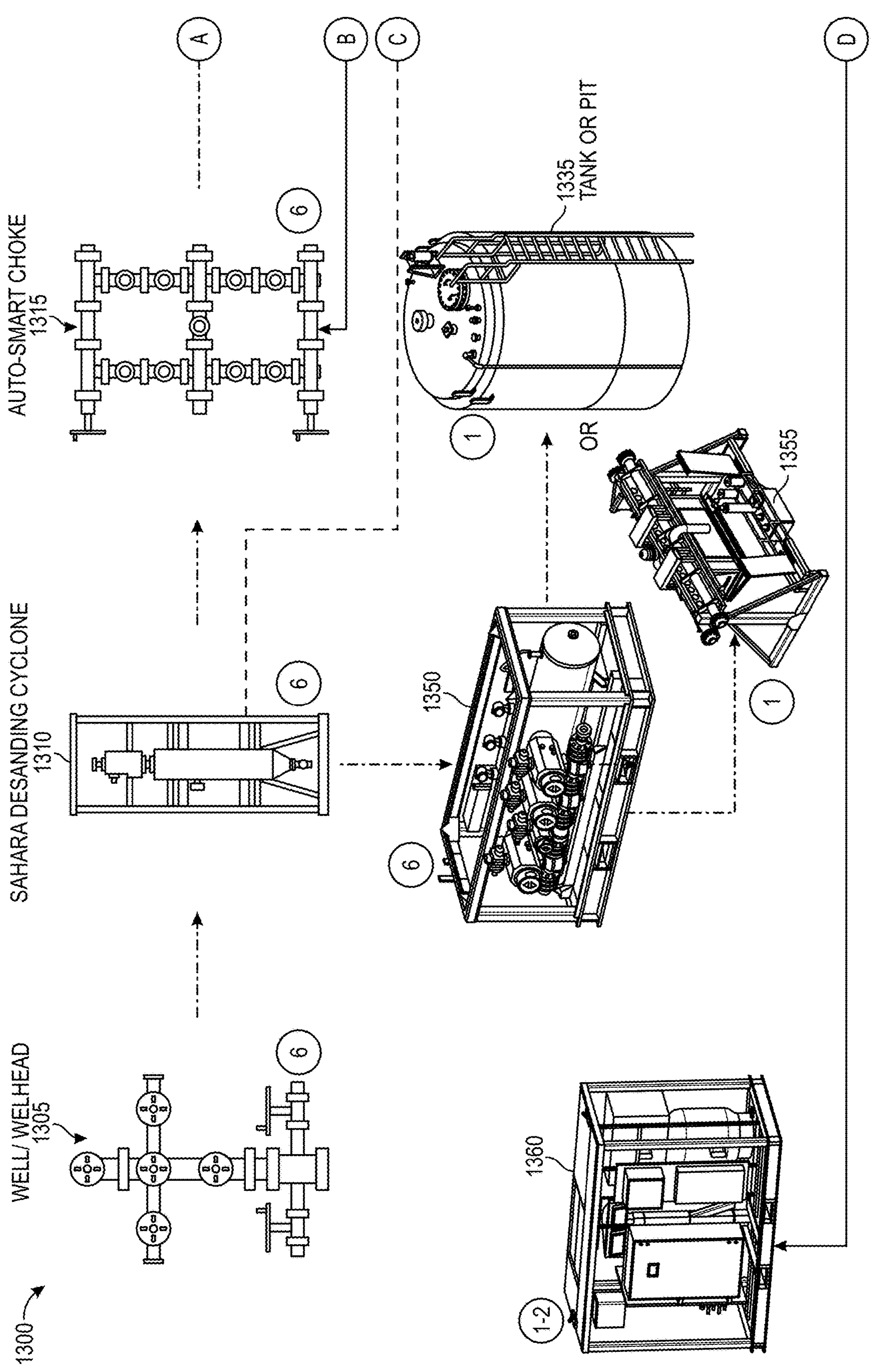

1300
WELL/WELHEAD
1305
6
SAHARA DESANDING CYCLONE
1310
6
AUTO-SMART CHOKE
1315
6
A
B
C
D
1335
TANK OR PIT
1
OR
1350
6
1355
1
1360
1-2

FIG. 15A

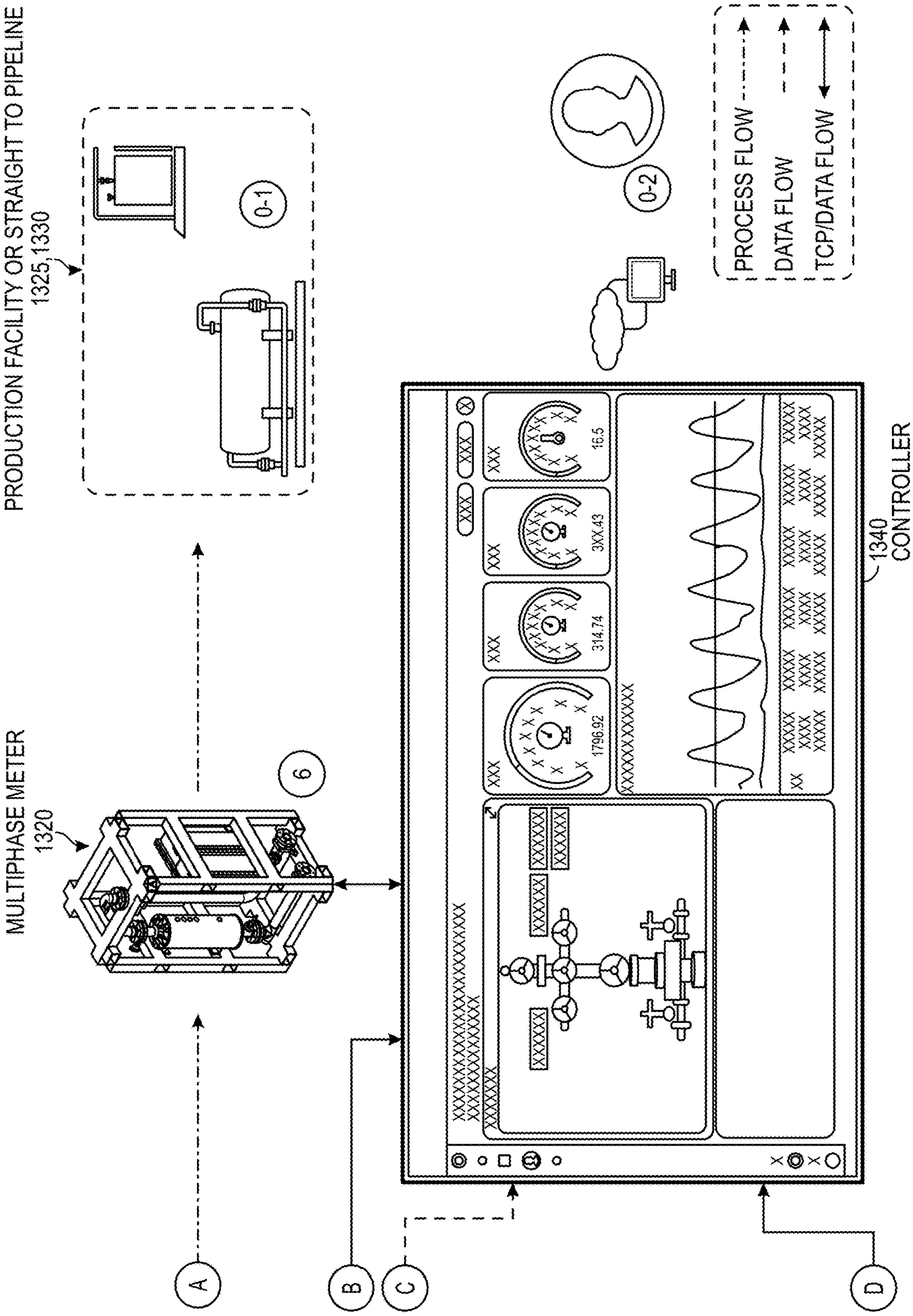
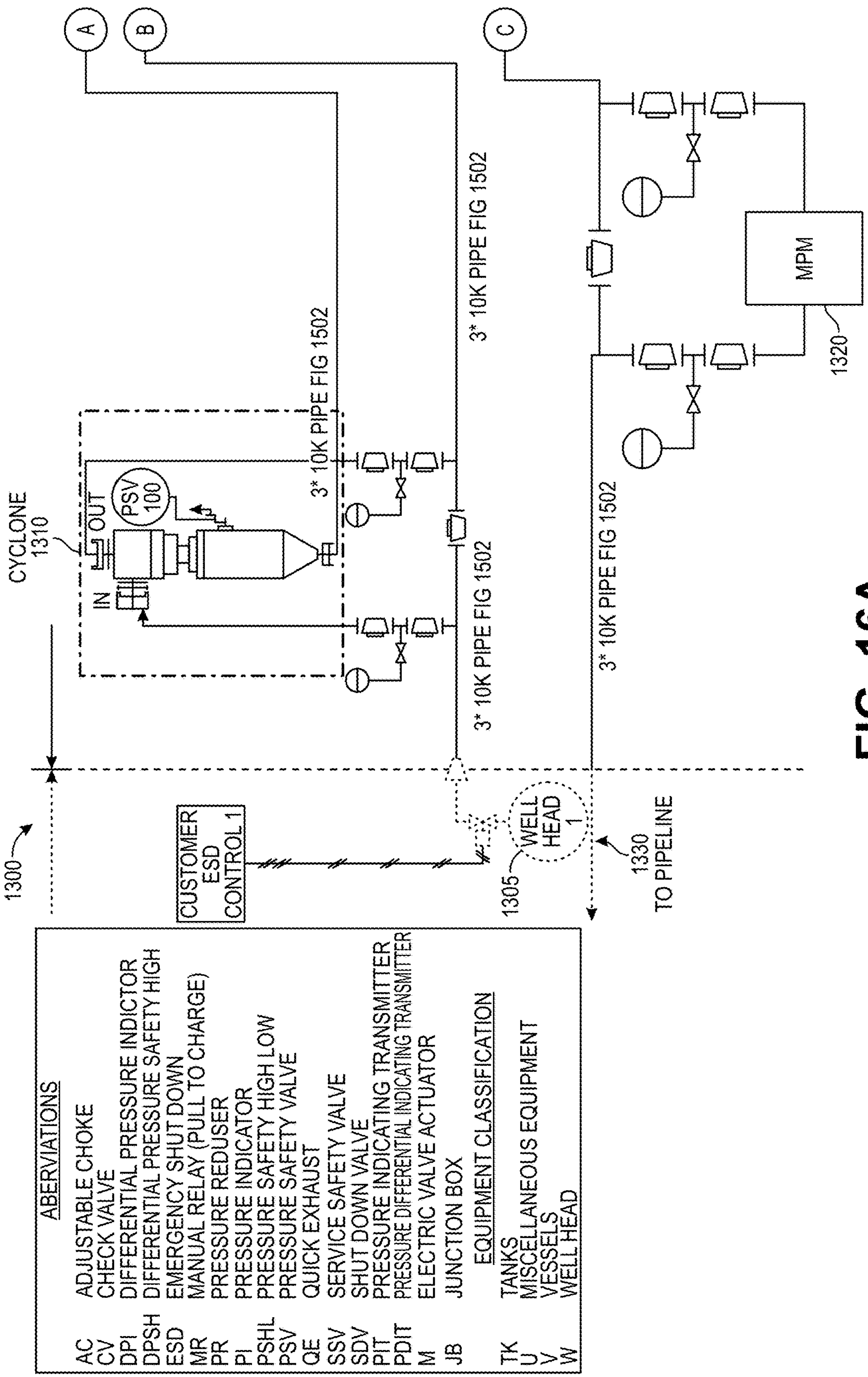

MULTIPHASE METER
1320
PRODUCTION FACILITY OR STRAIGHT TO PIPELINE
1325,1330
0-1
6
0-2
PROCESS FLOW
DATA FLOW
TCP/DATA FLOW
1796.92
314.74
3XX.43
16.5
1340
CONTROLLER
A
B
C
D

FIG. 15B



A
B
C
CYCLONE 1310
IN
OUT
PSV 100
3* 10K PIPE FIG 1502
3* 10K PIPE FIG 1502
3* 10K PIPE FIG 1502
3* 10K PIPE FIG 1502
3* 10K PIPE FIG 1502
MPM
1320
1300
CUSTOMER ESD CONTROL 1
WELL HEAD 1
1305
1330
TO PIPELINE
ABERVIATIONS
AC ADJUSTABLE CHOKE
CV CHECK VALVE
DPI DIFFERENTIAL PRESSURE INDICTOR
DPSH DIFFERENTIAL PRESSURE SAFETY HIGH
ESD EMERGENCY SHUT DOWN
MR MANUAL RELAY (PULL TO CHARGE)
PR PRESSURE REDUSER
PI PRESSURE INDICATOR
PSHL PRESSURE SAFETY HIGH LOW
PSV PRESSURE SAFETY VALVE
QE QUICK EXHAUST
SSV SERVICE SAFETY VALVE
SDV SHUT DOWN VALVE
PIT PRESSURE INDICATING TRANSMITTER
PDIT PRESSURE DIFFERENTIAL INDICATING TRANSMITTER
M ELECTRIC VALVE ACTUATOR
JB JUNCTION BOX
EQUIPMENT CLASSIFICATION
TK TANKS
U MISCELLANEOUS EQUIPMENT
V VESSELS
W WELL HEAD

FIG. 16A

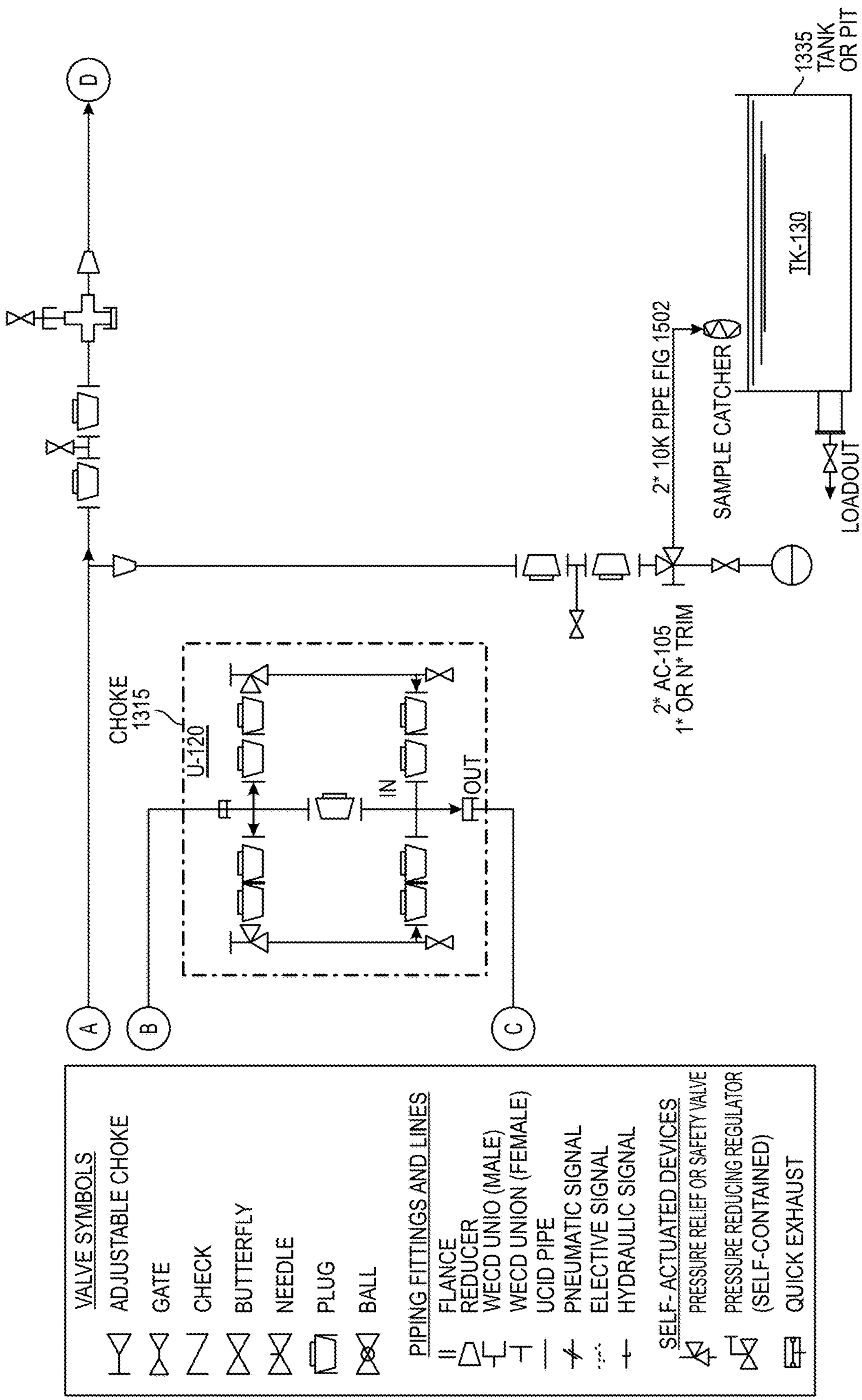

D
A
B
C
CHOKE
1315
U-120
IN
OUT
2* AC-105
1* OR N* TRIM
2* 10K PIPE FIG 1502
SAMPLE CATCHER
1335
TANK
OR PIT
TK-130
LOADOUT
VALVE SYMBOLS
ADJUSTABLE CHOKE
GATE
CHECK
BUTTERFLY
NEEDLE
PLUG
BALL
PIPING FITTINGS AND LINES
FLANCE
REDUCER
WECD UNIO (MALE)
WECD UNION (FEMALE)
UCID PIPE
PNEUMATIC SIGNAL
ELECTIVE SIGNAL
HYDRAULIC SIGNAL
SELF- ACTUATED DEVICES
PRESSURE RELIEF OR SAFETY VALVE
PRESSURE REDUCING REGULATOR
(SELF-CONTAINED)
QUICK EXHAUST

FIG. 16B

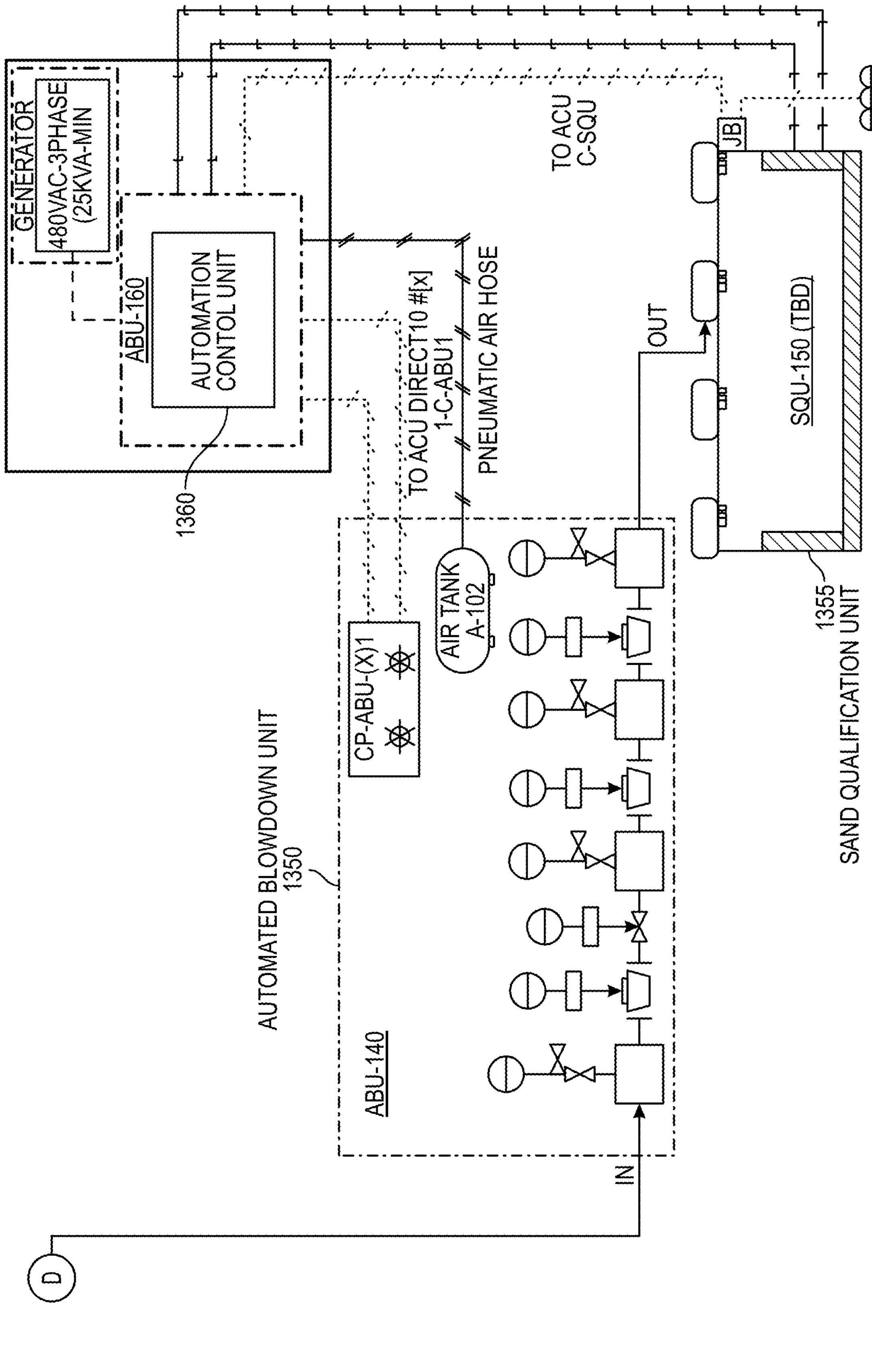

GENERATOR
480VAC-3PHASE
(25KVA-MIN
ABU-160
AUTOMATION
CONTOL UNIT
1360
TO ACU
C-SQU
JB
TO ACU DIRECT10 #[x]
1-C-ABU1
PNEUMATIC AIR HOSE
OUT
SQU-150 (TBD)
1355
SAND QUALIFICATION UNIT
AIR TANK
A-102
CP-ABU-(X)1
AUTOMATED BLOWDOWN UNIT
1350
ABU-140
IN
D

FIG. 16C

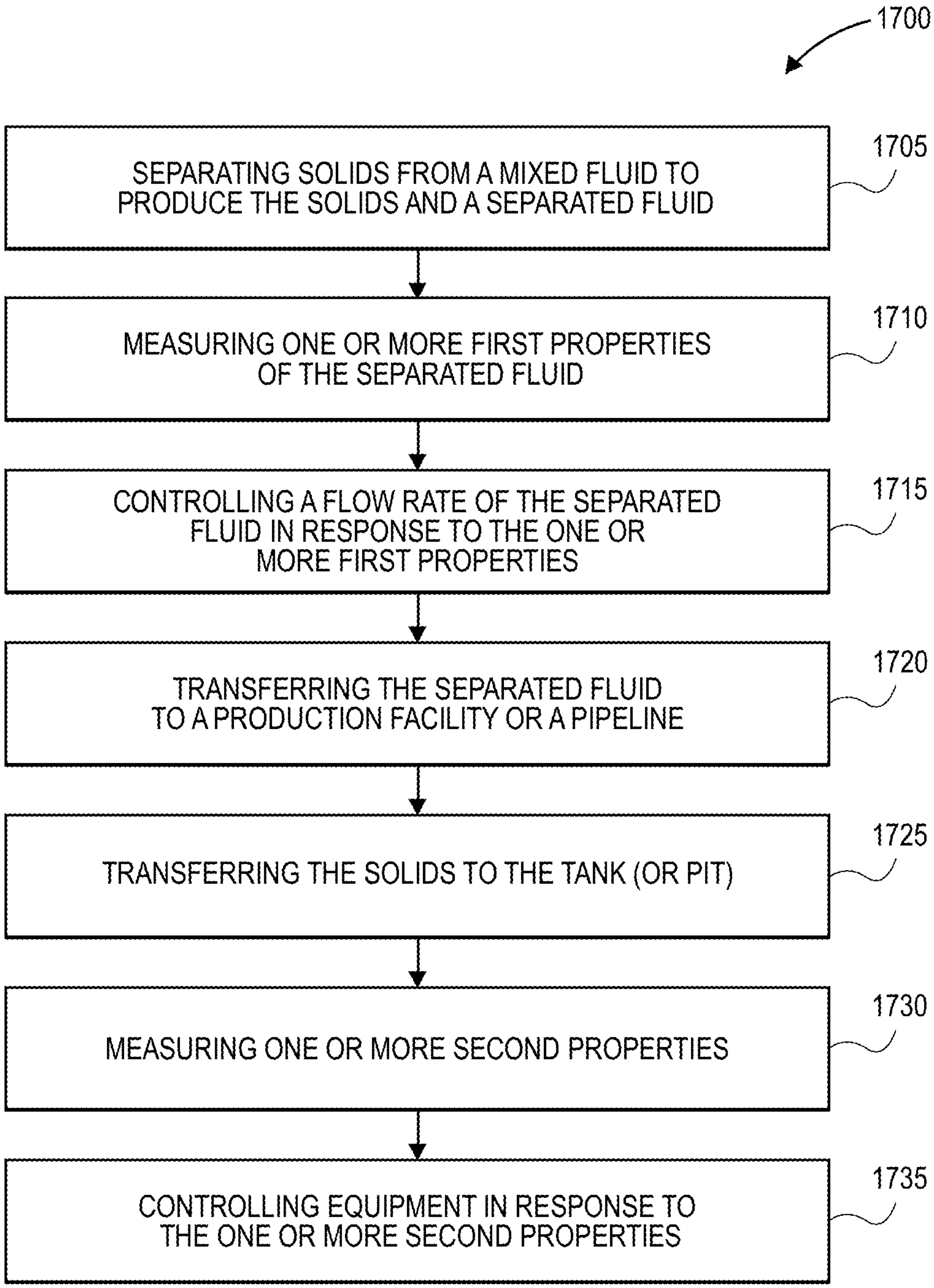

1700
SEPARATING SOLIDS FROM A MIXED FLUID TO PRODUCE THE SOLIDS AND A SEPARATED FLUID
1705
MEASURING ONE OR MORE FIRST PROPERTIES OF THE SEPARATED FLUID
1710
CONTROLLING A FLOW RATE OF THE SEPARATED FLUID IN RESPONSE TO THE ONE OR MORE FIRST PROPERTIES
1715
TRANSFERRING THE SEPARATED FLUID TO A PRODUCTION FACILITY OR A PIPELINE
1720
TRANSFERRING THE SOLIDS TO THE TANK (OR PIT)
1725
MEASURING ONE OR MORE SECOND PROPERTIES
1730
CONTROLLING EQUIPMENT IN RESPONSE TO THE ONE OR MORE SECOND PROPERTIES
1735

FIG. 17

SAND SEPERATION CONTROL SYSTEM AND METHOD

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional Patent Application No. 63/640,837, filed on Apr. 30, 2024, which is incorporated by reference. This application is also a continuation-in-part of U.S. patent application Ser. No. 18/338,944, filed on Jun. 21, 2023, which is a continuation-in-part of U.S. patent application Ser. No. 17/513,333, which was filed on Oct. 28, 2021 and is a continuation of U.S. patent application Ser. No. 17/096,490, which was filed on Nov. 12, 2020, and claims priority to U.S. Provisional Patent Application Ser. No. 62/957,585, which was filed on Jan. 6, 2020. Each of these applications is incorporated herein by reference in its entirety.

BACKGROUND

[0002] Hydraulic fracturing is a well-treatment process in which preferential flowpaths for hydrocarbons are established in a subterranean rock formation. The flowpaths are established by pumping a fluid at high pressure into a well to initiate fractures in the rock formation. The fracturing fluid may be predominately water, but may also include solids, such as sand or ceramic proppants, which at least partially fill the fractures and keep the fractures open, maintaining the preferential flowpaths through the rock after the process is complete.

[0003] When oil, water, or other fluids are produced/recovered from the well, it may be desirable to remove sand or other solids from the fluid. A separator system may be used for this purpose, and may include one or more separation devices (e.g., cyclonic separators), filters, screens, tanks, etc. The separated solids may be stored in the tank, which is periodically emptied or "blown down," while the fluids may be further separated (e.g., to separate hydrocarbons from water). Recovered hydrocarbons may be stored or otherwise transported for sale, and recovered water may be stored or otherwise recirculated for use in the well.

[0004] In some cases, it may be desirable to determine the amount of solids separated from the fluid in the separator, and/or the rate at which solids accumulate in the tank. In order to do this, the solids from the separator may be run through a "sock" during blowdown operations, which may catch the solids while allowing the fluid to flow through. The sock is then weighed, which reveals the amount of solids collected therein between blowdown operations. However, such a manual process exposes operations to worker-related delays and calls for the sock to be removed and weighed after each blowdown, which can be time and labor intensive. Moreover, the manual processes are not well-suited to managing blowdown operations in multi-separator and/or multi-well systems.

SUMMARY

[0005] A sand separation system is disclosed. The system includes one or more separators configured to receive a mixed fluid from one or more wells or wellheads and to separate solids from the mixed fluid to produce the solids and a separated fluid. The system also includes one or more chokes downstream from and in fluid communication with the one or more separators. Each of the one or more chokes is configured to receive the separated fluid from a corresponding one of the one or more separators and to control a flow rate of the separated fluid therethrough. The system also includes one or more multiphase meters downstream from and in fluid communication with the one or more chokes. Each of the multiphase meters is configured to measure one or more first properties of the separated fluid and to adjust the one or more chokes in response to the one or more first properties. The separated fluid is transferred from the one or more chokes or the one or more multiphase meters to a production facility or a pipeline.

[0006] A method for operating a sand separation system is also disclosed. The method includes separating solids from a mixed fluid using a separator to produce the solids and a separated fluid. The mixed fluid is received by the separator from a well or a wellhead. The method also includes measuring one or more first properties of the separated fluid using a multiphase meter. The method also includes controlling a flow rate of the separated fluid using a choke in response to the one or more first properties. The method also includes transferring the separated fluid to a production facility or a pipeline after the flow rate is controlled.

[0007] A sand separation system is disclosed. The system includes one or more separators configured to separate solids from a mixed fluid and to produce the solids and a separated fluid. The system also includes one or more chokes configured to receive the separated fluid from a corresponding one of the one or more separators and to control a flow rate of the separated fluid therethrough. The system further includes one or more multiphase meters configured to measure one or more first properties of the separated fluid and to adjust the one or more chokes in response to the one or more first properties. Additionally, the system includes a controller configured to measure more or more second properties of one or more separators, the one or more chokes, the one or more multiphase meters, the separated fluid, or combination thereof. The controller is configured to adjust the one or more separators and/or the one or more chokes in response to the one or more second properties.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] The present disclosure may best be understood by referring to the following description and the accompanying drawings that are used to illustrate embodiments of the invention. In the drawings:

[0009] FIG. **1** illustrates a schematic view of a sand separation system, according to an embodiment.

[0010] FIG. **2** illustrates a schematic view of a well and a separator of the sand separation system, according to an embodiment.

[0011] FIG. **3**A illustrates a schematic view of a blowdown unit of the sand separation system, according to an embodiment.

[0012] FIG. **3**B illustrates a schematic view of another embodiment of the blowdown unit.

[0013] FIG. **4** illustrates a schematic view of a sand disposal unit of the sand separation system, according to an embodiment.

[0014] FIG. **5** illustrates a schematic view of a central controller of the sand separation system, according to an embodiment.

[0015] FIG. **6** illustrates a flowchart of a method for blowdown and leak detection/mitigation to assist in automatically controlling a sand separation system, according to an embodiment.

[0016] FIG. **7** illustrates a flowchart of a method for automatically controlling a sand separation system, according to an embodiment.

[0017] FIG. **8** illustrates a schematic view of a sand separation system, according to an embodiment.

[0018] FIG. **9** illustrates a schematic view of a sand separation system, according to an embodiment.

[0019] FIG. **10** illustrates a side, cross-sectional view of a separator of any one of the foregoing systems, according to an embodiment.

[0020] FIG. **11**A, FIG. **11**B, FIG. **11**C, and FIG. **11**D illustrate side, schematic views of an accumulator for a separator, which may be provided with an external sand-level detector, according to an embodiment.

[0021] FIG. **12**A and FIG. **12**B illustrate a flowchart of a method for operating a sand separation system, according to an embodiment.

[0022] FIG. **13** illustrates a schematic view of another sand separation system, according to an embodiment.

[0023] FIG. **14**A and FIG. **14**B illustrate another schematic view of the sand separation system in FIG. **13**, according to an embodiment.

[0024] FIG. **15**A and FIG. **15**B illustrate a schematic view of the sand separation system in FIG. **13** with additional equipment, according to an embodiment.

[0025] FIG. **16**A, FIG. **16**B and FIG. **16**C illustrate another schematic view of the sand separation system in FIG. **15**, according to an embodiment.

[0026] FIG. **17** illustrates a flowchart of a method for operating a sand separation system, according to an embodiment.

DETAILED DESCRIPTION

[0027] The following disclosure describes several embodiments for implementing different features, structures, or functions of the invention. Embodiments of components, arrangements, and configurations are described below to simplify the present disclosure; however, these embodiments are provided merely as examples and are not intended to limit the scope of the invention. Additionally, the present disclosure may repeat reference characters (e.g., numerals) and/or letters in the various embodiments and across the Figures provided herein. This repetition is for the purpose of simplicity and clarity and does not in itself dictate a relationship between the various embodiments and/or configurations discussed in the Figures. Moreover, the formation of a first feature over or on a second feature in the description that follows may include embodiments in which the first and second features are formed in direct contact, and may also include embodiments in which additional features may be formed interposing the first and second features, such that the first and second features may not be in direct contact. Finally, the embodiments presented below may be combined in any combination of ways, e.g., any element from one exemplary embodiment may be used in any other exemplary embodiment, without departing from the scope of the disclosure.

[0028] Additionally, certain terms are used throughout the following description and claims to refer to particular components. As one skilled in the art will appreciate, various entities may refer to the same component by different names, and as such, the naming convention for the elements described herein is not intended to limit the scope of the invention, unless otherwise specifically defined herein. Further, the naming convention used herein is not intended to distinguish between components that differ in name but not function. Additionally, in the following discussion and in the claims, the terms "including" and "comprising" are used in an open-ended fashion, and thus should be interpreted to mean "including, but not limited to." All numerical values in this disclosure may be exact or approximate values unless otherwise specifically stated. Accordingly, various embodiments of the disclosure may deviate from the numbers, values, and ranges disclosed herein without departing from the intended scope. In addition, unless otherwise provided herein, "or" statements are intended to be non-exclusive; for example, the statement "A or B" should be considered to mean "A, B, or both A and B."

Flowback 1.0

[0029] FIG. **1** illustrates a schematic view of a sand separation system **100**, according to an embodiment. The system **100** is described herein in terms of separating sand, but it will be appreciated that in some contexts, "sand" may refer to particulate matter of various types, including, for example, ceramic proppant and the like, which may be injected and recovered from a well. The system **100** may include one or more separators (three shown: **102**, **104**, **106**), which may each be coupled to and configured to receive a mixture of sand and fluids from a well **108**, **110**, **112**, respectively. In the illustrated embodiment, one separator **102-106** is provided for each individual well **108-112**, but it will be appreciated that in other embodiments, a single separator **102-106** may receive fluid from two or more wells **108-112** and/or two or more separators **102-106** may receive fluid from a single well **108-112**.

[0030] The separators **102-106** may be configured to separate at least a portion of the sand from the fluids produced from the wells **108-112**. The separated fluid may be routed through an outlet **114**, **116**, **118** of each separator **102-106** and delivered, e.g., to a production separator or another device or location. The sand, along with some of the fluid, that is separated from the mixture, may be temporarily stored in the separator **102-106**. For example, the separators **102-106** may each provide a hopper, or another type of pressurized tank, which may, during normal operation, fill with the sand as it is separated. Before the sand entirely fills the separator **102-106**, it may be removed therefrom, i.e., a "blowdown" process is executed.

[0031] Accordingly, the system **100** may include one or more blowdown units (three are shown: **120**, **122**, **124**). For example, one blowdown unit **120-124** may be provided for each separator **114-116**; however, it will be appreciated that this one-to-one configuration is merely an example, and two or more blowdown units **120-124** could be used for a single separator **102-106** and/or a single one of the blowdown units **120-124** could be provided for two or more of the separators **102-106**. As will be described in greater detail below, the blowdown units **120-124** may include, among other things, one or more valves that are actuatable to control blowdown of the separators **102-106** associated therewith. Further, as indicated by the dashed lines between the blowdown units **120-124** and the separators **102-106**, the blowdown units **120-124** may be configured to communicate with the separators **102-104**. For example, the separators **102-106** may be provided with various chokes and/or pressure transducers, which may provide electrical data and/or control signals to the blowdown unit **120-124**.

[0032] When the blowdown units **120-124** initiate a blowdown procedure, one or more valves therein, which are in fluidic communication with the separators **102-106**, are opened, allowing the sand (e.g., as a slurry of sand and fluid) to flow out of the separators **102-106**, through the blowdown units **120-124**, and into a sand disposal unit **126**. In some embodiments, the sand disposal unit **126** may include a sand quantification feature, which may be configured to provide data representing an amount of sand that was stored in the separator **102-106** between blowdowns. For example, the sand disposal unit **126** may provide the sand quantification feature using load cells, e.g., as disclosed in U.S. Provisional Patent Application No. 62/930,175, which is incorporated herein by reference in its entirety. In other embodiments, such a sand quantification feature may be provided within the separator **102-106** itself. For example, the separators **102-106** may include load cells, such as the separators described in U.S. Provisional Patent Publication No. 2019/0388907, which is incorporated herein by reference in its entirety, to the extent not inconsistent with the disclosure herein. In another embodiment, the separators **102-106** may include other types of sensors that are able to detect an amount of sand that is in the separators **102-106**, e.g., as described in U.S. patent application Ser. No. 16/711,561 and/or U.S. Provisional Patent Application No. 62/946,520, which are both incorporated by reference herein in their entirety, to the extent not inconsistent with the present disclosure.

[0033] The system **100** may also include a central controller (or "control system" or "control unit") **130**, which may communicate at least with the blowdown units **120-124**. The central controller **130** may also communicate with the sand disposal unit **126**, e.g., in cases where the sand disposal unit **126** includes the sand quantification feature. The central controller **130** may be in communication with the blowdown units **120-124** via electric communication and/or the separators **102-106**. For example, the central controller **130** may send signals to the blowdown units **120-124** commanding the blowdown units **120-124** to open individual valves thereof, e.g., to initiate or terminate a blowdown procedure, mitigate valve malfunctioning, shut-off blowdown capabilities, etc. Further, the central controller **130** may be configured to receive feedback signals from the blowdown units **120-124**, e.g., pressure and/or flow measurements at specific locations therein and/or in the separators **102-106**. Additionally, the central controller **130** may include hardware enabling communication with local and/or remote operators, e.g., through a human-machine interface. For example, the central controller **130** may include output devices such as a computer terminal, an antenna for wireless communication, a web portal connection, etc. Additional details relevant to operation of the central controller **130**, according to various embodiments, are discussed below.

[0034] FIG. **2** illustrates a schematic view of the well **108** and the separator **102** of the system **100**, according to an embodiment. The separator **102** may also be representative of at least some embodiments of the separators **104** and **106**. As shown, the separator **102** includes a cyclonic separator **204** in combination with a tank **202**. In some embodiments, the cyclonic separator **204** may be positioned on top of the tank **202**, such that the tank **202** supports the weight of the cyclonic separator **200**. The tank **202** may receive and temporarily store solids (e.g., sand) separated from the sand/fluid mixture received at an inlet **214** of the separator **200**. The tank **202** may also include a blowdown outlet **206**. The blowdown outlet **206** may connect to the blowdown unit **120**, as noted above, such that the blowdown unit **120** may be considered "downstream" of the blowdown outlet **206**, in the sense that fluid flows toward the blowdown unit **120**.

[0035] The separator **102** may also include one or more pressure transducers (two shown: **208**, **210**). These transducers (or others) **208**, **210** may be in (e.g., electric) communication with a junction **212**. The junction **212**, in turn, may be in communication with the central controller **130**, e.g., via the blowdown unit **120**. That is, in at least one embodiment, the junction **212** may serve as an input for the blowdown unit **120**, which may send signals as an input to the central controller **130**. In other embodiments, the junction **212** may communicate directly with the controller **130** and/or may communicate only with the blowdown unit **120**. The pressure transducer **210** may be positioned at an inlet **214** to the separator **102** and may measure pressure in the mixture of fluid and solids received from the well **108**. The pressure transducer **208** may be positioned in the outlet **114** and configured to measure the pressure of the separated fluid received therein. Various other pressure transducers may be employed, e.g., to measure pressure-drop between the inlet **214** and the outlet **206** and/or outlet **114** and/or across chokes or other flow control mechanisms.

[0036] In at least one embodiment, the separator **102** may include a load cell **220** configured to produce a signal representative of the weight of the sand separated from the incoming fluid by the cyclonic separator **204**. As mentioned above, in at least one embodiment, the load cell **220** may be contained at least partially within the tank **202**. For example, a sand hopper may be suspended within the tank **202** via a linkage that includes the load cell **220**, such that the load cell **220** is configured to measure a weight of the sand without measuring a weight of the tank **202** or the cyclonic separator **204** (or at least a portion of either/both), thereby potentially increasing an accuracy of the weight measurement. At some point, the increasing weight may indicate that the tank **202** is near capacity or otherwise ready to be blown down. In other embodiments, this load cell **220** may be omitted in view of the measurements taken at the sand disposal unit **126**, as described herein.

[0037] FIG. **3**A illustrates a schematic view of the blowdown unit **120**, according to an embodiment. The blowdown unit **120** embodiment that is illustrated may also be representative of at least one embodiment of the other blowdown units **122**, **124**. The blowdown unit **120** may include a blowdown valve assembly **300**, which may be coupled to the blowdown outlet **206** of the separator **102** via an inlet **301**. The blowdown valve assembly **300** may be configured to initiate, control, and terminate the blowdown procedure for the separator **102**.

[0038] In an embodiment, the blowdown valve assembly **300** may include a shutdown valve **302**, a first valve **304**, and a second valve **306**. The first and second valves **304**, **306** may be plug valves, or any other suitable type of valve. The valves **302-306** may be in series, such that fluid flows through the valves **302-306** sequentially, one after the other, e.g., through a blowdown line **307** that extends from the inlet **301** and connects the valves **302-306** together. For example, the shutdown valve **302** may be the first in the series, with the first valve **304** being downstream therefrom, and the second valve **306** being downstream from the first valve **304**. Downstream of the second valve **306**, the blowdown line **307** may be connected to an outlet **309**, which may be connected to the sand disposal unit **126**.

[0039] In addition, in some embodiments, the blowdown valve assembly **300** may include a bypass valve **308**. The bypass valve **308** may be in parallel with the valves **302-306**. For example, a bypass line **310** may connect to the blowdown line **307** upstream of the shutdown valve **302**, and then again to the blowdown line **307** downstream of the second valve **306**.

[0040] The valves **302**, **304**, **306** may be actuated between open positions (permitting fluid flow therethrough) and closed positions (blocking fluid flow therethrough) via respective control valves **312**, **314**, **316**. The control valves **312**, **314**, **316** are in turn coupled to a control power source, which in this embodiment, is an accumulator **320** that contains a pressurized gas (e.g., air) received via a pressure line **317**. The accumulator **320** may also be coupled with a pressure line **319**, which may lead to the accumulator of another one of the blowdown units (e.g., unit **122**, as shown). In other embodiments, the control power source could be a battery or another source of electric power, a hydraulic power source, or any other suitable source of power.

[0041] The control valves **312**, **314**, **316** are shown in an open configuration, directing pressure from the accumulator **320** to the individual valves **302**, **304**, **306**. In some embodiments, the first and second valves **304**, **306** may be biased to their closed positions. Upon application of the pressure from the accumulator **320** via the control valves **314**, **316**, the first and second valves **304**, **306** may be individually actuated (e.g., lifted) to the open position, thereby permitting flow therethrough in the blowdown line **307**. Similarly, the shutdown valve **302** may have its closed position as a default and may be opened by application of pressure from the accumulator **320** via the control valve **312**. Actuating the control valves **312**, **314**, **316** to their closed positions may thus relieve pressure from the accumulator **320** to the valves **302-306**, which may cause them to close, or at least attempt to close, to block fluid flow through the blowdown line **307**. In some embodiments, the bypass valve **308** may be manually operated or operated using a separate control system. The bypass line **310** may thus normally be closed, and may be employed, e.g., in emergency situations.

[0042] The blowdown unit **120** may include one or more pressure transducers. For example, pressure transducers **322**, **324**, **326** may be positioned to measure pressure in the blowdown line **307**. For example, the pressure transducer **322** may be configured to measure pressure from the blowdown outlet **206**. In some embodiments, this pressure may be higher when the blowdown line **307** is closed (e.g., one or more of the valves **302-304** are closed) as opposed to when at least partially open. Further, the transducer **324** may measure a pressure in the line **307** between the first and second valves **304**, **306**. When the first valve **304** is closed, the pressure in the line **307** between the first and second valves **304**, **306** may be expected to drop, e.g., to ambient or at least to a pressure that is lower than the pressure at the inlet **301**. Similarly, the pressure transducer **326** may be positioned downstream of the second valve **306** and may be expected to read ambient or some other relatively low pressure when the first and/or second valves **302**, **304** are closed. When the valves **302-306** are open, pressure measured by the transducers **322-326** may be generally equal. In some embodiments, at least the pressure transducer **326** may be replaced or supplemented with a flow meter, so as to detect fluid flow past the second valve **306** and in the outlet **309**.

[0043] Another pressure transducer **328** may be coupled to the accumulator **320** or elsewhere in the control side of the blowdown unit **120**. The pressure transducer **328** may thus be configured to measure the pressure that is available to actuate the valves **302-306**.

[0044] The blowdown unit **120** may further include a junction box **330**. The junction box **330** may be coupled to the pressure transducers **322-328** and configured to receive electrical signals representing the pressures measured by each. Further, the junction box **330** may be coupled to the control valves **312-316** and may be configured to send a control signal thereto, which may cause the control valves **312-316** to actuate between the open and closed positions. Further, the junction box **330** may include or be coupled to a display panel **332**. The display panel **332** may include one or more lights **334**, **336**, alarms, digital display panels, etc., configured to indicate a status (blowdown procedure underway, blowdown procedure ready, warning, etc.).

[0045] FIG. 3B illustrates another embodiment of the blowdown unit **300**. In this embodiment, a choke valve **350** may be included to control fluid flow in the line **107**. For example, the choke valve **350** may be a cyclonic valve or another type of valve that integrates a choke therein. Such a cyclonic valve may, for example, provide two plates, each with slots or other openings formed therein that may be rotated into or out of alignment. The choke valve **350** may include a variable cross-sectional flowpath area, which may be, at its largest, smaller than the cross-sectional flowpath area of the line **107**. As such, even when open, the valve **350** may create a pressure drop in the line **107**, which may mitigate or otherwise slow erosion of the valves **302**, **304**, **306** downstream.

[0046] Further, the position of the valve **350** (e.g., open, closed, partially open, or partially closed) may be modulated through the use of a pneumatic control valve **352**, which may have two or more positions. In some embodiments, the valve **350** may be the first valve (among valves **350**, **304**, and **306**) to open, and the last of valves **350**, **302**, **304** to close during normal blowdown operations. As such, the choke valve **350** may experience the highest pressures among the valves **302-306** and **350** of the blowdown valve assembly **300**. The choke valve **350** may, in some embodiments, be considered consumable and regularly replaced, and may prevent or at least forestall the other valves **302-306** from similarly being consumed. Alternatively, the valve **350** may be replaced by a fixed-orifice choke, which may likewise induce a pressure drop in the line **107** upstream of the valves **302-306**. Further, such an orifice could be placed between or downstream of any/all of the valves **302-306**, and embodiments that include multiple orifices are also contemplated herein.

[0047] FIG. **4** illustrates a schematic view of the sand disposal unit **126**, according to an embodiment. The sand disposal unit **126** may include a disposal container **400**, e.g., a tank that may be open to the air and thus at ambient pressure. A basket **402** may be positioned over the container **400** and may be configured to receive sand (and some fluid, e.g., a slurry) from the separators **102-106** via the blowdown units **120-124**, as indicated. The basket **402** may include a screen or another type of filter media, such that, when a slurry of sand and fluid is received therein, the fluid drains out of the sand and into the container **400**. One or more load cells **404** may be provided to measure a weight of the basket **402**, from which the weight of the sand contained therein may be calculated. Further, a level sensor **405** (e.g., a float, viscosity sensor, etc.) may be positioned in the container **400** and configured to measure a level (or at least indicate when the level reaches a certain elevation) of the contents in the container **400**.

[0048] The basket **402** may include a bottom **406** that is openable via a hydraulic assembly **408** (or any other type of actuator assembly). The hydraulic assembly **408** is shown separate from the basket **402** in this schematic view, but it will be appreciated that the hydraulic assembly **408** may be configured to raise and lower the bottom **406**, e.g., pivotally, with respect to a remainder of the basket **402**. Thus, the hydraulic assembly **408** may be configured to dump the contents of the basket **402** into the container **400**.

[0049] In an embodiment, the sand disposal unit **126** may include an accumulator **410**, which may be coupled to a source of pressurized gas, e.g., air from a compressor. A pressure transducer **412** may be coupled to the accumulator **410**, so as to measure a pressure of the gas contained therein, e.g., to ensure that sufficient pressure is available in the accumulator **410**.

[0050] An air-over-hydraulic (AOH) system **416** may be provided as part of the sand disposal unit **126**. The AOH system **416** may receive pneumatic pressure from the accumulator **410** and may selectively employ the pneumatic pressure to actuate the hydraulic assembly **408** and thereby open and close the bottom **406**. Electrical or mechanical hydraulic options are also available for the system **416**, and thus an AOH embodiment should be considered merely as an example.

[0051] The sand disposal unit **126** may include a junction box **418**, which may be in electrical communication with the load cell(s) **404**, the level sensor **405**, the pressure transducer **412**, the AOH system **416**, and the central controller **130**. The junction box **418** may be operable to receive measurements from the load cell **404**, level sensor **405**, and the pressure transducer **412**, and may transmit these measurements to the central controller **130**.

[0052] In an embodiment, the level sensor **405** may communicate with the central controller **130** (or any other control system, e.g., a processor on-board the sand disposal unit **126**). The level sensor **405** feedback may be used to determine when the tank **400** is nearly full, and shut down blowdowns (and/or shut in the well(s)) to prevent such overfill. The feedback from the level sensor **405** may also serve as a trigger for empty the tank **400**. For example, when the level sensor **405** registers that the tank **400** is nearing full (or otherwise reaches a critical level), a vacuum truck may be notified to empty the tank **400**. Blowdown and/or other well operations may then recommence. As will be described in greater detail below, the level sensor **405** may also be employed to determine blowdown intervals and/or blowdown duration, potentially in combination with weight measurements from the load cell **404** (and/or **220**, FIG. **2**).

[0053] Further, the junction box **418** may receive commands from the central controller **130**. For example, such commands may include opening or closing the bottom **406** of the basket **402**. In an embodiment, the junction box **418** may send an electric signal to the AOH system **416**, which may actuate one or more valves thereof, causing the AOH system **416** to supply fluid to the hydraulic assembly **408**, and thereby open or close the bottom **406**.

[0054] The junction box **418** may also include a panel **420**, including one or more lights (two shown: **422**, **424**) and a weight indicator. The weight indicator may display a weight, which may be representative of the weight of the sand in the basket **402**. The lights **422**, **424** may display a status of the sand disposal unit **126**, e.g., ready for blowdown, ready for empty, emptying, low pneumatic pressure, warning of malfunction, etc.

[0055] FIG. **5** illustrates a schematic view of the central controller **130**, according to an embodiment. In addition to the central controller **130**, FIG. **5** also shows a light tower **501** and a compressor **503**. The compressor **503** may be coupled to any of the accumulators mentioned above and/or act as a source of pressurized fluid (e.g., air) for any other component of the system **100**.

[0056] The central controller **130** may include a programmable logic controller (PLC) **500**, microprocessor, or any other device(s) capable of executing computer-readable instructions and to cause the various components of the system **100** to perform operations. The PLC **500** may in turn include a blowdown control module **502**, a separator control module **504**, and a human-machine interface **506**. The blowdown control module **502** may include connections for the compressor **503**, the blowdown units **120-124**, and the sand disposal unit **126**. These connections may allow for input and output to/from the PLC **500**. For example, via the connection with the compressor **503**, the PLC **500** may control the speed, pressure, etc. of the compressor **503**. Via the connection with the blowdown units **120-124**, the PLC **500** may individually control the blowdown units **120-124**, causing the blowdown units **120-124** to perform a blowdown process (e.g., independently of one another). The PLC **500** may also be able receive sensor measurements from the blowdown units **120-124**, e.g., to determine whether the blowdown units **120-124** (e.g., the blowdown valve assemblies **300** thereof) are operating properly and/or have sufficient pneumatic pressure in the accumulator **320** to actuate the valves **302-306**. Moreover, via the connection with the blowdown units **120-124**, the PLC **500** may be configured to open/close individual valves **302-306** of the blowdown units **120-124**, e.g., using electric signals.

[0057] The PLC **500** may also be configured to communicate with the sand disposal unit **126** via the connection therewith. For example, the PLC **500** may receive sensor measurements therefrom, e.g., the weight of the sand in the basket **402** measured by the load cell(s) **404**. The PLC **500** may also be configured to send electric signals to the sand disposal unit **126**, e.g., so as to cause the bottom **406** to open or close (e.g., via command through the AOH system **416** and the hydraulic assembly **408**).

[0058] The PLC **500** may be in communication with the separators **102-106** via the separator control module **504**. Using this module **504**, the PLC **500** may be able to shutdown operation of the separators **102-106**, control flow rates, etc., via direct communication with the separators **102-106**, individually, e.g., by actuating one or more valves thereof. For example, one or more shutdown valves may be positioned upstream of the individual separators **102-106**, and may be closed to shutdown the separator **102-106**, and potentially shut-in the well **108-112** to which it is connected. In some embodiments, the PLC **500** may communicate with the system **100**. In a specific example, the prioritization hierarchy may be or include the following:

Priority	Scenario	Description	Action
1	High level tank	Sensor 405 indicates maximum tank level reached.	Shutdown valves 302 closed in each of the blowdown units 120-124. Provide notification to operator/vacuum truck provider.
2	Critical Leak Detected	Transducer 322 measures a pressure above a threshold and transducer 324 registers flow and/or pressure	Shutdown valve 302 closed in affected blowdown unit 120-124. Provide notification to operator.
3	Minor Leak Detected	Transducer 322 reads pressure below the critical threshold, but above another, lower threshold and/or transducer 324 register flow and/or pressure below critical	Activate leak mitigation routine and issue minor leak detection notification. If cycle counter is exceeded, issue minor leak detected alarm.
4	Blowdown from sensor trigger or internal scale	Setpoint trigger (e.g., weight of separator) received.	Perform blowdown and activate leak detection logic. If multiple calls for blowdown received, blowdown in the order received.
5	Scheduled Blowdown	Regularly scheduled blowdown time reached.	Perform when scheduled and activate leak detection logic.

the load cell **220** in the sensors **102-106** in lieu of or in addition to communicating with the sand disposal unit **126** to determine the amount of sand expelled during a blowdown.

[0059] The PLC **500** may be configured to provide output to and receive input from a local user via the HMI **506**. For example, the HMI **506** may provide for a manually-initiated blowdown, a manual dump of the basket **402**, a read out of the weight of the sand in the basket **402**, calibration (e.g., tare) of the load cell(s) **404**, blow down, a counter of the number of times blowdown operations have occurred, and plots of the historical blowdown (e.g., sand accumulation) data.

[0060] In addition to the PLC **500**, the central controller **130** may include hardware and/or software configured to provide a variety of other functions. For example, the central controller **130** may include a modem **510**, which may be configured to broadcast signals to a remote system and/or receive signals therefrom. This may allow for remote communication with the controller **130** and remote control thereof. For example, the modem **510** may be in communication with the PLC **500** so as to communicate data signals therewith.

[0061] The controller **130** may further include a light-tower controller **512**, which is coupled to the light tower **501** and configured to control the lights thereof. The controller **130** may also include a power source **514**, which may be coupled to an external source of power (e.g., a generator or municipal grid), and may be configured to convert AC power to (e.g., 12V or 24V) DC power. The controller **130** may further include a panel showing a status of the controller **130** and/or various components of the system **100**, e.g., when blowdown is initiated, detection of a malfunction, etc.

[0062] The controller **130** may provide a central control system for the system **100**, able to pass along commands and receive sensor measurements, e.g., system-wide. Thus, the controller **130** may enforce a prioritization hierarchy of commands or processes in response to a detected status of

[0063] FIG. **6** illustrates a flowchart of a method **600** for blowdown and leak detection/mitigation to assist in automatically controlling a sand separation system, e.g., the sand separation system **100**, according to an embodiment. Although a particular order for the steps of the method **600** is described, it will be appreciated that the steps may be executed in a different order and/or steps may be combined or separated.

[0064] The method **600** may begin by turning the system on, as at **602**. For example, the controller **130** may be energized by closing a relay connect the controller **130** to its power source. Likewise, the blowdown units **120-124** may be powered on, e.g., upon receipt of electrical and/or pneumatic power. The wells **108-112** may also be turned on, e.g., to commence production of fluids therefrom and into the separators **102-106**.

[0065] The method **600** may then include receive tank level data, e.g. from the sensor **405** regarding the level of sand, water, etc., contained in the container **400**, as at **604**. Further, the method **600** may include opening the shutdown valve **302** of at least one of the blowdown units **120-124** (e.g., blowdown unit **120**), as at **606**. At this stage, the first and second valves **304**, **306** (and/or the choke valve **350**) of the blowdown unit **120** may be or remain closed, thereby preventing blowdown of the corresponding separator **102**.

[0066] The separator **102** may be operated normally, receiving and separating a mixture of sand or other solids and water or other fluids from a well **108**. Eventually, a blowdown trigger may be received, as at **610**. The trigger may be based on one or more pressures measured by the transducers **208** and/or **210** (e.g., a differential therebetween) in the separator **102**. Additionally or alternatively, the trigger may be the expiration of a timer or reaching a predetermined scheduled time for blowdown of the separator **102**.

[0067] Prior to initiating blowdown, however, the method **600** may include determining whether the level in the container **400** exceeds a maximum, as at **612**, e.g., using the level sensor **405**. The maximum may be predetermined or may be dynamic, e.g., varying on how much sand is typically received into the container **400** during a blowdown procedure.

[0068] If the container **400** level is at or above its maximum, the shutdown valve **302** may be returned to the closed position, and the controller **130** may be notified, as at **614**. The controller **130** may thus take steps to notify rig personnel that the container **400** is full and should be emptied or drained, thereby avoiding unintended overfilling of the container **400**. The controller **130** may also, based on this notification, prevent blowdown procedures from being initiated for other separators **102-106** of the system **100**.

[0069] If the container **400** has capacity (e.g., lower than maximum level), the method **600** may proceed to determining a pre-blowdown sand level, as at **616**. This may be determined using the sensor **404** (e.g., load cells attached to the basket **402**) and/or the level sensor **405** in the tank **400** but could also or instead be derived by the weight of the separator **102**.

[0070] The method **600** may then proceed to opening the choke valve **350**, as at **617**. The method **600** may then proceed to opening the first valve **304**, as at **618**. After a delay, the second valve **306** may then be opened, as at **620**. Accordingly, if the valves **302-306** and **350** are functioning properly, the blowdown unit **120** may thus permit blowdown of the separator **102**, such that its contents are emptied into the basket **402** via the blowdown line **307**. During or after such blowdown, the sand level may again be determined, as at **622**. The differences in the values of sand measured at **616** and **622** may thus be representative of the sand and/or fluids removed from the separator **102** during blowdown.

[0071] After a delay sufficient to allow for blowdown of the separator **102** (measured, e.g., from the opening of the second valve **306**), i.e., a "blowdown duration", the method **600** may include closing the choke valve **350** (if provided), as at **623** and then the first valve **304**, as at **624**. After a delay, e.g., to allow closure of the first valve **304**, the method **600** may proceed to closing the second valve **306**, as at **626**.

[0072] At this stage, leakage detection and/or mitigation may be initiated. The method **600** may also include initializing a cycle counter, which may count the number of times valve closure is attempted, to one, as at **628**. The method **600** may include receiving pressure measurements from one or more of the pressure transducer(s) (e.g., pressure transducer **324**) of the blowdown unit **120**, as at **630**.

[0073] The method **600** may then include determining whether a leak in the valve(s) **304**, **306** is apparent, as at **632**. For example, if the pressure measurement received from the pressure transducer **324**, between the first and second valves **304**, **306** is higher than ambient, it may indicate that the first valve **304** is leaking. The second valve **306** may be provided, partially as a redundancy, to prevent unintended blowdown of the separator **102**. As such, fluid leaking through the first valve **304** may tend to equalize the pressure between the pressure transducer **322** upstream of the first valve **304** and the pressure measured by the pressure transducer **324** downstream of the first valve **304**. If the valve **304** is not leaking, the pressures measured by the pressure transducer **324** and the pressure transducer **326** may be approximately equal. If both the first and second valves **304**, **306** are leaking, the pressure transducer **326** may read a pressure value approximately equal to that measured by the pressure transducer **322**.

[0074] In some embodiments, pressure may be injected between the first and second valves **304**, **306** to facilitate leak detection. For example, low-flow meters, which may be employed as the sensor (e.g., transducer) **324** downstream of the second valve **306**, may not be entirely reliable. Accordingly, a fluid or gas may be injected into the line **307** between the first and second valves **304**, **306** when the first and second valves **304**, **306** are closed. The pressure may be measured using the pressure transducer **322**. If the pressure reduces over time, without opening the first and second valves **304**, **306**, it may be evidence of a leak in either or both of the valves **304**, **306**.

[0075] If, based on the pressure measurements, the controller **130** determines that leakage is not occurring at **632**, no leak mitigation may be called for, and the method **600** may return to awaiting the next blowdown trigger at **610**. Otherwise, the method **600** may enter the leak mitigation phase. In this phase, the method **600** may check whether the cycle counter, which was initialized to one in block **628**, is less than or equal to a maximum (e.g., two), as at **634**. If the cycle counter is less than or equal to the maximum, the method **600** may attempt to wash out the first and/or second valves **304**, **306**, e.g., in case leakage is occurring because the valve(s) **304**, **306** are being prevented from closing fully by sand. Accordingly, for example, the method **600** may include opening the second valve **306** and then opening the first valve **304**, as at **636**. The method **600** may then include closing the first valve **304** and then closing the second valve **306**, as at **638**. The method **600** may then proceed to incrementing the cycle counter, as at **640**.

[0076] The method **600** may then receive the pressure measurements again at **630**, and again determine whether a leak is detected at **632**, based on these pressure measurements. If a leak is still indicated, the method **600** may determine if the number of leak mitigation cycles, as recorded by the cycle counter, remains less than the maximum at **634**. If it is, another round of wash out attempts occurs at **636**, **638**. This process of washing out and determining if a leak is apparent may repeat for as many times as the counter allows. When the counter exceeds the maximum, the method **600** may determine that the first valve **304** and/or the second valve **306** is/are damaged, and may thus close the shutdown valve **302** and notify the controller **130**, as at **614**.

[0077] Further, when a leak is detected, the method **600** may include tolling blowdown of other separators (in this case, the separators **104** and **106**). This may permit the leak mitigation process to proceed without interfering with the sand quantification for (or other aspects of) blowdown of the other separators **104**, **106**. For example, if leak mitigation is being performed for one separator **102** during a regularly scheduled blowdown for another separator **104**, the blowdown of the separator **104** may be postponed. However, there may be a maximum tolling for blowdown of the other separator **104**, so as to avoid flooding the separator **104**. Thus, if leak mitigation for the separator **102** blowdown takes too long, it may be stopped to allow for blowdown of the other separator **104**. Similarly, as noted above, sensor-initiated blowdowns may be queued if multiple are received in a short time period, so that blowdown of two separators does not occur simultaneously, in at least some embodiments.

[0078] The foregoing describes detecting leakage in the valves **302-306** of the blowdown valve assemblies **300** of the individual blowdown units **300**. However, the method

600 may also include a redundancy measure which may enable checking for system-wide leakage. In particular, the method **600** may include monitoring the sand level in the tank **400** measured by the level sensor **1020** and/or the sand weight in the basket **402** measured by the load cell **404**. If either or both of these measurements increase, indicating that sand and/or fluid is being received into the sand disposal unit **126**, when none of the blowdown units **120-124** have been signaled to blowdown the separators **102-106**, it may be inferred that one or more of the blowdown units **120-124** is permitting leakage. In response, the method **600** may implement the leak mitigation phase, as discussed above, for each of the blowdown units **120-124**, further investigate the source of the leakage, shut down the system **100**, call for maintenance, or otherwise take actions to avert any potential overfilling of the tank **400**.

[0079] FIG. **7** illustrates a flowchart of a method **700** for automatically controlling a sand separation system, e.g., the sand separation system **100**, according to an embodiment. Although a particular order for the steps of the method **700** is described, it will be appreciated that the steps may be executed in a different order and/or steps may be combined or separated.

[0080] The method **700** may include separating sand from a fluid produced from a well **108-112** using a plurality of separators **102-106**, as at **702**. The separators **102-106** may temporarily store the sand therein and provide the separated fluid to a production separator. The method **700** may also include signaling, from a controller **130** to a blowdown unit **120**, to blowdown one of the separators (e.g., the separator **102**), as at **704**. This may be conducted automatically, e.g., at scheduled times or at intervals between blowdowns. In some embodiments, the blowdown may be conducted in response to a sensor-based trigger, e.g., a weight of the separator **102** reaching a particular threshold that indicates it is reaching its sand-storage capacity.

[0081] The method **700** may include opening one or more blowdown valves (e.g., the valves **302-306**) coupled to a blowdown outlet **206** of the separator **102** using the blowdown unit **120** in response to the signaling, as at **706**.

[0082] The method **700** may then include receiving the stored contents from the separator **102** into a sand disposal unit **126**, as at **708**. The method **700** may further include measuring a weight of the sand stored in the separator **102**, e.g., as represented by a weight of the sand evacuated therefrom during a blowdown and received into the sand disposal unit **126** or directly by measurement from the load cell **220** positioned in the separator **102**. For example, the sand disposal unit **126** may include a basket **402** that receives the fluid from the separators **102-106**, and filters the sand therefrom, allowing the fluids to drain into the tank **400**. The weight of the basket **402** can then be measured, which provides an indication of how much sand was received during a blowdown procedure.

[0083] The method **700** may also include dynamically determining a blowdown interval for subsequent blowdown operations of one or more of the separators **102-106** based in part on the weight of the sand, as at **712**. Thus, if sand is being produced from the well **108** more quickly than in previous intervals, the blowdown interval for the separator **102** may be reduced, so as to avoid overfilling the separator **102**. On the other hand, if sand is being produced from the well **108** more slowly than in previous intervals, the blowdown interval for the separator **102** may be increased, so as to avoid unnecessary wear of the valves and other components of the separator **102** and/or blowdown unit **120**. In other words, the time between blowdowns may be maximized up to a point, so as to avoid filling the separator **102** fully with sand which may carryover between blowdowns, while avoiding blowing down more frequently than necessary.

[0084] The method **700** may additionally include dynamically determining a blowdown duration for one or more of the separators **102-106** based in part on the weight and/or level of the sand, as at **714**. As noted above, "blowdown duration" refers to the amount of time the blowdown line **107** is open in a given blowdown unit **120-124**, e.g., with the valves **302**, **304**, **306** (and **350**, if included) open and prior to closing one or more of the valves **302-306** (and **350**). For example, if blowdown operations reveal large amounts of sand being introduced to the tank **400** of the sand disposal unit **126**, then the blowdown duration may be lengthened (e.g., holding the valves **302-306/350** open longer) so as to more fully clear the separators **102-106** of sand. If sand amount decreases, blowdown duration may be shortened, e.g., to prevent a well from "gasing out" by emptying the separator **102-106** and blowing mostly gas out the blowdown line **107**. If consistent readings come in, a test may be performed to ensure the blowdown duration is sufficient, e.g., by performing a longer than normal blowdown and determining if additional sand, and how much, is received in the sand disposal unit **126**. If the sand produced during the test is larger than was received in previous blowdown operations, or received at a relatively consistent rate throughout the blowdown duration, it may indicate that a longer blowdown duration is called for. Further, it will be appreciated that the different separators **102-106** may call for different blowdown durations, as the wells to which they are connected may produce sand at different rates.

[0085] In some embodiments, the method **700** may provide leak detection and/or mitigation. For example, the method **700** may include receiving a feedback (e.g., electrical) signal from the blowdown unit **120** that represents that one or more valves **302-306** of the blowdown unit are malfunctioning (e.g., leaking). For example, the signal may be generated by a pressure and/or flow sensor, or two or more sensors in combination. In response to receiving the feedback signal, one or more scheduled blowdown operations for other separators **104-106** may be tolled (e.g., delayed). The leak mitigation efforts may then include attempting to correct operation of the one or more valves **302-306** while the one or more scheduled blowdown operations are tolled.

[0086] In an embodiment, the method **700** may include determining that a maximum tolling time has been reached for the one or more scheduled blowdown operations, and in response to determining that the maximum tolling time has been reached, shutting down the separators **102**. This may prevent the other separators **104**, **106** from overfilling by delaying blowdown thereof too long.

[0087] In some embodiments, to detect leakage, rather than (or in addition to) relying on sensor readings related to fluid evacuating as part of the blowdown from the separator **102**, the method **700** may include injecting a pressurized fluid between the first and second valves **304**, **306** when the first and second valves **304**, **306** are closed. The feedback signal may thus be representative of the pressure between the first and second valves **304**, **306**. As the first and second valves **304**, **306** being closed should retain the pressure until one or other are opened, the feedback signal represents that at least one of the first valve **304** or the second valve **306** is malfunctioning when the feedback signal represents a pressure that lowers over time.

Flowback 2.0

[0088] FIG. **8** illustrates a schematic view of a sand separation system **800**, according to an embodiment. The system **800** may be similar to the system **100** and may include the separators **102**, **104**, **106**, which may be connected to the wells **108**, **110**, **112**, respectively, as discussed above. In addition, the system **800** may include the blowdown unit **120**, control system **130**, and sand disposal unit **126**.

[0089] However, the system **800** may be configured such that the multiple separators **102**, **104**, **106** (and potentially others) feed the single blowdown unit **120**, e.g., instead of feeding separate blowdown units as in FIG. **1**. To permit such several-to-one flow from the separators **102**, **104**, **106** to the blowdown unit **120**, a manifold valve assembly **801** may be provided. In particular, the manifold valve assembly **801** may include a plurality of manifold valves **802**, **804**, **806**, e.g., one for each of the separators **102**, **104**, **106**, and positioned downstream thereof. The manifold valves **802**, **804**, **806** may be controlled via communication with the control system **130**, and may be independently operable (e.g., opened, closed, choked, etc.) with respect to one another, responsive to signals from the control system **130**. Downstream of the manifold valves **802**, **804**, **804**, the outlet flows from the manifold valves **802**, **804**, **806** may be combined into a single input into the blowdown unit **120**. As such, the valves of the blowdown unit **120**, as discussed above, may be configured to control blowdown operations of the several separators **102**, **104**, **106** (and/or others) by selectively permitting or blocking fluid flow through the separators **102**, **104**, **106**. In at least some embodiments, the manifold valves **802**, **804**, **806** may be positioned in close physical proximity to the separators **102**, **104**, **106** so as to reduce the potential sand build up in the line. Accordingly, the manifold valves **802**, **804**, **806** may be discrete, separate valves positioned near the respective separators **102**, **104**, **106**. In other embodiments, the manifold valves **102**, **104**, **106** may be provided as a centralized manifold and connected to the separators **102**, **104**, **106** with sections of pipe coming from each separator **802**, **804**, **806**.

[0090] The control system **130** may be configured to maintain the manifold valves **802**, **804**, **806** in a closed position as a default, as blowdown operations may be intermittent, while normal operation may be generally continuous except when interrupted by blowdown. The control system **130** may determine a blowdown duration and frequency for the individual separators **102**, **104**, **106** based on historical sand-production rates (e.g., as measured by a load cell within the separator **102**, **104**, **106**, in the sand disposal unit **126**, or elsewhere). Further, the controls system **130** may coordinate the blowdown times for the separators **102**, **104**, **106**, e.g., to avoid two separators **102**, **104**, **106** being blowndown at the same time. For example, the control system **130** may signal to the manifold valve **802** to open, and then for the blowdown unit **120** to execute a blowdown operation, resulting in the blowdown of the separator **102**, while the other manifold valves **802**, **804**, **806** remain closed and prevent blowdown thereof. As such, the manifold valves **802**, **804**, **806** may permit a selection of which separator **102**, **104**, **106** to blowdown, while using a single blowdown unit **120**.

[0091] It will be appreciated that a single system **800** may include several blowdown units, e.g., each connected to two or more separators, and all or some of these blowdown units may be controlled by the control system **130** and/or one or more additional control systems **130**. In such cases, manifold valves may be provided for each of the separators, e.g., to permit the control system **130** to select which separator to blowdown, so as to coordinate blowdown timing as between the different separators, taking into consideration leak mitigation, etc., as discussed above.

[0092] FIG. **9** illustrates a schematic view of a sand separation system **900**, according to an embodiment. The system **900** may be similar to the system **100**. The system **900** may include one or more separators, e.g., the separator **102**, which may be connected to the well **108**. In addition, the system **800** may include the blowdown unit **120** and the sand disposal unit **126**. Although not shown, the system **900** includes a control system (e.g., the control system **130**), which may communicate with sensors and actuators to control the system **900**.

[0093] The system **900** may include one or more pressure sensors, e.g., pressure sensors **902**, **904**, **906**, **908**, **910** as shown. The system **900** may also include a debris catcher **912**, a bypass valve system **914**, and an adjustable choke **916** that is downstream of the blowdown unit **120**. The adjustable choke **916** may be provided to mitigate the erosion of the valve train within the blowdown unit **120**. For example, the adjustable choke **916** may reduce the pressure drop across the blowdown unit **120**, e.g., such that the blowdown unit **120** does not step the pressure down from wellhead to ambient, but to some intermediate pressure upstream of the adjustable choke **916**. The adjustable choke **916** may then step the pressure down to ambient.

[0094] Having this choke **916** also allows the operator (and/or control system) to finely tune the blowdown duration. They can set this time, and then adjust to choke **916** to allow more or less flow through the system **900** during the time the blowdown unit **120** permits blowdown (e.g., the time that the first valve **302** of FIG. **3A** is open). This provides a tool to combat "gas out", a situation in which the separator **102** is fully evacuated of liquid and large amounts of gas begin to flow through the system, which may surge the well **108**.

[0095] It will be appreciated that the choke **916** may be used in embodiments that do not include a debris catcher **912**, and the debris catcher **912** may be used in embodiments that do not include a choke **916**.

[0096] The bypass valve system **914**, which may include one or more bypass valves, adjustable chokes, etc., may be positioned between the separator **102** and the blowdown unit **120**. The bypass valve system **914** may be coupled to the sand disposal unit **126**, and may normally permit fluid to flow from the separator **102** to the debris catcher **912**, but may be modulated to redirect fluid directly to the sand disposal unit **126**, bypassing the blowdown unit **120**, e.g., in response to signals from the control system **130** (e.g., FIG. **3A**) or manually by operation of a user.

[0097] The debris catcher **912** may also be between the separator **102** and the blowdown unit **120**, e.g., downstream of the bypass valve system **914**. The pressure sensor **902** may be positioned between the wellhead **108** and the separator **102**. The pressure sensor **904** may be positioned between the separator **102** or downstream thereof on outlet **114** (e.g., FIG. **1**) and the debris catcher **912**. In other embodiments, the pressure sensor **904** may be placed in any position upstream of the debris catcher **912**. In some embodiments, the pressure sensor **904** may be redundant to the pressure sensor **902** and could be omitted. The pressure sensor **906** may be positioned between the debris catcher **912** and the blowdown unit **120**. In some embodiments, the pressure sensor **906** may be provided as part of the blowdown unit **120** (e.g., pressure transducer **322** of FIG. **3**A). The pressure sensors **908** may be positioned between the blowdown unit **120** and the adjustable choke **916**. The pressure sensor **910** may be positioned between the adjustable choke **916** and the sand disposal unit **126**.

[0098] In some embodiments, during initial flowback, significant amounts of solids are produced from the well **108**. As this may be the first time the well **108** is opened, pieces of completions devices, plug parts, large particles of debris, etc., that are left in the well from the completions and drilling processes can be brought to surface. The trash can be dense metal, and large mass. The separator **102** separates these large pieces and captures them in its accumulator. When the blowdown unit **120** performs a blowdown of the separator **102**, these pieces of debris or "trash" are pushed through the primary blowdown valve, which can damage the primary blowdown valve or prevent the primary blowdown valve from functioning correctly, e.g., become packed off, stuck open or closed, etc.

[0099] Accordingly, the debris catcher **912** may be provided to prevent such separated trash from reaching the blowdown unit **120** and damaging the valves therein. As shown, the debris catcher **912** may be a ball catcher device. The debris catcher **912** may have a removable filter element (e.g., a metal screen) that is received perpendicular to the direction of flow, which may be removed when it is packed off (fouled with trash).

[0100] The pressure sensors **902-910** may be configured to provide signals that the control system **130** uses to determine when the debris catcher **912** is packed off. For example, when not under blowdown conditions, the pressure sensor **902** may record measurements approximately equal to wellhead pressure. The pressure sensor **904** may read slightly lower pressures, as the separator **102** may produce a small amount of pressure drop, and the pressure sensor **906** may read a generally equal pressure. The pressure sensors **908** and **910** may read equal, generally atmospheric pressures.

[0101] During a normal blowdown operation, the pressure sensors **902** and **904** may be generally unchanged, observing wellhead pressure and slightly below wellhead pressure, respectively. Further, pressure sensors **904** and **906** may read a generally consistent, equal pressure. Further, the pressure recorded by the pressure sensor **908** may be generally higher than the pressure recorded at the pressure sensors **910**, as the adjustable choke **916** may produce a pressure drop in the fluid flowing therethrough from the blowdown unit **120** to the sand disposal unit **126** during the blowdown.

[0102] When the debris catcher **912** is plugged, the pressure read by the pressure sensor **906** may be substantially lower than what is read during the normal blowdown operation. For example, in normal operations, the pressure read by pressure sensor **906** may be between about 55% and about 65% of the wellhead pressure. During a blowdown, if the pressure read by the pressure sensor **906** is outside of this range, e.g., below the range, the debris catcher **912** may be plugged. In addition, the pressure sensors **904**, **908**, **910** may vary in pressure readings from a normal blowdown operation, as the total flow allowed through the debris catcher **912** is reduced. Accordingly, at least partially in response to the change (e.g., reduction) in pressure sensed by the pressure sensor **906** downstream of the debris catcher **912**, the control system **130** (e.g., FIG. **3**A) connected thereto may determine that the debris catcher **912** is fouled. The control system **130** may then take an appropriate mitigation action, such as stopping blowdowns with unit **120**, engaging the bypass valve **914** to route blowdown fluid directly to the sand disposal unit **126**, scheduling maintenance, producing a visual or audible warning, etc.

[0103] FIG. **10** illustrates a side, cross-sectional view of a separator **1000** of any one of the foregoing systems, according to an embodiment. For example, the separator **1000** may be an embodiment of one or more of the separators **102-106** of FIG. **3**A. The separator **1000** may include a cyclone **1002** and an accumulator **1004**, which may be positioned below the cyclone **1002** and configured to receive solids (e.g., particulate matter such as sand) that is separated from a flow of fluid in the cyclone **1002**. An inlet **1006** may provide the particulate-laden fluid to the cyclone **1002**, and a fluid outlet **1008** may receive the fluid flow from the cyclone **1002**. The separated solids (and some of the fluid) may drop out of the cyclone **1002** via a solids outlet **1010**.

[0104] A blowdown outlet **1012** and a drain **1014** may be coupled to the accumulator **1004**. During blowdown operations, sand and other solids **1016** may be evacuated from the accumulator **1004** via the blowdown outlet **1012**, as lower pressure downstream draws a slurry of the solids **1016** and liquid from within the accumulator **1004** out through the blowdown outlet **1012**. The accumulator **1004** also contains a level sensor **1020** therein. The level sensor **1020** may be a load cell measuring the weight of the sand, a density or viscosity measurement device, and/or a device that measures an electromagnetic tomography. Accordingly, the level sensor **1020** may provide a signal that permits a binary determination of whether or not sand has reached the level sensor **1020**, as this may represent a measurable change in density and/or viscosity surrounding the level sensor **1020**, or the weight of the sand in the accumulator **1004**. The level sensor **1020** may be positioned toward the top of the accumulator **1004**, such that solids reaching the level sensor **1020** may provide a trigger for the control system **130** (e.g., FIG. **3**A) to initiate a blowdown.

[0105] FIGS. **11**A, **11**B, **11**C, and **11**D illustrate side, schematic views of an accumulator **1100** for a separator, which may be provided with an external sand-level detector **1102**, according to an embodiment. The external sand-level detector **1102** may be a nuclear emitter **1104** and receiver **1106** combination. The detector **1102** may employ nuclear densitometry to determine sand level within the accumulator **1100**, without requiring a penetration of the pressure vessel or exposing the detector **1102** to the high-pressure environment therein. In particular, the nuclear emitter **1104** may be placed on one lateral side of the accumulator **1100**, and the receiver **1106** may be placed on the opposite lateral side of the accumulator **1100**. As sand builds up in the accumulator **1100**, the sand shields the receiver **1106** from the radiation emitted by the emitter **1104**. This reduction can be measured.

[0106] In at least some embodiments, the detector **1102** may provide an analog scale that may provide indications of potentially several sand levels, as the sand fills the accumulator **1100** during use. For example, the receiver **1106** may be formed as a long rod, as shown. The emitter **1104** may emits radiation on, e.g., a 45-degree field **1109**. As the sand accumulates (e.g., proceeding from FIGS. **11**A to **11**B, **11**C, and **11**D, sand **1110** is shown accumulating), more of the field is obstructed by the sand **1110**, and less radiation reaches the receiver **1106**.

[0107] In another embodiment, a smaller, point source may be employed as the emitter **1104**, with a more concentrated "beam of radiation" that would pass through the vessel to the receiver **1108** (in this embodiment, a point receiver rather than a long rod). When sand built up and breaks the beam of radiation, the detector **1102** would signal to the controls system **1130** that the accumulator **1100** is full (or nearly full).

[0108] FIGS. **12**A and **12**B illustrate a flowchart of a method **1200** for operating a sand separation system, e.g., any one or a combination of the systems **100**, **800**, **900** discussed above, according to an embodiment. The method **1200** may include separating sand from a fluid using a plurality of separators **102-106**, as at **1202**. The separators **102-106** each temporarily store the sand therein, e.g., in an accumulator (e.g., the accumulator **1004** of FIG. **10**). A plurality of manifold valves **802-806** are each coupled to a respective one of the separators **102-106**, e.g., in the configuration of FIG. **8**.

[0109] The method **1200** may also include selecting, using a control unit (or control "system") **130**, one of the plurality of separators (e.g., the separator **102**) to blowdown, as at **1204**.

[0110] The method **1200** may further include signaling, from the control unit **130**, to one of the manifold valves (e.g., valve **802**), the one of the manifold valves being coupled to the separator **102**, for the manifold valve **802** to open, as at **1206**.

[0111] The method **1200** may include opening the manifold valve **802**, as at **1208**, while the other manifold valves **804**, **806** remain closed.

[0112] The method **1200** may also include signaling, from the control unit **130** to a blowdown unit **126**, for the blowdown unit **120** to execute a blowdown, as at **1210**.

[0113] The method **1200** may include opening one or more valves (e.g., valves **302**, **304**, **306**) of the blowdown unit **120** in response to the signaling, so as to blowdown the selected one of the separators **102**, as at **1212**.

[0114] The method **1200** may include receiving the sand from the selected one of the separators into a sand disposal unit **126**, as at **1214**. The sand passes through the manifold valve **802** that is opened and through the blowdown unit **126** (via the open valves **302**, **304**, **306** thereof).

[0115] The method **1200** may also include measuring the sand that was separated in the separator **102** using a sensor of the one of the separators, a load cell of the sand disposal unit, or both, as at **1216**. In at least some embodiments, the control unit **130**, e.g., as part of the method **1200**, may determine that it is time to execute a blowdown operation based on measuring the sand that was separated in the one or more separators **102** using the sensor of the one or more separators. For example, the sensor may be the level sensor **1020** and/or the nuclear detector **1102**. As noted above, the nuclear detector **1102** may include the nuclear emitter **1104** that emits a field of radiation **1109**. Thus, the method **1200** may include detecting a level of the sand in the accumulator based on the sand obstructing at least a portion of the field of radiation, e.g., as part of the measuring at **1216**.

[0116] In another embodiment, measuring the sand that was separated in the separator uses the level sensor **1020** positioned at least partially in an accumulator **1004** of the separator **1000** (e.g., a representative example of the separator **102**). The level sensor **1020** may thus provide a signal representing whether or not a sand level in the accumulator has reached the level sensor **1020**.

[0117] The method **1200** may include determining a blowdown interval for subsequent blowdown operations of the selected separator **102** based in part on the measurement of the sand, as at **1218**. The blowdown interval may include a safety interval, which may be determined based on collected production information. The safety interval may be set as a function of sand production rate and accumulator capacity, and may thus be set to avoid overfill in the case that the level sensor fails to trigger. That is, the safety interval may be set at a time that is less than the accumulator capacity (the amount of sand that can be contained in the separator before an overfill) divided by recent/past sand production rate. The method **1200** may thus determine that it is time to blowdown the separator based on either the level sensor determining that the sand has reached a blowdown/trigger level, or at the expiration of the safety interval since the last blowdown of the separator, whichever comes first.

[0118] For example, a previous blowdown quantification may show that a well is producing 100 kg/hr of sand. The internal level sensor is set at an elevation at which the accumulator contains 200 kg of sand. Therefore, the level sensor **1020** or another may be expected to trigger within the next two hours of operating time. By comparison, the accumulator **1004** holds 400 kg of sand. Because sand production rates can vary, a safety interval may be set to force the blowdown at some time after the trigger, but before the time at which overfill may be expected based on recent production rates (e.g., the 100 kg/hr). In this example, three hours to force a blowdown may be a suitable safety interval, to ensure that the 400 kg accumulator is not overfilled, although different operators may select different safety intervals. Accordingly, using such a safety interval, the separator (s) may be blowndown and emptied every three hours, or upon the level sensor being triggered, whichever comes first.

[0119] In an embodiment, the method **1200** may include measuring a pressure downstream of a debris catcher, the debris catcher positioned between the separator and the blowdown unit, as at **1220**. The method **1200** may also include determining that the pressure measured upstream of the debris catcher is out of a predetermined range (e.g., below a certain threshold percentage of wellhead pressure, e.g., less than about 70%, less than about 65%, less than about 60%, or less than about 55% thereof). In response to determining that the pressure measured upstream of the debris catcher **912** is out of the predetermined range, the method **1200** may include the control unit **130** executing one or more mitigation actions in response to the debris catcher being plugged. The mitigation actions may include opening a bypass valve that routes fluid to the sand disposal unit and not to the blowdown unit or the debris catcher, or cleaning out a filter screen of the debris catcher.

[0120] At **1222**, the method **1200** includes adjusting a choke **916** that is positioned downstream of the blowdown unit **120** and upstream of the sand disposal unit **126**, to tune the blowdown operation and reduce a pressure drop across the blowdown unit **126**, as described above.

Flowback 3.0

[0121] Flowback 3.0 may eliminate permanent facilities at wellpad locations as well as all the equipment used in conventional flowback operations. Flowback 3.0 may be monitored remotely. As described in greater detail below, one or more multiphase meters may have a data feed sending the flow parameters through data transmission methods.

[0122] Flowback 3.0 may be performed with or without eFlowback (e.g., an automation control unit (ACU), an automatic blowdown unit (ABU), and/or a sand quantification unit (SQU)). Flowback 3.0 differs from conventional flowback techniques because it uses the multiphase meter(s) that allow the removal/omission of the facility separator that is required to separate the fluids so as to measure them separately (after which they are just recombined and sent to the pipeline).

[0123] FIGS. **13**, **14**A, and **14**B illustrate schematic views of a sand separation system **1300**, according to an embodiment. The system **1300** may include one or more wells or wellheads **1305**. In the example shown, the system **1300** may include six wells or wellheads **1305**.

[0124] The system **1300** may also include one or more separators **1310**. The separators **1310** may be or include high-efficiency de-sanding cyclones (HEDCs). An example of the separators **1310** may be found in U.S. Pat. Nos. 11,839,883; 11,235,263; U.S. Patent Pub. No. 2022/0097081, U.S. Patent Pub. No. 2022/0347700, or a combination thereof, which are incorporated by reference herein. Each separator **1310** may be downstream from and/or in fluid communication a corresponding one of the wells or wellheads **1305**. Thus, continuing with the example above, the system **1300** may include six separators **1310**, each configured to receive a mixed fluid from one of the wells/wellheads **1305**. The mixed fluid may include a fluid (e.g., water and/or hydrocarbons) with solids (e.g., sand) therein. The separators **1310** may be configured to separate the solids from the mixed fluid to produce (1) the solids and (2) a separated fluid.

[0125] This initial debottlenecking provided by the separators **1310** allows for nearly unrestricted flow from the wells/wellheads **1305** to the production facility **1325** or pipeline **1330**. The restriction from downhole to anywhere (e.g., the separators **1310** or the pipeline or the facility, etc.) may be created by the high solid percentage returns due to the high momentum/velocity of the fluid coming from the formation. Without the separator or some equivalent de-sanding technology, the well may be restricted, or the massive quantities of sand may destroy or render the facilities downstream of the wellhead inoperable so flow is restricted to minimize the sand returns and spread them out over time. A second restriction may be the separators' ability to process the high fluid rates during early stages of flowback, as they are greater than the specifications of the separators to separate. For this reason, the wells either need to be restricted, or additional equipment (e.g., tanks/flares, etc.) may be used to handle the temporary additional flowrates. Thus, these options are two separate, but closely-related, debottlenecking opportunities.

[0126] Prior to the separators **1310**, the wells or wellheads **1305** had to be severely restricted during flowback to reduce the solids (e.g., sand) return coming out of the wells or wellheads **1305**. As may be seen in FIGS. **14**A and **14**B, the system **1300** may not include a facility separator. The system **1300** does include the desanding separators **1310**, but that is one of the de-bottlenecking technologies that allows for unrestricted flow. This is the separator that is the other bottleneck.

[0127] The system **1300** may also include one or more chokes (also referred to as choke valves) **1315**. Each choke **1315** may be downstream from and/or in fluid communication with a first (e.g., separated fluid) outlet of a corresponding one of the separators **1310**. Thus, continuing with the example above, the system **1300** may include six chokes **1315**, each configured to receive the separated fluid from one of the separators **1310**. The chokes **1315** may be configured to control (e.g., choke) the volume and/or rate of the separated fluid flowing therethrough.

[0128] The system **1300** may also include one or more multiphase meters (MPMs) **1320**. Each multiphase meter **1320** may be downstream from and/or in (e.g., electrical and/or fluid) communication with a corresponding one of the separators **1310** and/or chokes **1315**. Thus, continuing with the example above, the system **1300** may include six multiphase meters **1320**, each configured to measure one or more first properties of the separated fluid. The first properties may be or include volume, flowrate, sand content, sand volume, other solids content, or a combination thereof. Based on the real-time data being measured and/or received from the multiphase meters **1320** (and other on-site data), the chokes **1315** may be manually or automatically adjusted (e.g., opened, closed, or throttled) to control (e.g., optimize) efficiency, pipeline capacity, downhole consideration, or other factors.

[0129] The multiphase meters **1320** may be nuclear or non-nuclear. The multiphase meters **1320** may eliminate the requirement to have facility and/or temporary separators on-site to separate and measure the three flow streams (i.e., gas, oil and/or condensate, and water). Separators may only operate properly within their design range, so early stage flowback (e.g., 0-30 days) when fluid and gas rates are often flowing back significantly higher than those the separators and meters are designed to handle may force the operators to hold back flow and/or restrict production from the wells and/or wellheads **305**. Flowback 3.0 may eliminate this limitation and allow for a fully debottlenecked flowback.

[0130] The separated fluid output from the choke(s) **1315** and/or the multiphase meter(s) **1320** may then be transferred to a production facility **1325** or a pipeline **1330**.

[0131] The system **1300** may also include one or more tanks (or pits) **1335**. The tank (or pit) **1335** may be downstream from and/or in fluid communication with second (e.g., solids) outlets of the separators **1310**. As the solids (e.g., sand) accumulate(s) in the lower section of the separators **1310**, it may be manually or automatically (i.e., eFlowback) purged from the separators **1310** to the tank (or pit) **1335**.

[0132] The system **1300** may also include a controller **1340**. The controller **1340** may be in communication with the separators **1310**, the chokes **1315**, the multiphase meters **1320**, the tanks (or pits) **1335**, or a combination thereof. The controller **1340** may be configured to measure and/or receive one or more second properties from the separators **1310**, the chokes **1315**, the multiphase meters **1320**, and/or the tanks (or pits) **1335**. The second properties may be or include flowrate (oil, water, gas, and sand), differential pressure, static pressure, sand volume accumulated, pressure, temperature, conductivity, solidity, electromagnetic properties, or combination thereof. The controller **1340** may also be configured to generate and transmit signals to control (e.g., modify) the separators **1310**, the chokes **1315**, the multiphase meters **1320**, the tanks (or pits) **1335** in response to the second properties.

[0133] Reference number **1345** in FIG. **14**A indicates where a production separator (also called a facility separator) would be located on each well pad in a conventional system. The system **1300**, however, may allow for the omission of such a production separator, which saves space and cost.

[0134] FIGS. **15**A, **15**B, and **16**A-**16**C illustrate schematic views of the sand separation system **1300** including additional equipment, according to an embodiment. The sand separation system **1300** may also include one or more automated blowdown units (ABUs) **1350**. The automated blowdown units **1350** may be downstream from and/or in fluid communication with the second (e.g., solids) outlets of the separators **1310**. Thus, continuing with the example above, the system **1300** may include six automated blowdown units **1350**, each configured to receive the solids from a corresponding one of the separators **1310**. The automated blowdown units **1350** may allow for the extraction and/or evacuation of sand from the separator **1310** either manually, or timed, or from feedback from sensors in the sand quantification units **1355** (described below) using algorithms, or other advanced methods such as artificial intelligence (AI) or machine learning (ML). This is done in a way to minimize excess fluids and emissions.

[0135] The sand separation system **1300** may also include one or more sand quantification units (SQUs) **1355**. The sand quantification unit **1355** may be downstream from and/or in fluid communication with the automated blowdown units **1350**. The sand quantification unit **1355** may be configured to receive the solids from the automated blowdown units **1350** and to measure and/or quantify (e.g., weigh) the solids.

[0136] The sand separation system **1300** may also include one or more automated control units (ACUs) **1360**. The automated control unit **1360** may be configured to manage blowdown timing for various wells based on the method being used. It may also or instead be used to control and record information from the other eFlowback components such as the ABU **1350** and the SQU **1355**. It may also provide pressurized air or power to activate the valves and sensors on that allow eFlowback to function as designed.

[0137] FIG. **17** illustrates a flowchart of a method **1700** for operating a sand separation system (e.g., the system(s) of FIGS. **13-16**), according to an embodiment. More particularly, the method **1700** may combine the HEDC(s) **1310** with the MPMs **1320**, which may de-bottleneck production and/or flowback. The method **1700** may de-bottleneck the opening of a well and/or substantially reduce the capital costs and ongoing maintenance costs of a well pad.

[0138] An illustrative order of the method **1700** is provided below; however, one or more steps of the method **1700** may be performed in a different order, simultaneously, repeated, or omitted.

[0139] The method **1700** may include separating the solids from the mixed fluid to produce the solids and the separated fluid, as at **1705**. The separation may be performed by the separator(s) **1310**.

[0140] The method **1700** may also include measuring one or more first properties of the separated fluid, as at **1710**. The one or more first properties may be measured by the multiphase meter(s) **1320**. As mentioned above, the first properties may be or include volume, flowrate, sand content, sand volume, other solids content, or a combination thereof.

[0141] The method **1700** may also include controlling a flow rate of the separated fluid in response to the one or more first properties, as at **1715**. The flow rate may be controlled using the choke(s) **1315**.

[0142] The method **1700** may also include transferring the separated fluid to a production facility or a pipeline, as at **1720**. The separated fluid may be transferred after the flow rate is controlled.

[0143] The method **1700** may also include transferring the solids to the tank (or pit) **1335**, as at **1725**. The solids may be transferred from the separator(s) **1310** to the tank (or pit) **1335**.

[0144] The method **1700** may also include measuring one or more second properties, as at **1730**. The second properties may be measured by the controller **1340**. As mentioned above, the one or more second properties may be of or related to the separator(s) **1310**, the choke(s) **1315**, the multiphase meter(s) **1320**, the tank (or pit) **1335**, the separated fluid, or a combination thereof.

[0145] The method **1700** may also include controlling the separator(s) **1310**, the choke(s) **1315**, the multiphase meter (s) **1320**, and/or the tank (or pit) **1335** in response to the one or more second properties, as at **1735**.

[0146] In an embodiment, a performance of the separator (s) **1310** may be evaluated based upon the one or more first properties, the one or more second properties, or both. In another embodiment, one or more nozzles and/or inserts of the separator(s) **1310** may be selected, installed, removed, or modified based upon the one or more first properties, the one or more second properties, or both.

[0147] As used herein, the terms "inner" and "outer"; "up" and "down"; "upper" and "lower"; "upward" and "downward"; "above" and "below"; "inward" and "outward"; "uphole" and "downhole"; and other like terms as used herein refer to relative positions to one another and are not intended to denote a particular direction or spatial orientation. The terms "couple," "coupled," "connect," "connection," "connected," "in connection with," and "connecting" refer to "in direct connection with" or "in connection with via one or more intermediate elements or members."

[0148] The foregoing has outlined features of several embodiments so that those skilled in the art may better understand the present disclosure. Those skilled 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. Those skilled in the art should also realize that such equivalent constructions do not depart from the spirit and scope of the present disclosure, and that they may make various changes, substitutions, and alterations herein without departing from the spirit and scope of the present disclosure.

What is claimed is:

1. A sand separation system, comprising:
one or more separators configured to receive a mixed fluid from one or more wells or wellheads and to separate solids from the mixed fluid to produce the solids and a separated fluid;
one or more chokes downstream from and in fluid communication with the one or more separators, wherein each of the one or more chokes is configured to receive the separated fluid from a corresponding one of the one or more separators and to control a flow rate of the separated fluid therethrough; and
one or more multiphase meters downstream from and in fluid communication with the one or more chokes, wherein each of the multiphase meters is configured to measure one or more first properties of the separated fluid and to adjust the one or more chokes in response to the one or more first properties, and wherein the separated fluid is transferred from the one or more chokes or the one or more multiphase meters to a production facility or a pipeline.

2. The sand separation system of claim 1, wherein the one or more separators provide de-bottlenecking and allow for unrestricted flow of the mixed fluid from the one or more wells or wellheads to the production facility or the pipeline.

3. The sand separation system of claim 1, wherein the sand separation system does not include a separator between the one or more chokes or the one or more multiphase meters and the production facility or the pipeline.

4. The sand separation system of claim 1, further comprising a tank or pit downstream from and in fluid communication with the one or more separators, wherein the tank or pit is configured to receive the solids from the one or more separators.

5. The sand separation system of claim 4, further comprising a controller in communication with the one or more separators, the one or more chokes, the one or more multiphase meters, and the tank or the pit.

6. The sand separation system of claim 5, wherein the controller is configured to measure more or more second properties of one or more separators, the one or more chokes, the one or more multiphase meters, the tank or the pit, the separated fluid, or combination thereof, and wherein the controller is configured to adjust the one or more separators and/or the one or more chokes in response to the one or more second properties.

7. The sand separation system of claim 1, further comprising an automatic blowdown unit in communication with the one or more separators, wherein the automatic blowdown unit is configured to permit the solids stored in the one or more separators to exit the one or more separators.

8. The sand separation system of claim 7, further comprising a sand quantification unit in communication with the automatic blowdown unit, wherein the sand quantification unit is configured to measure and/or quantify the solids.

9. A method for operating a sand separation system, the method comprising:
separating solids from a mixed fluid using a separator to produce the solids and a separated fluid, wherein the mixed fluid is received by the separator from a well or a wellhead;
measuring one or more first properties of the separated fluid using a multiphase meter;
controlling a flow rate of the separated fluid using a choke in response to the one or more first properties; and
transferring the separated fluid to a production facility or a pipeline after the flow rate is controlled.

10. The method of claim 9, wherein the separator provides de-bottlenecking and allows for unrestricted flow of the mixed fluid from the well or wellhead to the production facility or the pipeline.

11. The method of claim 9, wherein the separated fluid flows from the choke to the production facility or the pipeline without having additional solids removed therefrom by a second separator.

12. The method of claim 9, further comprising transferring the solids to a tank or a pit.

13. The method of claim 9, further comprising:
measuring one or more second properties of the separator, the multiphase meter, the choke, or a combination thereof using a controller; and
controlling the separator, the multiphase meter, the choke, or a combination thereof in response to the one or more second properties.

14. The method of claim 9, further comprising evaluating a performance of the separator based upon the one or more first properties.

15. The method of claim 9, further comprising quantifying the solids exiting the separator and controlling the separator.

16. A sand separation system, comprising:
one or more separators configured to separate solids from a mixed fluid and to produce the solids and a separated fluid;
one or more chokes configured to receive the separated fluid from a corresponding one of the one or more separators and to control a flow rate of the separated fluid therethrough;
one or more multiphase meters configured to measure one or more first properties of the separated fluid and to adjust the one or more chokes in response to the one or more first properties; and
a controller configured to measure more or more second properties of one or more separators, the one or more chokes, the one or more multiphase meters, the separated fluid, or combination thereof, and wherein the controller is configured to adjust the one or more separators and/or the one or more chokes in response to the one or more second properties.

17. The sand separation system of claim 16, further comprising a tank or pit configured to receive the solids from the one or more separators.

18. The sand separation system of claim 16, wherein the one or more chokes are downstream from the one or more separators and the one or more multiphase meters are downstream from the one or more chokes.

19. The sand separation system of claim 16, wherein the separated fluid is transferred from the one or more chokes or the one or more multiphase meters to a production facility or a pipeline.

20. The sand separation system of claim 19, wherein the sand separation system does not include a separator between the one or more chokes or the one or more multiphase meters and the production facility or the pipeline.

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