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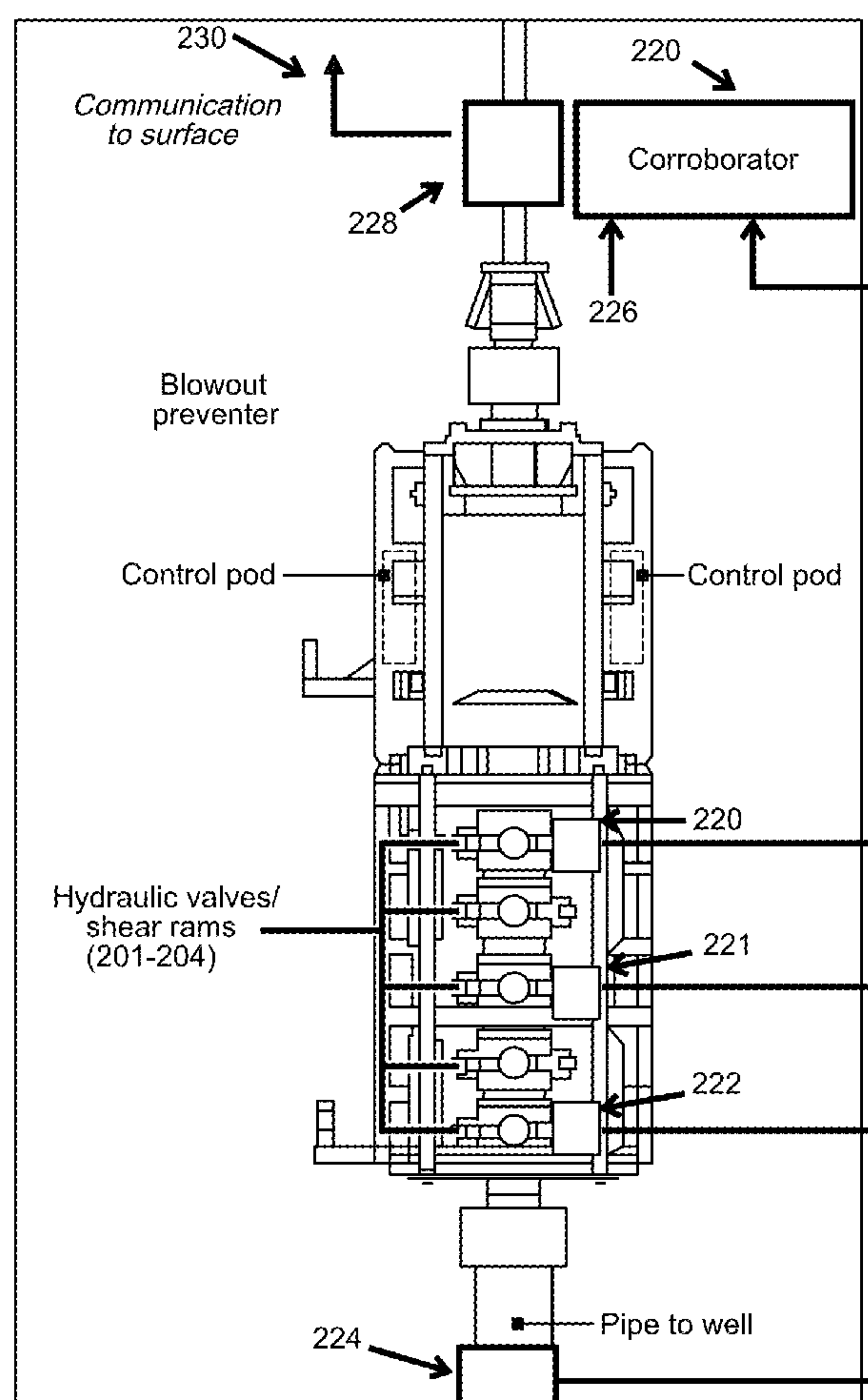
(19) **United States**(12) **Patent Application Publication**  
**Mallinson et al.**(10) **Pub. No.: US 2013/0153241 A1**(43) **Pub. Date: Jun. 20, 2013**(54) **BLOW OUT PREVENTER (BOP)**  
**CORROBORATOR**(52) **U.S. Cl.**CPC ..... *E21B 34/04* (2013.01)USPC ..... **166/363**(75) Inventors: **Theodore James Mallinson**, Houston,  
TX (US); **Thomas O'Donnell**, New  
York, NY (US); **Sergey Sotskiy**,  
Moscow (RU)

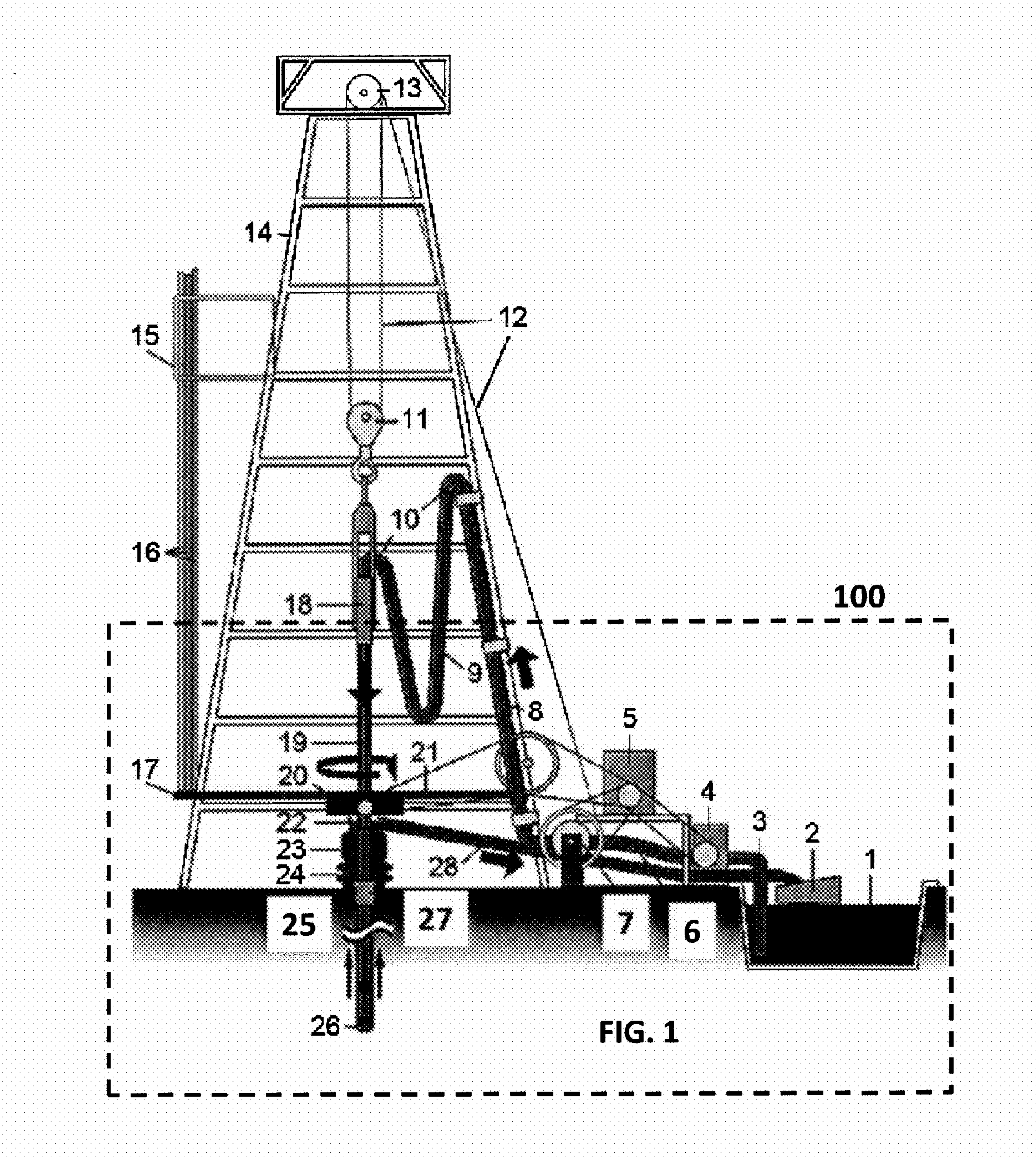
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**ABSTRACT**(73) Assignee: **Siemens Corporation**, Iselin, NJ (US)(21) Appl. No.: **13/585,118**(22) Filed: **Aug. 14, 2012****Related U.S. Application Data**(60) Provisional application No. 61/570,358, filed on Dec.  
14, 2011.**Publication Classification**(51) **Int. Cl.***E21B 34/04*

(2006.01)

Systems and methods supplementing existing management methods to corroborate performance of a blow out preventer for a submerged well. The corroborator is located on the blow out preventer and includes a flow meter external to a pipe to measure flow inside the pipe, a pipe joint locator, a ram seal confirmation agent and a dedicated communication connection from the corroborator to a computer topside. Data from at least one sensor topside, which may represent a mud tank level, is also received. The computer calculates a probability that a malfunction related to the well occurs. The computer implements a Principal Component Analysis model of the well based on historical data, to assess a likelihood that a threshold value will be surpassed based on collected sensor data and to generate an alert.







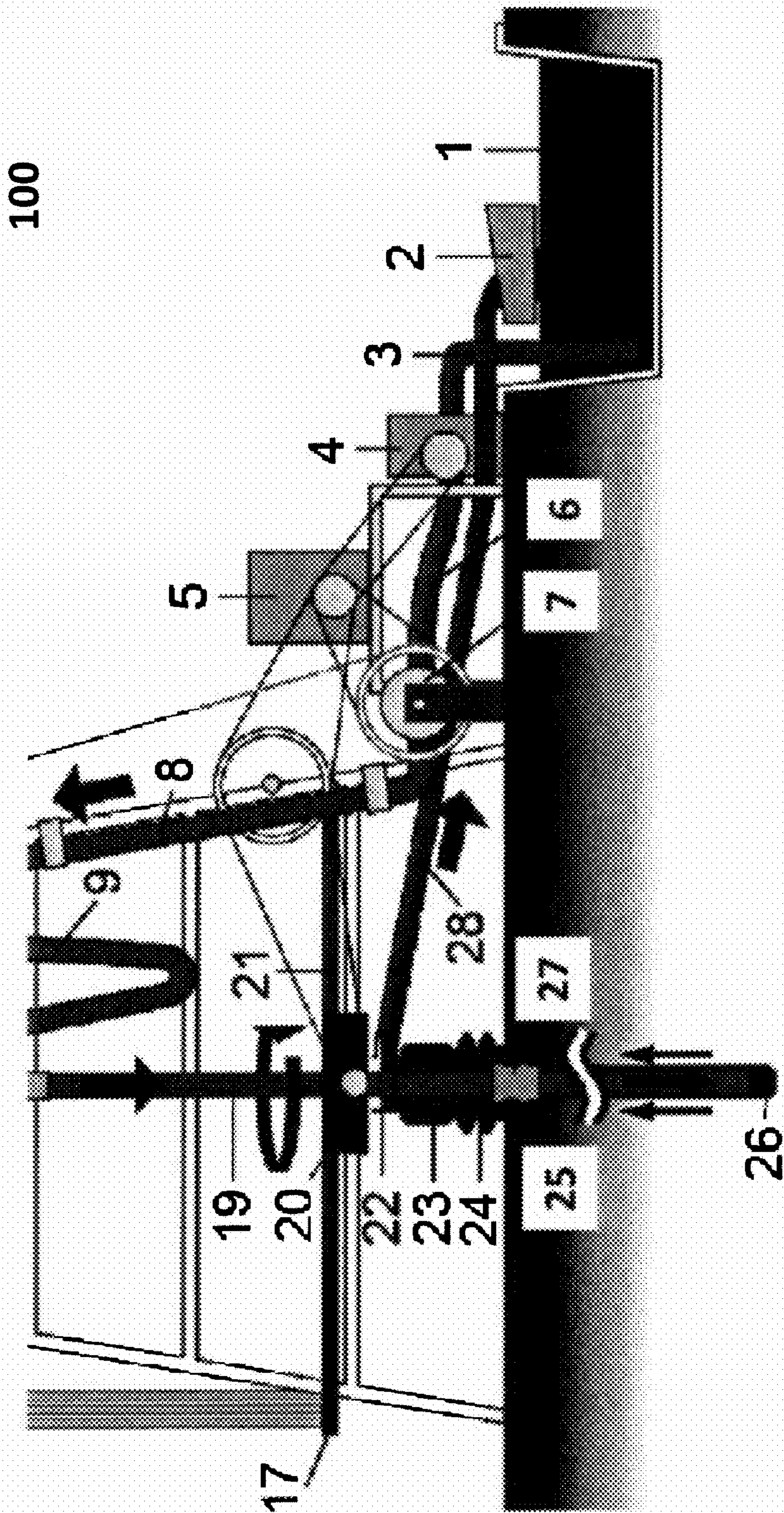


FIG. 2



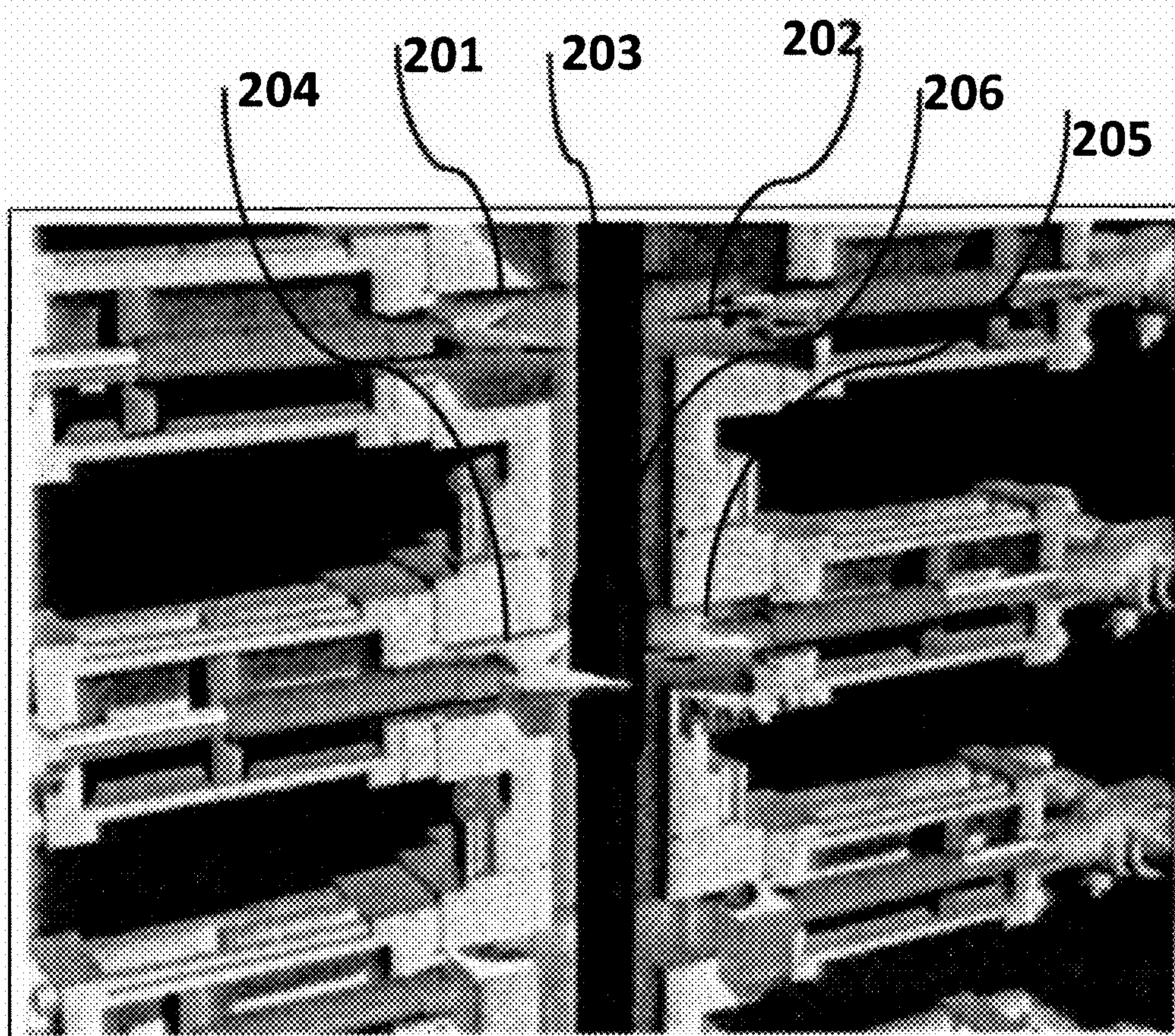


FIG. 3

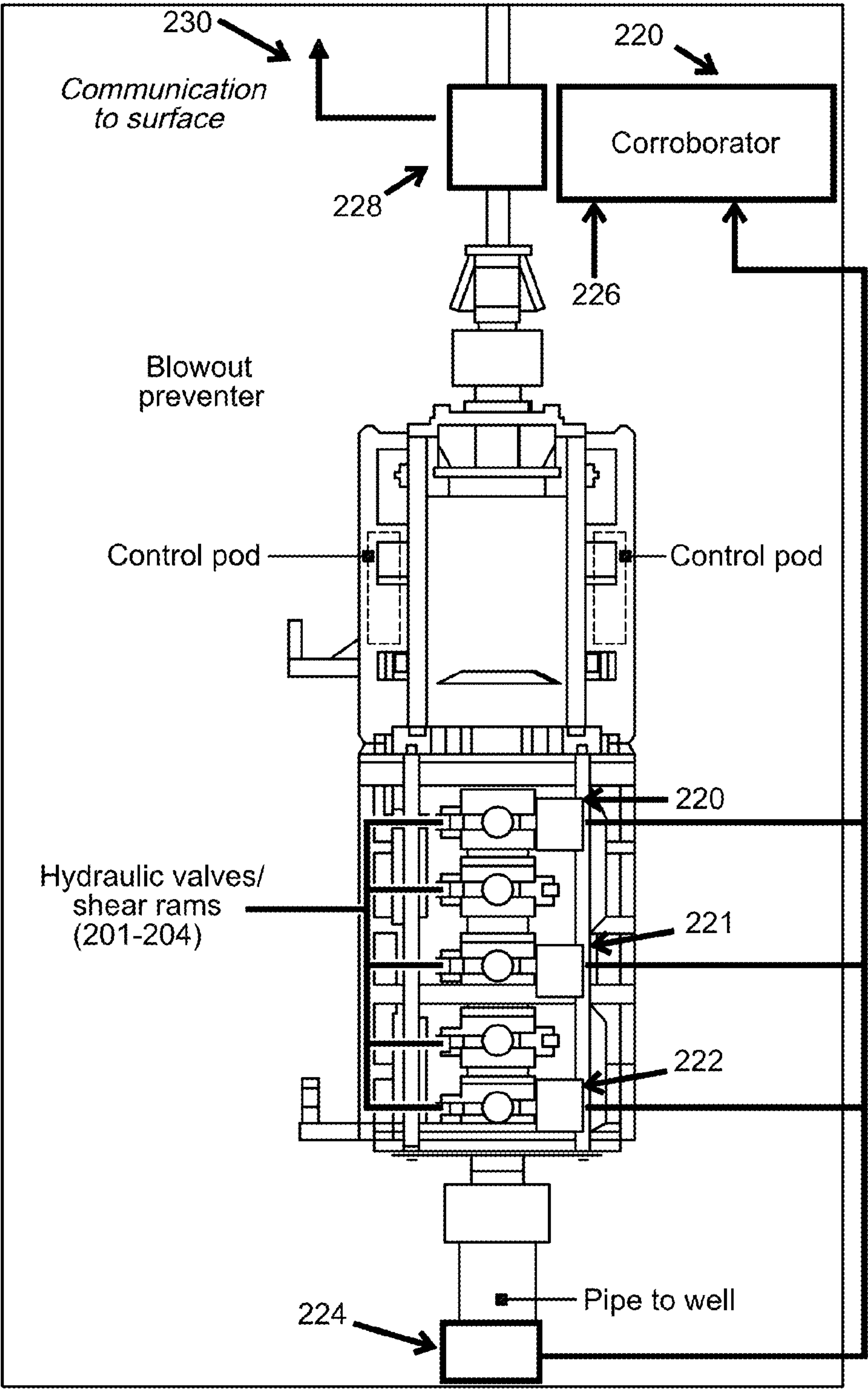
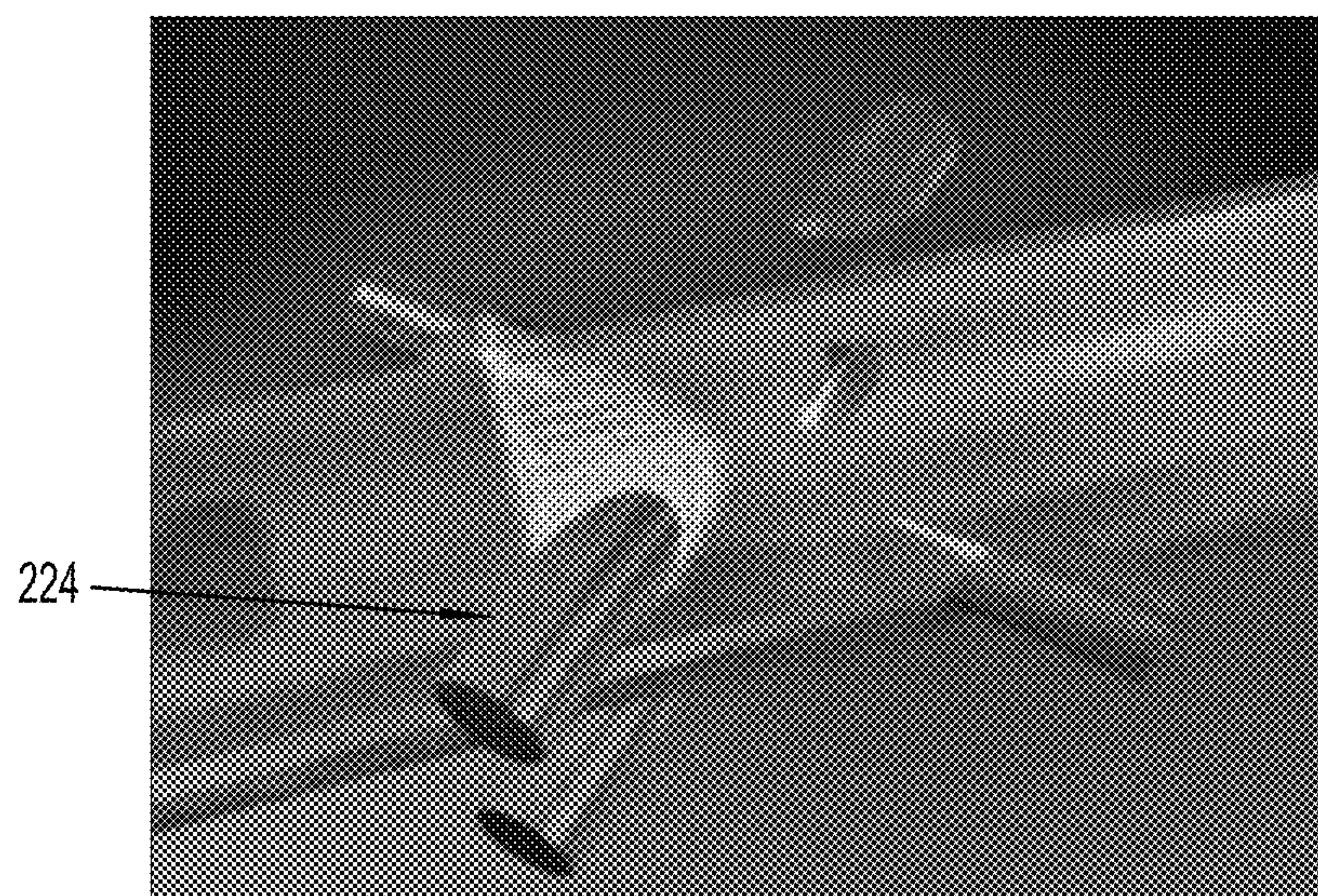
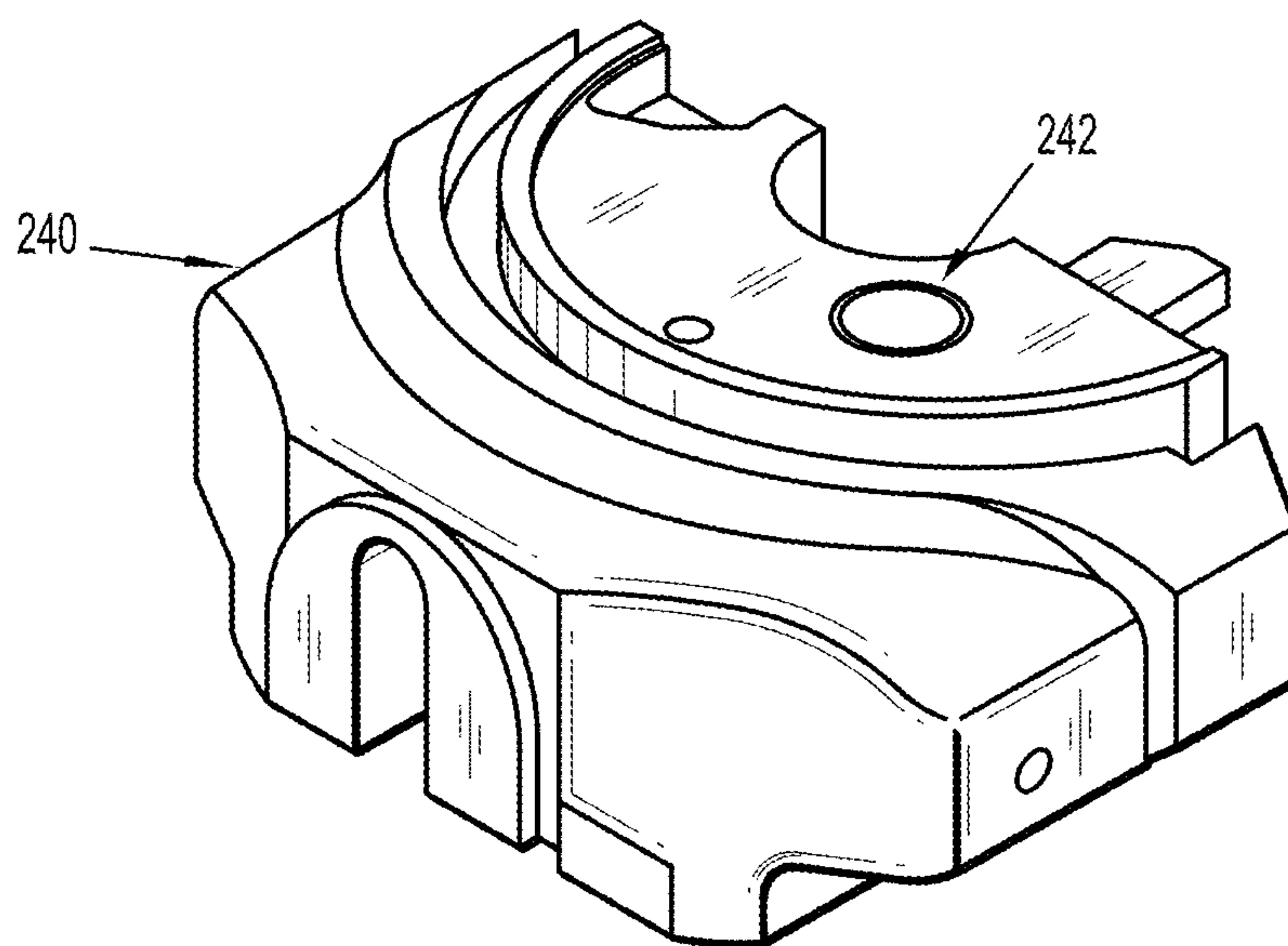


FIG. 4





**FIG. 5**



**FIG. 6**

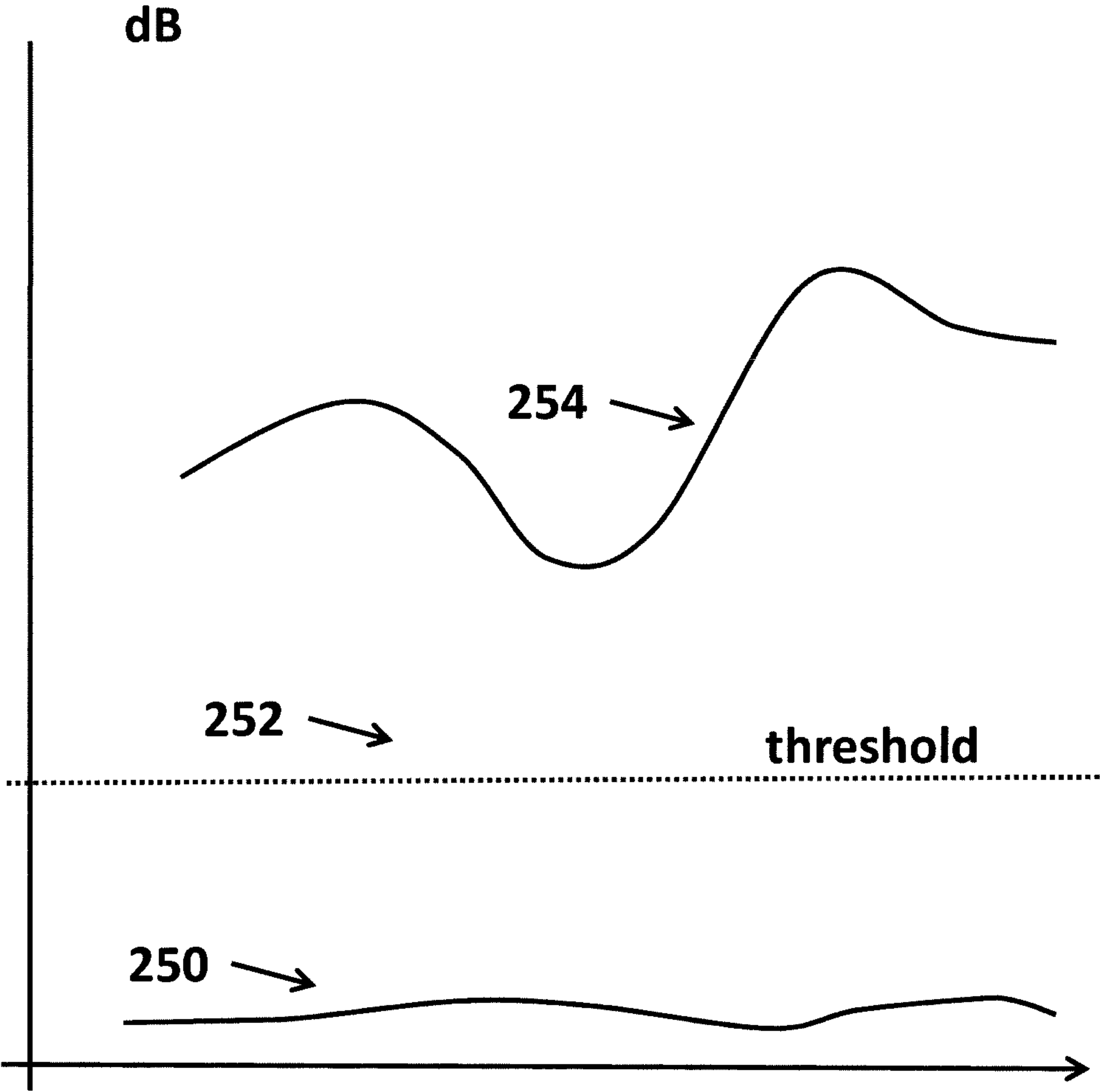
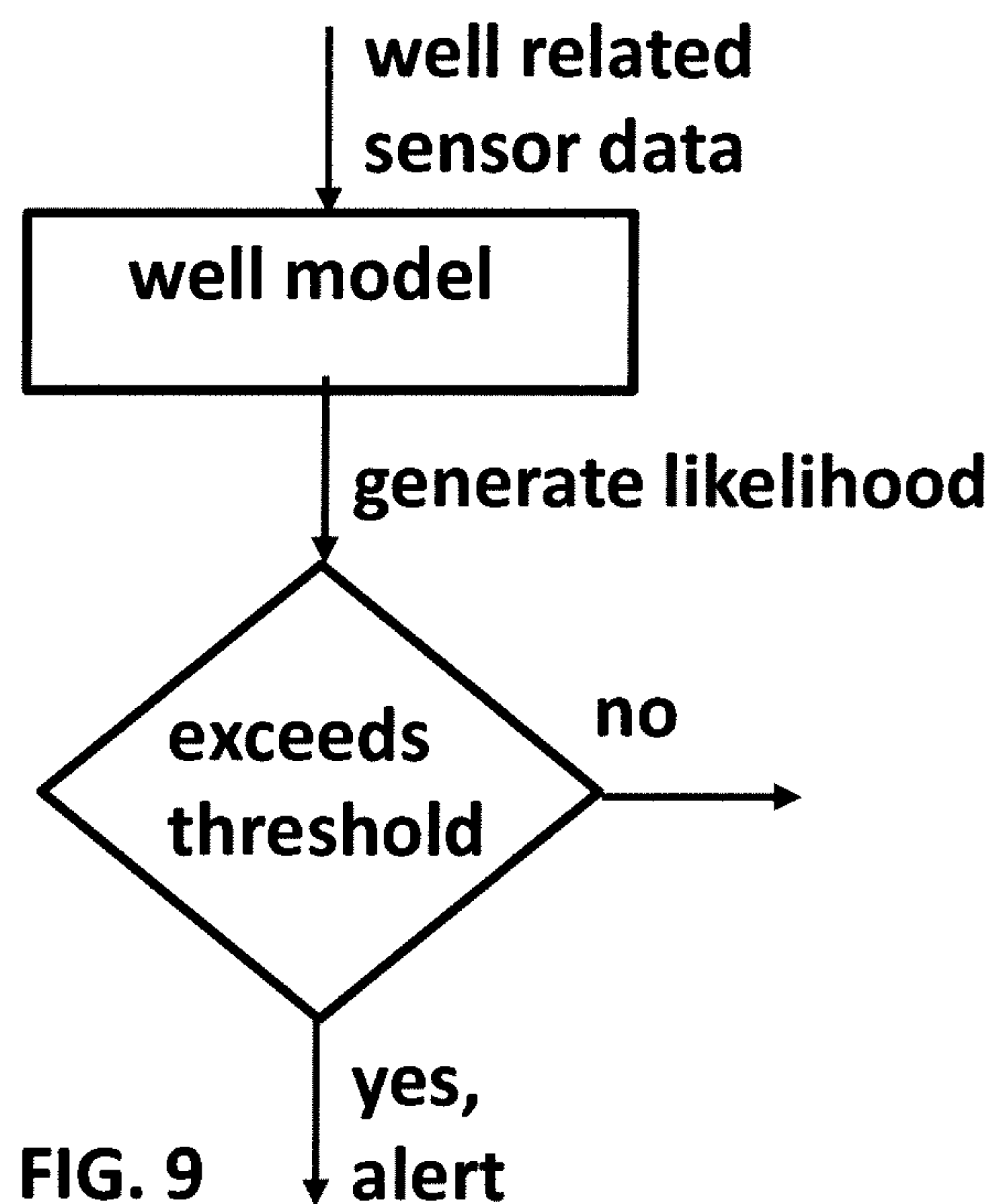
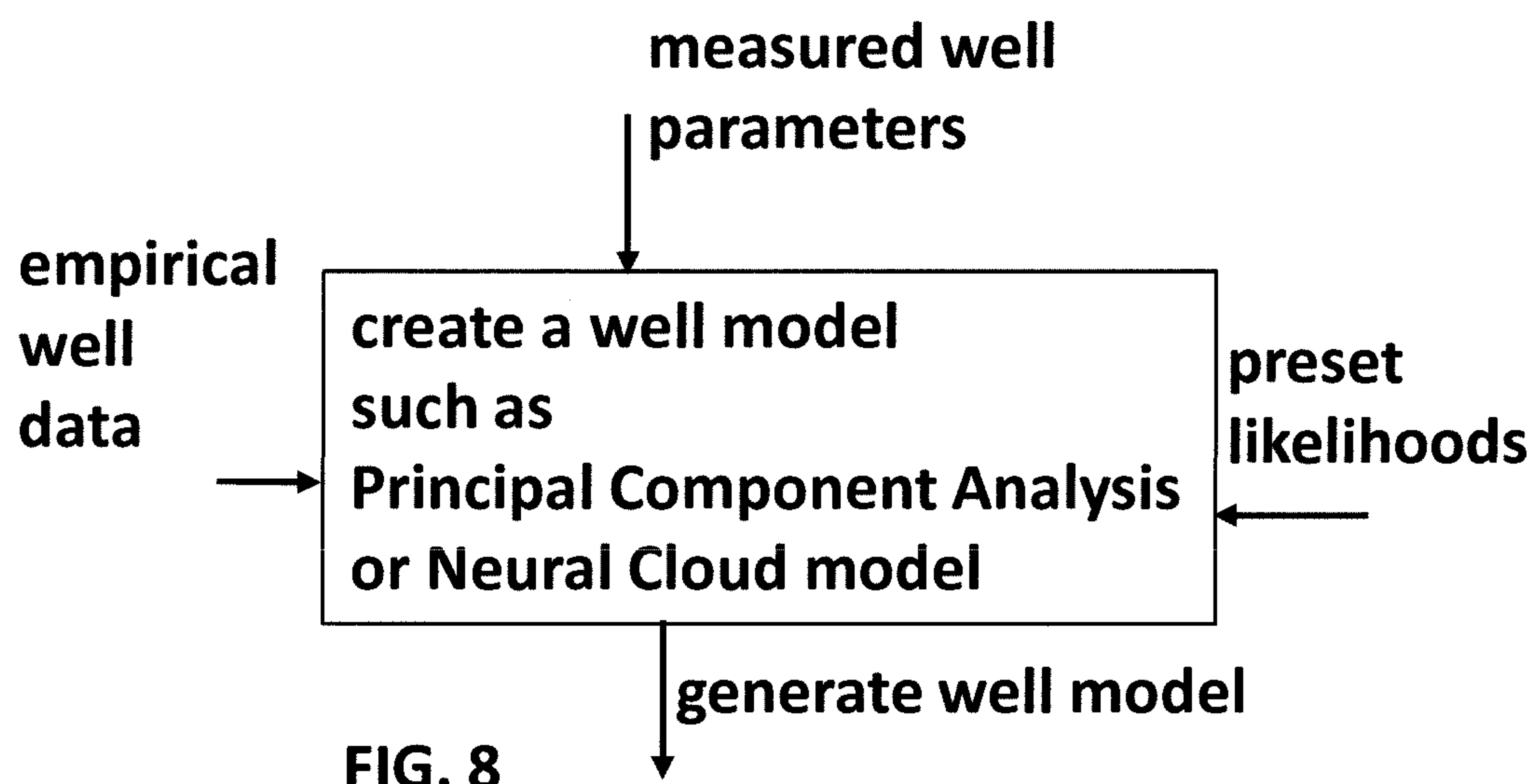


FIG. 7





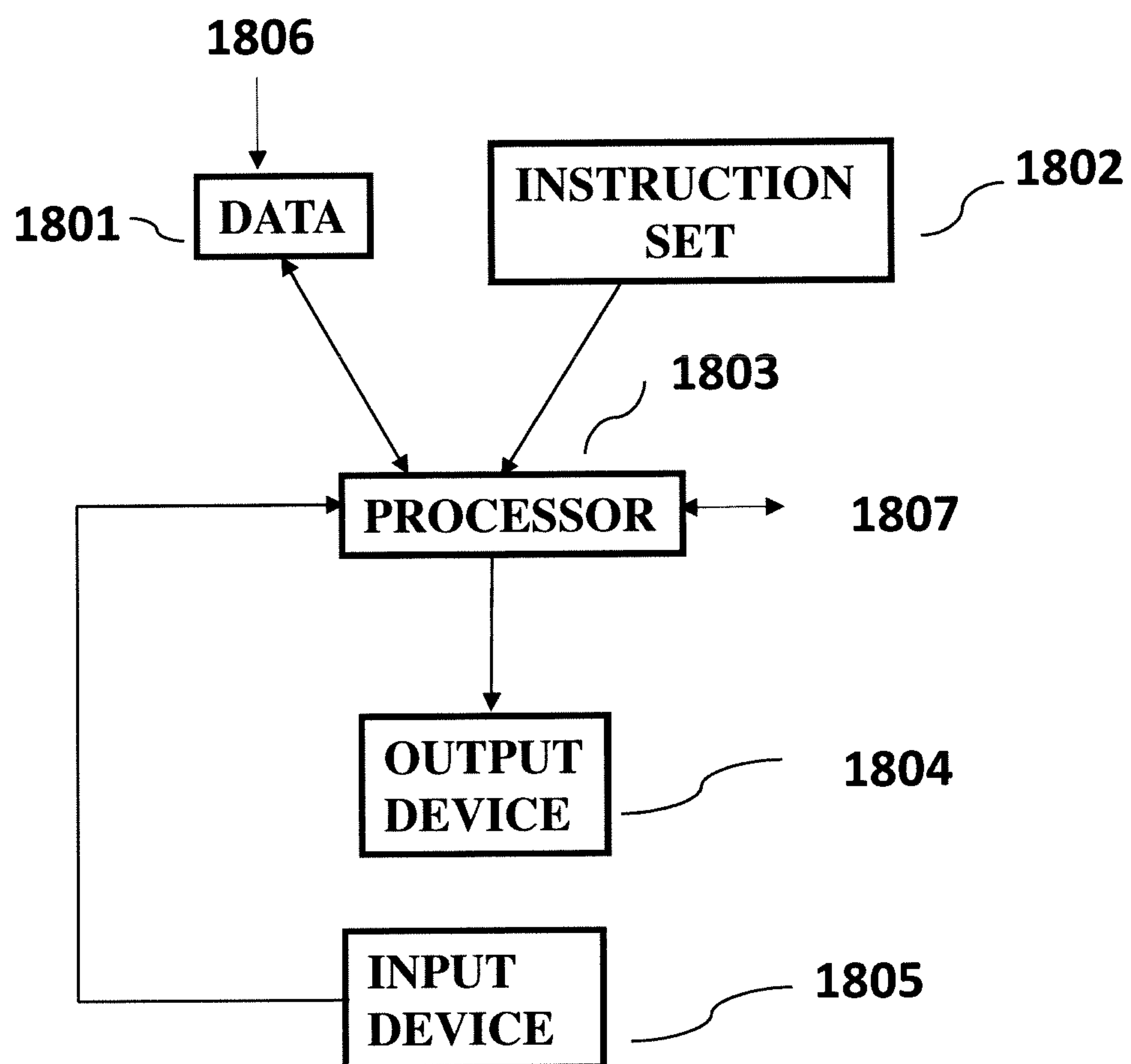


FIG. 10



## **BLOW OUT PREVENTER (BOP) CORROBORATOR**

### STATEMENT OF RELATED CASES

**[0001]** The present application claims priority to and the benefit of U.S. Provisional Patent Application Ser. No. 61/570,358 filed on Dec. 14, 2011, which is incorporated herein by reference in its entirety.

### FIELD OF THE INVENTION

**[0002]** The present invention relates generally to managing a Blow Out Preventer (BOP) at a gas or oil off-shore well operation prior to, in prevention of, or during an evolving emergency. The invention in particular relates to providing early decision support to managing the BOP at the earliest stages of the emergency. The invention also relates to a novel BOP structure.

### BACKGROUND OF THE INVENTION

**[0003]** Oil and gas field operations typically involve drilling and operating wells to locate and retrieve hydrocarbons. Increasingly, rigs are positioned at wellsites in relatively deep water. Tools, such as drilling tools, tubing and pipes and are deployed at these wells to explore submerged reservoirs. It is important to prevent spillage and leakage of fluids from the well into the environment.

**[0004]** While well operators generally do their utmost to prevent spillage or leakage, it is sometimes unavoidable that equipment malfunction or breakdown takes place. Because of the nature of deep water drilling, there is an inherent time lag between events taking place downhole or at the BOP and the effects of the events being seen at the facility. To prevent or limit spillage from the well or pipes into open waters it is important to collect and have data available to assess an emerging equipment failure at the earliest opportunity and for personnel and control systems to have access to clear and visible evidence enabling appropriate counter-measures to be taken.

**[0005]** Published analyses of the Deepwater Horizon accident (Macondo) suggest a lack of sufficient information about the condition of the well and the related equipment and a lack of timely information about the evolving emergency contributed to a failure to support key decisions to address the evolving disaster. It has been discovered that several key pieces of information could have led to a different and more positive outcome to the ensuing events.

**[0006]** These include a lack of accurate information about the pipe configuration, incomplete feedback on BOP performance, and a lack of information about the effectiveness of the BOP sealing and other critical and timely information.

**[0007]** Accordingly, improved and novel methods and systems for providing and/or assessing timely, accurate and complete information related to well equipment are required.

### SUMMARY OF THE INVENTION

**[0008]** Aspects of the present invention provide systems and methods to assist in the operation of a well blow out preventer with a corroborator positioned on the blow out preventer.

**[0009]** In accordance with an aspect of the present invention, a method is provided to monitor a blow-out preventer (BOP) of a well submerged under a water surface including at least one pipe from the well to a location above the water

surface, generating a plurality of signals including a signal from a flow meter external to the at least one pipe to measure a flow inside the at least one pipe, and a ram seal confirmation agent signal from an acoustic sensor, collecting and sending the plurality of signals by a BOP corroborator over a dedicated transmission connection to a monitoring computer device at the location above the water surface, and the monitoring computer device enabled to decide based on the received plurality of signals to generate an alert related to an activation of the BOP.

**[0010]** A novel BOP structure is also provided. In accordance with an aspect of the present invention, the BOP includes a corroborator to assist operation of a submerged well blow out preventer (BOP) attached to a pipe from the well to topside. The corroborator can include a processor having a direct communication link to the surface with interfaces to systems such as the mud tank for level balance indication, a flow meter attached external to the pipe to measure a flow inside the pipe that provides a signal representative of the flow to the processor, a pipe joint locator to determine locations of a plurality of joints in the pipe which provides information regarding the locations to the processor; and a ram seal confirmation agent, to detect vibrations from an interior of the pipe after the pipe has been sealed by a ram which provides a measure of the vibrations to the processor. The processor provides information related to the surface conditions, the flow, the locations and the vibrations to topside over the communication link.

**[0011]** In accordance with another aspect of the present invention, a method and apparatus are provided to monitor a blow-out preventer (BOP), further comprising the monitoring computer device receiving data from at least one sensor installed above the water surface.

**[0012]** In accordance with yet another aspect of the present invention, a method and apparatus are provided to monitor a blow-out preventer (BOP), wherein the at least one sensor measures a mud tank level.

**[0013]** In accordance with yet another aspect of the present invention, a method and apparatus are provided to monitor a blow-out preventer (BOP), wherein the at least one sensor measures a pressure.

**[0014]** In accordance with yet another aspect of the present invention, a method and apparatus are provided to monitor a blow-out preventer (BOP), wherein the monitoring computer device applies a well model that calculates a probability of a well malfunction.

**[0015]** In accordance with yet another aspect of the present invention, a method and apparatus are provided to monitor a blow-out preventer (BOP), wherein the probability is a likelihood of a malfunction that includes leakage of material into the water within a period of one hour.

**[0016]** In accordance with yet another aspect of the present invention, a method and apparatus are provided to monitor a blow-out preventer (BOP), wherein the model is based on a Principal Component Analysis of sensor data.

**[0017]** In accordance with yet another aspect of the present invention, a method and apparatus are provided to monitor a blow-out preventer (BOP), further comprising a sensor generating a joint signal related to a joint in the at least one pipe.

**[0018]** In accordance with yet another aspect of the present invention, a method and apparatus are provided to monitor a blow-out preventer (BOP), further comprising determining a position of the joint in the at least one pipe.



**[0019]** In accordance with yet another aspect of the present invention, a method and apparatus are provided to monitor a blow-out preventer (BOP), further comprising positioning shears of the BOP in such a manner that when activated the shears will not have to cut through the joint.

**[0020]** In accordance with yet a further aspect of the present invention, a corroborator and methods are provided, wherein the corroborator is located on the blow out preventer.

**[0021]** In accordance with yet a further aspect of the present invention, a corroborator and methods are provided, further comprising a dedicated transmission connection from the corroborator to a computer device topside to transmit a plurality of signals collected by the corroborator.

**[0022]** In accordance with yet a further aspect of the present invention, a corroborator and methods are provided, wherein the computer device is enabled to decide based on the plurality of signals transmitted by the corroborator to generate an alert related to an activation of the blow out preventer.

**[0023]** In accordance with yet a further aspect of the present invention, a corroborator and methods are provided, wherein the computer device receives a signal from at least one sensor installed topside.

**[0024]** In accordance with yet a further aspect of the present invention, a corroborator and methods are provided, wherein the at least one sensor measures a mud tank level.

**[0025]** In accordance with yet a further aspect of the present invention, a corroborator and methods are provided, wherein the computer device applies a well model that calculates a probability of a well malfunction.

**[0026]** In accordance with yet a further aspect of the present invention, a corroborator and methods are provided, wherein the model is based on a Principal Component Analysis of sensor data.

**[0027]** In accordance with yet a further aspect of the present invention, a corroborator and methods are provided, wherein the probability is a likelihood of a malfunction that includes leakage of material from the well within a period of one hour.

**[0028]** In accordance with yet a further aspect of the present invention, a corroborator and methods are provided, wherein shears of the blow out preventer are positioned based on a signal generated by the pipe joint locator in such a manner that when activated the shears will not have to cut through the joint.

#### BRIEF DESCRIPTION OF THE DRAWINGS

**[0029]** FIGS. 1 and 2 illustrate components of a drill well;

**[0030]** FIG. 3 illustrates a shear ram failure;

**[0031]** FIG. 4 illustrates a blow out preventer in accordance with an aspect of the present invention;

**[0032]** FIG. 5 illustrates a flow meter in a pipe in accordance with an aspect of the present invention;

**[0033]** FIG. 6 illustrates a hub near a ram having an integral acoustical sensor in accordance with an aspect of the present invention;

**[0034]** FIG. 7 illustrates a method of processing information from the blow out preventer in accordance with an aspect of the present invention;

**[0035]** FIGS. 8 and 9 illustrate methods in accordance with various steps of the present invention; and

**[0036]** FIG. 10 illustrates a system enabled to perform steps of methods provided in accordance with various aspects of the present invention.

#### DETAILED DESCRIPTION

**[0037]** It has been argued that a key contributor to the Deepwater Horizon accident at Macondo was lack of sufficient/timely information to support key decisions. As the events unfolded, engineers on the rig were aware that there was a problem. However, they were either:

**[0038]** 1) not aware of the true extent of the problem;

**[0039]** 2) did not trust that the data on hand reflected the downhole or mudline conditions accurately;

**[0040]** 3) did not receive the relevant information soon enough; or

**[0041]** 4) some combination of above.

**[0042]** Several key pieces of information may have led to a different outcome to this series of events. For example,

**[0043]** 1) Knowledge of the pipe position might have avoided failed attempts at deploying the Blow Out Preventer (BOP) shear rams.

**[0044]** 2) Proper information could have alerted the rig engineers to the seriousness of the situation more rapidly, through indication that some pipe had been pushed out of hole, that is, that the pipe position had changed unexpectedly.

**[0045]** 3) Feedback on the BOP performance could have prevented it from being relied upon in its compromised state during the incident, indicating that ram seal material was no longer intact during previous pressure tests.

**[0046]** 4) Confirmation of the effectiveness of the BOP in sealing the well was missing for some time resulting in multiple fruitless attempts at ROV activation.

**[0047]** This lack of information is not exclusive to the Macondo case. Operators of conventional BOPs lack adequate means to arrive at appropriate conclusions in a timely fashion, even though these devices are commonly seen as fail safe and are intended to protect the facility against a variety of events.

**[0048]** A simple diagram of a drilling rig and its basic operation is provided at and copied from the Wikipedia webpage: <URL[http://en.wikipedia.org/wiki/List\\_of\\_components\\_of\\_oil\\_drilling\\_rigs](http://en.wikipedia.org/wiki/List_of_components_of_oil_drilling_rigs)>. It is reproduced in FIG. 1. The identified components include: a Mud tank 1; Shale shakers 2; Suction line (mud pump) 3; Mud pump 4; Motor or power source 5; Vibrating hose 6; Draw-works 7; Standpipe 8; Kelly hose 9; Goose-neck 10; Traveling block 11; Drill line 12; Crown block 13; Derrick 14; Monkey board 15; Stand (of drill pipe) 16; Pipe rack (floor) 17; Swivel 18 (on newer rigs this may be replaced by a top drive); Kelly drive 19; Rotary table 20; Drill floor 21; Bell nipple 22; Blowout preventer (BOP) Annular type 23; Blowout preventer (BOP) Pipe ram & blind ram 24; Drill string 25; Drill bit 26; Casing head or Wellhead 27; and Flow line 28. A hook is also provided. To better show smaller components, section 100 of FIG. 1 is reproduced enlarged in 100 in FIG. 2.

**[0049]** An example of conventional information from which an engineer may infer a blowout is the rising of mud tank levels as illustrated in FIG. 1. In the far right, denoted by numeral 1, is the mud tank. Drilling fluid (mud) is pumped from this tank into the well being drilled to remove cuttings, cool the bit, and other purposes, and mud returns from the well to the pit during normal operations. During a blowout, reservoir fluids displace mud from the borehole into the mud tank. Mud is deposited via the flow line 28.

**[0050]** During normal drilling, the mud tank levels rise and fall predictably in accordance with the operation being performed. During a blowout, reservoir fluids displace the mud,



significantly and rapidly increasing the mud tank level. However, it takes some minutes to travel the several thousands of feet necessary to arrive topside. By the time it is apparent that the mud levels are abnormally high, precious minutes may have been lost. Further discussion with the mud engineer may be necessary to determine whether this rise in level is due to imminent blowout or some other activity.

**[0051]** Once it has been determined that a blowout is imminent or in progress, or if safety demands that the well be shut down for another reason, BOP pipe rams are deployed. Though there are a variety of pipe rams employed, most of them employ some sort of elastomer as a sealing surface. In cases where a ram is used to seal flow, if there is any damage to the sealing face there may continue to be a leak path, which could rapidly grow due to erosion and high pressure differential across the ram. This is especially true when pipe rams are used to close off annular flow (typically the return path to the surface), since these can be damaged by pulling pipe through the ram while engaged. This sealing face damage has been listed as a contributing cause to the accident at Macondo.

**[0052]** If the variety of pipe rams fails, the last BOP device to be used is a shear ram, which acts as a pair of scissors to shear the drill string and prevent both annular and tubing flow. The shear rams typically deployed are not designed to shear through tool joints (where two pieces of pipe connect) or pipe collars (heavy wall pipe employed at the end of the drill string). If the pipe is positioned such that the shear rams will be working against a tool joint, the shear ram may deploy but not shear the pipe completely. If this condition is known a priori, it is often possible to compensate by repositioning the pipe.

**[0053]** FIG. 3 illustrates the working of a shear ram. It shows a pipe 202 with a thicker pipe joint 206. A first pair of shears 201 and 202 is positioned to shear the normal pipe. The second pair of shears 204 and 205 is positioned to shear the pipe joint 206 and without further means may not be able to shear and close the pipe at joint 206. So, if the ram is deployed to sever the pipe at a joint or obstruction, it may not be able to completely stem the flow of oil due to inadequate closure.

**[0054]** Sometimes it is difficult to determine whether the deployment of the ram has succeeded or failed from a flow perspective. The ram may indicate that it is sealed. And, ROVs (Remotely Operated Vehicles) inspecting the exterior of the BOP may report similarly based on position indicators. However, the flow may not actually be stemmed. Direct measurements indicating the actual condition (rather than, for example, secondary indicators such as valve position) provide useful information in assessing the true state of the BOP.

**[0055]** Accordingly, conventional BOP technology does not solve the problems associated with blow out conditions and can be supplemented to provide information that is redundant, reliable, and timely. Herein, a system with a plurality of components, and a method of using those components, are provided in accordance with one or more aspects of the present invention that serves to corroborate the state of the BOP.

**[0056]** The Subsea BOP Corroborator, provided in accordance with an aspect of the present invention, preferably includes:

**[0057]** 1) A Flow Meter;

**[0058]** 2) A Pipe Joint Locator;

**[0059]** 3) A Ram Seal Confirmation Agent;

**[0060]** 4) An Artificial Intelligence system, for alerting personnel such as engineers to possible dangerous events;

**[0061]** 5) An Independent communication connection to the topside, including a transmitter and a receiver and preferably a multiplexer to combine data into a combined data stream and a demultiplexer to separate the individual data from the combined data stream, wherein the communication line is dedicated to carrying data traffic from the corroborator to topside for instance for rapid transfer of flow meter data to topside; and

**[0062]** 6) At least one computer device that collects and analyzes the data transmitted over the independent communication connection and creates an alert based on the analysis.

**[0063]** FIG. 4 illustrates several aspects of the present invention. The Corroborator 220 sits atop the BOP and has an independent communication line 230 to the topside. The corroborator could also be located below the BOP. The communication line 230 can be directly from the corroborator or can be provided from a communication device 228. One aspect of the corroborator's usefulness is this fast direct line to the surface. This allows engineers to react to events at the borehole and take steps to ameliorate or prevent a blowout. This communications channel may piggyback on the drilling riser to topside. Components will be described further below.

**[0064]** Flow Meter (Item 224 in FIG. 4)

**[0065]** This component monitors the contents of the flow line and detects the occurrence of flow aberrations long before they manifest topside. It determines the direction and velocity of the fluids and reports the approximate composition based on density or other collected data. The flow meter 224 is connected to the corroborator 220 via a communication line and reports the information regarding the flow to the corroborator 220. There are several types of flow meter technologies which can fill this role, including ultrasound using for instance Doppler and/or transit time approaches and gamma ray. For example, an ultrasound flow meter from Krohne can be used, as illustrated further in FIG. 5. The flow meter 224 can be placed below the BOP. It can also be placed above the BOP in the line running directly to the surface. For example, the flow meter can be located near or at 228 in FIG. 4.

**[0066]** Through use of an external sensor no obstruction is presented to the drilling equipment passing through the BOP. The flow meter in one embodiment of the present invention is used to also determine a direction of flow. The flow meter in one embodiment of the present invention is used to also determine an approximate composition of contents of material in the flow through collection of fluid density data.

**[0067]** Pipe Joint Locator

**[0068]** This unit "counts" the joints as they pass by. In this way, the relative distance to the nearest joint at any time can be determined. In theory, it should be possible to determine this topside since the piping is rigid. However, the long distance between topside and BOP exacerbates any measurement errors.

**[0069]** There are many methods for doing the actual counting. The simplest involves the flow meter, if located at 228, which, depending on the technology, should be able to identify changes in the pipe wall thickness through the detection of increased attenuation. As a result, one knows where the joints are in the pipe and one can predict the position of the shear rams in a BOP relative to the joint (or the joint relative to the shears) so that the shears in the BOP when activated do not have to cut through a joint. Each time the increased thickness is measured, a processor in the corroborator 220



notes the position of the pipe joint. This is used by a processor to monitor the positions of the pipe joints in relation to the ram shears in the BOP. The pipe can be moved relative to the BOP to ensure that the rams are not positioned at a joint. Alternatively, the rams of the BOP can be staggered such that if one is located at a joint, the other rams will not be located at a joint, and joint location compared to shear ram location can be confirmed by the tool. In all cases, the positioning information is recorded. The processing can either be done at the corroborator 220 or the positioning information can be sent topside to a processor where the positioning of the ram shears in relation to the pipe joints can be determined and the position of the pipe adjusted as necessary to avoid locating pipe joints in the shear ram space.

**[0070]** Ram Seal Confirmation Agent(s) (Items 220-222 in FIG. 4)

**[0071]** In accordance with an aspect of the present invention, the ram seal conformation agent is an acoustic sensor or sensors 220-222 which detect the vibrations coming from the interior of the pipe and act as a redundancy check for the flow meter. If the ram seals the line properly, there should be no flow and hence no acoustic signature generated by flow. These sensors 220 to 222 in this unit, trained to learn the ambient background noise of the corroborator, are able to distinguish the flow state. Though this is a post operation datum, failure on the previous deployment may indicate sealing face problems and prevent engineers from trying to use the BOP in a damaged state. Damage resulting from tripping pipe through an activated ram in particular will be detected through the next pressure test. In one embodiment of the present invention, an acoustic signature of fluid passing a device intended to provide closures (e.g. annular ram, shear ram) is learned under different operating conditions. Such acoustic signature detection is applied after a ram has been closed to determine if flow still occurs through the device. The outputs from the acoustical sensors 242 in the hubs 240 (at locations 220 to 222) are reported to the corroborator 220 via the communication lines illustrated in FIG. 4. The corroborator can also be in communication with other surface facility data points.

**[0072]** The acoustic sensor can be located in a hub near the shear rams. FIG. 6 illustrates such a hub 240. The hub 240 includes an acoustic sensor 242 which senses flow near the pipe where ram shears operate. FIG. 7 illustrates processing of the acoustical signal in accordance with one aspect of the present invention. A threshold 252 for the acoustical signal is established. Ordinarily, the threshold is just above 0, but this can be varied depending on experience. If the ram shears have been activated, and a signal 250 from the sensors 242 is below the threshold, then the processor in the corroborator 220 determines that ram shears were successfully activated. On the other hand, if the signal 254 from any of the sensors 220 to 222 is above the threshold, either completely, partially or on average, then the processor in the corroborator determines that the ram shears were not successfully activated.

**[0073]** The information from the flow meter, the pipe joint position sensor and the ram shear acoustical sensors can be sent to a processor in the corroborator 220 for processing. Alternatively, the information can be sent topside without processing via communication line 230 to be processed topside.

**[0074]** A monitoring system which may be an Artificial Intelligence system for alerting engineers to possible dangerous events. This component uses condition monitoring tech-

nologies (e.g., neural clouds) to determine the likelihood of a blowout occurring. Its input would include the flow meter data and relevant surface measures (pressure, mud tank level, etc.) and its output would be a probability measure. In one embodiment of the present invention, a probability of a blow-out is assigned to a measurement of a single meter and a probability of a blow-out is assigned, wherein either a sudden and/or an unusual change in measurement may indicate an evolving problem. In one embodiment of the present invention a correlation is established between measurement results of different meters such as flow meters, pressure and tank level meters and is associated with a likelihood of a blow-out. In one embodiment of the present invention a set of measurements of several meters is determined from a plurality of wells and determine a normal operational range of wells.

**[0075]** In one embodiment of the present invention, measurements associated with well problems and with sensor problems are included. One can then apply known methods for instance by creating a Principal Components Analysis (PPCA) model as described in commonly owned US Patent Application Pub. No. 20120072173 to Yuan published on Mar. 22, 2012 and filed on Jul. 20, 2011 which is incorporated herein by reference. One can create a PPCA model from sensor data of a drilling well to model operational parameters of such a well. This is illustrated in FIG. 8, wherein actual sensor data, historic well data from other wells and perhaps preset thresholds are applied to generate a well model. This model can be dynamic wherein it learns from fresh data generated by well sensors and which is associated with actual well states. This allows for tuning of the system and for avoiding false positives and/or false negatives. It also allows for learning situations wherein sensor or data connection faults may be identified.

**[0076]** The model can generate a likelihood of the well moving to or being close to or being in a blow-out situation based on instant sensor data as illustrated in FIG. 9. In case the likelihood passes for instance a learned or a preset threshold, topside alarms will be activated alerting well operators to the potential danger.

**[0077]** In one embodiment of the present invention, the computing device calculates the need for an alert on a continuous basis. In one embodiment of the present invention, the computing device calculates the need for an alert at least every second. In one embodiment of the present invention, the computing device calculates the need for an alert at least every 10 seconds. In one embodiment of the present invention the computing device calculates the need for an alert at least every 30 seconds. In one embodiment of the present invention, the computing device calculates the need for an alert at least every minute. In one embodiment of the present invention, the computing device calculates the need for an alert at least every five minutes.

**[0078]** In one embodiment of the present invention, a timing of calculating a probability is determined by the operation, for instance while tripping pipe in or out, when a well is flowing, during a pressure test, prior to disengagement of the BOP, may all require different periods for data frequency. This could depend also on the depth of the BOP, as this would correspond to the magnitude of lag before the effect is noted at the surface. Accordingly, a system in accordance with an aspect of the present invention calculates probabilities at a faster rate when more activities are being performed affecting the well and its related equipment. In a further embodiment of the present invention, probabilities are calculated at a faster



rate when the BOP is submerged at a greater depth to off-set for increased delay in response.

**[0079]** Furthermore, the system in one embodiment of the present invention will generate probabilities at a faster rate when a calculated probability of a potential malfunction exceeds a threshold or when a calculated probability of a potential malfunction has increased beyond a threshold. In one embodiment of the present invention a probability is calculated at a first rate when all sensor data is within a first preset range. When at least one sensor provides data that meets a threshold the system will increase its calculation rate and its reporting. This addresses the issue of not overwhelming operators with irrelevant data, but timely alerting operators when the probability for an event has increased.

**[0080]** In one embodiment of the present invention, a computer applying a well model and receiving sensor data related to the well calculates a probability or likelihood that a malfunction of the well occurs within a certain time period that could involve a leak and/or a spillage into the water where the submerged well is located. In one embodiment of the present invention, the time period over which the probability is calculated is less than six hours. In one embodiment of the present invention, the time period over which the probability is calculated is less than one hour. In one embodiment of the present invention, the time period over which the probability is calculated is less than 30 minutes. In one embodiment of the present invention, the time period over which the probability is calculated is less than 15 minutes.

**[0081]** In one embodiment of the present invention, an increase of a probability of a malfunction is calculated. The reaction of monitoring staff to a calculation or an alert generated by the computer based on a calculation clearly depends on a magnitude of the probability and/or the time that a probability increases. For instance, if a small increase on an already small probability is expected over a period of six hours, then one action may be to apply a camera possibly on an ROV to inspect the part of the well that causes increased concern. However, if a significant probability of a malfunction within the next 1 hour is calculated and the probability of a malfunction increases substantially one may take immediate measures, including shutting down the well, flooding the well with mud or activating other aspects of the BOP including shearing the pipe and sealing the pipe. In accordance with one aspect of the present invention early indicators of an evolving malfunction would preferably alert operators six or more hours in advance and allow the evolving malfunction to be addressed in a planned and recoverable manner.

**[0082]** A rapid increase in probability of a malfunction, for instance a 5% increase of the probability of a malfunction every 10 minutes causes an alert that requires an immediate reaction by the well operators.

**[0083]** In one embodiment of the present invention, either the probability of a malfunction determined by the computer is so high or a change in probability is so rapid that a malfunction is either imminent or is already underway and no manual reaction by operators are expected to address or correct the malfunction. In that case the computer could instruct the BOP to activate and shut down the well immediately.

**[0084]** The methods as provided herein are, in one embodiment of the present invention, implemented on a system or a computer device. Thus, steps described herein are implemented on a processor, as shown in FIG. 10. A system illustrated in FIG. 10 and as provided herein in accordance with an aspect of the present invention is enabled for receiving, pro-

cessing and generating data. The system is provided with data that can be stored on a memory **1801**. Data may be obtained from a sensor such as flow sensor or a mud level sensor or from any other data relevant source. Data may also be provided on an input **1806**. Such data may be well sensor data or any other data that is helpful in a system as provided herein. The processor is also provided or programmed with an instruction set or program executing the methods of the present invention that is stored on a memory **1802** and is provided to the processor **1803**, which executes the instructions of **1802** to process the data from **1801**. Data, such as alert data or any other data triggered or caused by the processor can be outputted on an output device **1804**, which may be a display to display an alert or images that identify a faulty device in or around the well, or to a data storage device. The processor also has a communication channel **1807** to receive external data from a communication device and to transmit data to an external device. The system in one embodiment of the present invention has an input device **1805**, which may include a keyboard, a mouse, a pointing device, one or more cameras or any other device that can generate data to be provided to processor **1803**.

**[0085]** The processor can be dedicated or application specific hardware or circuitry. However, the processor can also be a general CPU, a controller or any other computing device that can execute the instructions of **1802**. Accordingly, the system as illustrated in FIG. 6 provides a system for processing data resulting from a sensor or any other data source and is enabled to execute the steps of the methods as provided herein as one or more aspects of the present invention.

**[0086]** In accordance with an aspect of the present invention, a system has been provided for directly communicating the state of a BOP to the topside in order to make corroborative information available to accurately determine the possibility of a failure on demand of this critical item, potentially leading to a blowout. Further, in accordance with an aspect of the present invention the deployment and probability of success for BOP ram activation is facilitated with a pipe joint locator and a ram seal confirmation agent. Also in accordance with an aspect of the present invention the application of a monitoring system is provided which combines information about the BOP state and its expected readiness with drilling operations data to automatically detect the onset of a blowout.

**[0087]** While there have been shown, described and pointed out fundamental novel features of the invention as applied to preferred embodiments thereof, it will be understood that various omissions and substitutions and changes in the form and details of the methods and systems illustrated and in its operation may be made by those skilled in the art without departing from the spirit of the invention. It is the intention, therefore, to be limited only as indicated by the scope of the claims.

1. A method to monitor a blow-out preventer (BOP) of a well submerged under a water surface including at least one pipe from the well to a location above the water surface, comprising:

generating a plurality of signals including a signal from a flow meter external to the at least one pipe to measure a flow inside the at least one pipe, and a ram seal confirmation agent signal from an acoustic sensor;

collecting and sending the plurality of signals by a BOP corroborator over a dedicated transmission connection to a monitoring computer device at the location above the water surface; and



the monitoring computer device enabled to decide based on the received plurality of signals to generate an alert related to an activation of the BOP.

2. The method of claim 1, further comprising the monitoring computer device receiving data from at least one sensor installed above the water surface.

3. The method of claim 2, wherein the at least one sensor measures a mud tank level.

4. The method of claim 2, wherein the at least one sensor measures a pressure.

5. The method of claim 1, wherein the monitoring computer device applies a well model that calculates a probability of a well malfunction.

6. The method of claim 5, wherein the probability is a likelihood of a malfunction that includes leakage of material into the water within a period of one hour.

7. The method of claim 5, wherein the model is based on a Principal Component Analysis of sensor data.

8. The method of claim 1, further comprising:  
a sensor generating a joint signal related to a joint in the at least one pipe.

9. The method of claim 8, further comprising:  
determining a position of the joint in the at least one pipe.

10. The method of claim 9, further comprising:  
positioning shears of the BOP in such a manner that when activated the shears will not have to cut through the joint.

11. A corroborator to assist operation of a submerged well blow out preventer (BOP) attached to a pipe from the well to topside, the corroborator in communication with a mud tank or other surface facility data points, comprising:

a processor having an interface that provides a level of contents of the mud tank or other surface facility data and having a direct communication link to topside;

a flow meter attached external to the pipe to measure a flow inside the pipe that provides a signal representative of the flow to the processor;

a pipe joint locator to determine locations of a plurality of joints in the pipe which provides information regarding the locations to the processor; and

a ram seal confirmation agent, to detect vibrations from an interior of the pipe after the pipe has been sealed by a ram which provides a measure of the vibrations to the processor;

wherein the processor provides information related to the level or other surface facility data, the flow, the locations and the vibrations to topside over the communication link.

12. The corroborator of claim 11, wherein the corroborator is located on the blow out preventer.

13. The corroborator of claim 11, further comprising:

a dedicated transmission connection from the corroborator to a computer device topside to transmit a plurality of signals collected by the corroborator.

14. The corroborator of claim 13, wherein the computer device is enabled to decide based on the plurality of signals transmitted by the corroborator to generate an alert related to an activation of the blow out preventer.

15. The corroborator of claim 14, wherein the computer device receives a signal from at least one sensor installed topside.

16. The corroborator of claim 15, wherein the at least one sensor measures a mud tank level.

17. The corroborator of claim 14, wherein the computer device applies a well model that calculates a probability of a well malfunction.

18. The corroborator of claim 7, wherein the model is based on a Principal Component Analysis of sensor data.

19. The corroborator of claim 17, wherein the probability is a likelihood of a malfunction that includes leakage of material from the well within a period of one hour.

20. The corroborator of claim 11, wherein shears of the blow out preventer are positioned based on a signal generated by the pipe joint locator in such a manner that when activated the shears will not have to cut through the joint.

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