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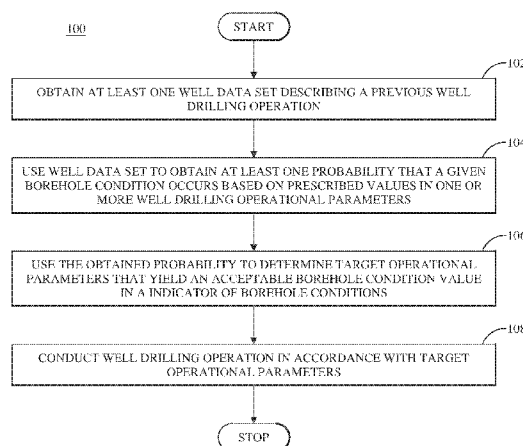


FIG. 1

(57) **Abstract:** A method for determining well drilling operational parameters (100) identifies at least one well data set describing a previous well drilling operation (102). The well data set is used to obtain at least one probability that a given borehole condition occurs based on prescribed values in one or more well drilling operation parameters (104). This obtained probability is used to determine target operational parameters that yield an acceptable borehole condition value in an indicator of borehole conditions (106), where the indicator of borehole conditions is a function of well drilling operational parameters.

IMPROVING DRILLING OPERATIONS USING DISPARATE WELL DATA TYPES

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority and benefit from U.S. Provisional Patent Application Nos. 62/016,671, filed June 25, 2014, for “Methods and Systems for Improving Drilling Operations Using Disparate Well Data Types” and 62/045,022, filed September 3, 2014 for “Methods and Systems for Improving Drilling Operations Using Disparate Well Data Types”, the entire contents of which are incorporated herein by reference.

TECHNICAL FIELD

[0002] Embodiments of the subject matter disclosed herein generally relate to methods and systems for drilling wells, more particularly, to the use of drilling data generated during the drilling of gas and oil wells.

BACKGROUND

[0003] In accessing oil and gas reserves, wells are drilled through a variety of geological formations with differing lithologies, e.g., shale, sandstone and limestone. A priority of drill operators is the generation of a fast well with minimal drilling problems as any wasted time during the drilling operation has a major financial impact. Offshore drilling, for example, costs between \$0.5-\$1m per day. Typical drilling problems include a stuck or sticking tool string, excessive borehole wall collapse and formation blow out. These drilling problems require expensive and time consuming solutions. Some of the drilling problems impinge on the subsequent operations in the well, for example, well logging to identify and quantify producing zones.

[0004] Data generated during the drilling process are used in real time to guide the drilling process and to minimize these costly drilling problems. Current drilling processes record significant amounts and types of drilling parameter data including Weight on Bit (WOB), Rate of Penetration (ROP), Torque, Mud Weight and equivalent circulation density (ECD), which is mud weight plus any extra material. For example, the vast majority of boreholes have at least one log recorded giving a borehole diameter. This gives a good indication of borehole conditions.

[0005] Geoscientists that interpret the generated data rely on data acquired from within or near the borehole with tools either as part of the drill string (LWD) or lowered after on a 'wireline'. The quality of data is often adversely affected by the borehole condition, especially the hole size. Wells are drilled with different nominal
5 bit sizes, e.g. 12.25 inches, and the holes are often much larger than this. Poor data quality has an impact on the computation of formation properties such as porosity and saturation which give the viability of a reservoir. Errors could lead to the need for expensive testing or result in poor completion decisions.

10 SUMMARY

[0006] Exemplary embodiments are directed to systems and methods that utilize a hazard probability matrix to assist well planning decisions both during drilling operations and before drilling operations commence. Drilling parameters are altered
15 or adjusted in real time or prior to drilling commencement to improve operations and completions based upon well logs indicating borehole conditions, for example oversize, undersize and borehole wall irregularities. Additional data considered include any other outlier or metric and any of the drilling parameters utilized in operation that may include differences specific to the geological formation of interest.

[0007] Exemplary embodiments are directed to a method for determining well drilling operational parameters. This method identifies at least one well data set describing a previous well drilling operation. The well data set includes at least one
20 of previous well drilling operational parameters, well borehole condition data and geological formation data. In one embodiment, the previous well drilling operational parameters include caliper, density log correction, tension, weight on bit, rate of penetration, torque, mud weight, deviation from vertical, equivalent circulation density and combinations thereof. In one embodiment, the well borehole condition data include pressure, hole diameter, stuck pipe, sticking tool string, borehole stability, formation blowout, borehole wall collapse and combinations thereof. In one
25 embodiment, the geological formation data include lithology, formation tops, porosity, saturation, physical location and combinations thereof.

[0008] The well data set is used to obtain at least one probability that a given borehole condition occurs based on prescribed values in one or more well drilling

operation parameters. In one embodiment, a plurality of well data sets describing a plurality of previous well drilling operations is identified, and the plurality of well data sets is used to obtain a plurality of probabilities of a plurality of given borehole conditions occurring based on prescribed values in one or more well drilling operation parameters.

[0009] The obtained probability is used to determine target operational parameters that yield an acceptable borehole condition value in an indicator of borehole conditions, the indicator of borehole conditions is a function of well drilling operational parameters. In one embodiment, the indicator of borehole conditions is differential caliper. In one embodiment, the obtained probability is used to determine current operational parameters by determining current operational parameters for a current well drilling operation, determining a current value for the indicator of borehole conditions using the current operational parameters and determining a transformation in one or more current operational parameters to change the current value of the indicator of the borehole conditions to the acceptable value.

[0010] In addition, the transformation is associated with a given probability of occurrence of a selected borehole condition based on prescribed values in one or more well drilling operation parameters, and a severity level is assigned that is associated with the selected borehole condition. The one or more current operation parameters are modified if the assigned severity level is greater than a pre-determined level. A chart is used to express the association of the transformation with the given probability of occurrence of the selected borehole condition, the assigned severity level and the transformation. In one embodiment, the chart is associated with a given geological formation. In one embodiment, the target operational parameters are used to determine a drilling plan, and a current well drilling operation is conducted in accordance with the drilling plan.

[0011] Exemplary embodiments are also directed to a method for drilling a well, the method in which at least one well data set describing a previous well drilling operation is identified. The well data set is used to obtain at least one probability that a given borehole condition occurs based on prescribed values in one or more well drilling operation parameters. The obtained probability is used to determine target operational parameters that yield an acceptable borehole condition value in an indicator of borehole conditions. The indicator of borehole conditions is a function of

well drilling operational parameters. A current well drilling operation is conducted in accordance with the target operational parameters.

[0012] In one embodiment, the target operational parameters are used to determine a drilling plan, and the current well drilling operation is conducted in accordance with the drilling plan. In another embodiment, current operational parameters are determined for the current well drilling operation as is a current value for the indicator of borehole conditions using the current operational parameters. A transformation is determined in one or more current operational parameters to change the current value of the indicator of the borehole conditions to the acceptable value. In one embodiment, the transformation is associated with a given probability of occurrence of a selected borehole condition based on prescribed values in one or more well drilling operation parameters. A severity level associated with the selected borehole condition is assigned, and the one or more current operation parameters is modified if the assigned severity level is greater than a pre-determined level.

[0013] In one embodiment, a chart is used to express the association of the transformation with the given probability of occurrence of the selected borehole condition, the assigned severity level and the transformation. The chart is associated with a given geological formation in which the current drilling operation is conducted.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate one or more embodiments and, together with the description, explain these embodiments. In the drawings:

[0015] Figure 1 is a flowchart of an embodiment of a method for determining well drilling operational parameters;

[0016] Figure 2 is a flowchart of an embodiment of a method of using target operational parameters for determining a well drilling plan;

[0017] Figure 3 is a flowchart of an embodiment of a method of using target operational parameters for determining a transformation in current well drilling parameters;

[0018] Figure 4 is graph of rate of penetration versus weight on bit illustrating the use of the transformation to modify a relationship between these well drilling parameters;

[0019] Figure 5 is an embodiment of a drilling analysis chart to provide a visual summary of the target well drilling parameters and transformations; and

[0020] Figure 6 illustrates an exemplary data processing device or system which can be used to implement the methods.

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DETAILED DESCRIPTION

[0021] The following description of the embodiments refers to the accompanying drawings. The same reference numbers in different drawings identify the same or similar elements. The following detailed description does not limit the invention. Instead, the scope of the invention is defined by the appended claims. Some of the following embodiments are discussed, for simplicity, with regard to local activity taking place within the area of well drilling activities. However, the embodiments to be discussed next are not limited to this configuration, but may be extended to other arrangements that include regional activity.

[0022] Reference throughout the specification to “one embodiment” or “an embodiment” means that a particular feature, structure or characteristic described in connection with an embodiment is included in at least one embodiment of the subject matter disclosed. Thus, the appearance of the phrases “in one embodiment” or “in an embodiment” in various places throughout the specification is not necessarily referring to the same embodiment. Further, the particular features, structures or characteristics may be combined in any suitable manner in one or more embodiments.

[0023] Referring initially to Figure 1, exemplary embodiments are directed to methods for determining well drilling operational parameters 100. These well drilling operational parameters can be used to modify current operational parameters during a current well drilling operation. Alternatively, the well drilling operational parameters are used to create a well drilling plan that is used to execute a new well drilling operation. Exemplary embodiments are also directed to conducting well drilling operations, i.e., drilling wells, in given geological formation conditions using the determined well drilling operational parameters.

[0024] In general, the historical data from one or more well drilling operations are used to create a well drilling plan that leverages the operational information obtained in these previous well drilling operations in order to avoid operational

problems that could arise during a current well drilling operation. Therefore, at least one well data set is obtained or computed describing a previous well drilling operation 102. Alternatively, a plurality of well data sets is obtained that describes a plurality of previous well drilling operations. In general, each well data set includes one or more categories of information about a given previous well drilling operation. These categories include, but are not limited to, well drilling operational parameters, well borehole condition data and geological formation data and geographical parameters.

[0025] Suitable previous well drilling operational parameters include, but are not limited to, caliper, density log correction, tension, weight on bit (WOB), rate of penetration (ROP), torque, mud weight (MW), deviation from vertical, i.e., from a well drilled vertically downward, and equivalent circulation density (ECD), which is a measure of mud weight plus any extra material. In addition, combinations of one or more of these previous well drilling operational parameters can be used. Suitable well borehole condition data include, but are not limited to, pressure, hole diameter, stuck pipe, sticking tool string, borehole stability, formation blowout, borehole wall collapse and combinations thereof. Suitable geological formation data include, but are not limited to, lithology, formation tops, porosity, saturation, physical location and combinations thereof. In one embodiment, the geological formation data are used to group the well drilling operation parameters and well borehole condition data by common geological formations.

[0026] Having obtained one or more well data sets, each well data set is used to obtain at least one probability of occurrence of a given borehole condition based on prescribed values in one or more well drilling operation parameters being measured or anticipated during that well drilling operation 104. Suitable analysis for determining the probabilities includes, but is not limited to, uni or multivariate analysis, regression, design of experiments (DoE) and Monte Carlo analysis. In general, the probability has the form $P(A|B)$, i.e., the probability of A given that B has occurred. As used herein, A is the defined indicator for bad or unacceptable borehole conditions, and B is the correlated factor or factors. P is the probability of the occurrence.

[0027] An example of this probability of occurrence is a probability of having a differential caliper (DCAL) reading greater than 0.5 if the WOB increases by 20%. In one embodiment, a plurality of well data sets is used to obtain a plurality of probabilities of occurrence of given borehole conditions based on the measurement or anticipation

of prescribed values in one or more well drilling operation parameters occurring during the well drilling operations.

[0028] The obtained probability is then used to determine target operational parameters that yield an acceptable borehole condition value in an indicator of borehole conditions 106. The determination of operational parameters could be conducted as a live or real-time operation, updated at certain intervals or milestones or conducted as a one-time operation. The indicator of borehole conditions is a function of well drilling operational parameters. Therefore, modifications in one or more well drilling operational parameters, e.g., modifying WOB or MW, change the indicator of borehole conditions. Modifying the indicator of borehole conditions avoids undesirable conditions in the borehole, e.g., excessive borehole diameter. Suitable indicators of borehole conditions include, but are not limited to, differential caliper (DCAL). Differential caliper measures the distance between the nominal bit size and the wellbore diameter as measured by a tool sensor and is an indicator of the borehole conditions including the size and the shape of the borehole.

[0029] When multiple probabilities are obtained, then target operational parameters or a set of target operational parameters are determined for each probability. Each determined set of target operational parameters avoids the occurrence of a given undesirable or unacceptable borehole condition. Each probability and, therefore, each set of target operational parameters can be associated with a given geological formation. A severity level can also be associated with each occurrence of an unacceptable borehole condition. In addition, a correlation between the probability of occurrence and the target operational parameters after transformation can be rated from strong through moderate to weak, with a strong correlation having a large influence and a weak correlation having little to none. This is possible simply on a well-by-well basis but is much more useful on a large scale view using one or preferable multiple metrics or parameters. The severity level and correlation are used in deciding whether to apply the associated target operational parameters, for example, using a cost/benefit type of analysis.

[0030] The target operational parameters are used to modify current operational parameters in real time for a current drilling operation. In addition, the target operational parameters are used in the planning of a new well drilling operation. Referring to Figure 2, an embodiment of the use of target operational parameters to create a drilling plan

for a new or current well drilling operation 200 is illustrated. Geological formation data are obtained 202 for an area in which the current well drilling operation is to be conducted. Then, target operational parameters associated with the identified geological formation data are identified 204, and these target operational parameters are used to determine a drilling plan 206.

[0031] Referring to Figure 3, an embodiment of the use of target operational parameters to modify an active current well drilling operation 300 is illustrated. Geological formation data are obtained 302 for an area in which the current well drilling operation is being conducted. Then, target operational parameters associated with the identified geological formation data are identified 304, and these target operational parameters are used to calculate an acceptable borehole condition value in the indicator of borehole conditions 306. The current operational parameters for the current well drilling operation are then identified 308, and a current value for the indicator of borehole conditions is calculated 310 using the current operational parameters.

[0032] A transformation or modification is determined in one or more current operational parameters in order to change the current value of the indicator of the borehole conditions to the acceptable value 312. This transform describes a process where the probability is converted to a function that allows the desired acceptable borehole condition to be met. When the indicator of borehole conditions is DCAL, a general form of the equation is of the form $DCAL = f(a * WOB^b, c * Torque^d, e * ROP^f, g * deviation^h, Formation)$. For a good or acceptable indicator of borehole conditions the term $DCALg$ is used. For a bad or unacceptable borehole conditions to term $DCALb$ is used. The resulting transform function, F , is such that $DCALg = F(DCALb)$, for a constant or common geological formation. The transform is applied to the bad data curve or equation to obtain the correct parameters to maintain a good borehole. The result is a drilling plan or modified drilling operational parameters that represent the optimum parameters.

[0033] Referring to Figure 4, a graph 400 showing ROP 401 versus WOB 403 for a given geological formation. ROP can be expressed as a function of WOB. As illustrated, the relationship is linear, and undesirable data points 404 yield a first equation 406 that describes a first line 402 having a given slope, m , and an offset equal to the value *constant*. The transformation to acceptable data points 410 yields a second equation 412 that describes a second line 408 having a modified slope, a , and

no offset. The well drilling operation is then conducted in accordance with this relationship between ROP and WOB.

[0034] Returning to Figure 1, having determined the target operations parameters, then the well drilling operation is conducted in accordance with these target operations for a given geological formation 108. This includes conducting the current well drilling operation in accordance with the drilling plan or modification of one or more well drilling operational parameters within a current active well drilling operation.

[0035] In one embodiment, the target operational parameters are output visually or digitally, e.g., .las, Excel, ascii, in association with depth and geological formation information to allow drilling operators to query or to input a drilling plan automatically to compare with real time drilling operation data. In one embodiment, this visual representation includes the probability or confidence intervals, for example, of the result and of future states. The exact output can be optimized or customized to the field, geology, or client specific needs.

[0036] As well drilling data is collected and analyzed from well drilling operations over time, a well drilling knowledge database is established. This knowledge database is consulted as a drilling plan is being created or drilling operations are being conducted. The knowledge database provides the probability that a given set of parameters will lead to a safer more efficient well than others.

[0037] Referring to Figure 5, in one embodiment, a chart 500 is used to express visually the association of the transformation of operational parameters, and therefore the value indicator of borehole conditions with a given probability of occurrence. The chart is associated with a one or more given geological formations 502 and includes probabilities of occurrence 506 of selected borehole conditions, assigned severity levels 510 and transformations 508. The chart can also include additional information, for example, deviation 504. In one embodiment, the chart includes an indication of the strength of correlation between the probabilities and the transformation.

[0038] In one embodiment, using the obtained probability to determine current operational parameters in order to generate the chart includes associating each transformation with a given probability of occurrence of a selected borehole condition based on prescribed values in one or more well drilling operation parameters. A severity level associated with the selected borehole condition is assigned. This

information is then used to populate the chart. In use, then a potential problem is identified, the chart is used to determine the associated corrective transform. One or more current operation parameters are then modified if the assigned severity level is greater than a pre-determined level.

5 **[0039]** Exemplary embodiments are used in real time to guide the drillers and avoid problems including stuck or sticking tool string, excessive borehole wall collapse, and formation blow out, among others. Drilling parameters are altered or adjusted in real time or prior to commencement of the drilling operation to improve operations and completions based upon well logs indicating borehole conditions (for example oversize,
10 undersize and/or borehole wall irregularities) or any other outlier or metric, and any of the drilling parameters utilized in operation which may include differences specific to the geological formation of interest.

[0040] Methods and systems in accordance with exemplary embodiments can be hardware embodiments, software embodiments or a combination of hardware
15 and software embodiments. In one embodiment, the methods described herein are implemented as software. Suitable software embodiments include, but are not limited to, firmware, resident software and microcode. In addition, exemplary methods and systems can take the form of a computer program product accessible from a computer-usable or computer-readable medium providing program code for use by
20 or in connection with a computer, logical processing unit or any instruction execution system. In one embodiment, a machine-readable or computer-readable medium contains a machine-executable or computer-executable code that when read by a machine or computer causes the machine or computer to perform a method for determining well drilling operational parameters in accordance with exemplary
25 embodiments and to the computer-executable code itself. The machine-readable or computer-readable code can be any type of code or language capable of being read and executed by the machine or computer and can be expressed in any suitable language or syntax known and available in the art including machine languages, assembler languages, higher level languages, object oriented languages and
30 scripting languages.

[0041] As used herein, a computer-usable or computer-readable medium can be any apparatus that can contain, store, communicate, propagate, or transport the program for use by or in connection with the instruction execution system, apparatus,

or device. Suitable computer-usable or computer readable mediums include, but are not limited to, electronic, magnetic, optical, electromagnetic, infrared, or semiconductor systems (or apparatuses or devices) or propagation mediums and include non-transitory computer-readable mediums. Suitable computer-readable
5 mediums include, but are not limited to, a semiconductor or solid state memory, magnetic tape, a removable computer diskette, a random access memory (RAM), a read-only memory (ROM), a rigid magnetic disk and an optical disk. Suitable optical disks include, but are not limited to, a compact disk - read only memory (CD-ROM), a compact disk - read/write (CD-RW) and DVD.

10 **[0042]** In one embodiment, a computing device for performing the calculations as set forth in the above-described embodiments may be any type of computing device capable of processing and communicating seismic data associated with a seismic survey. An example of a representative computing system capable of carrying out operations in accordance with these embodiments is illustrated in Figure
15 6. The computing system 600 includes a computer or server 602 having one or more central processing units 604 in communication with a communication module 606, one or more input/output devices 610 and at least one storage device 608. All of these components are known to those of ordinary skill in the art, and this description includes all known and future variants of these types of devices. The
20 communication module provides for communication with other computing systems, databases and data acquisition systems across one or more local or wide area networks 612. This includes both wired and wireless communication. Suitable input-output devices include keyboards, point and click type devices, audio devices, optical media devices and visual displays.

25 **[0043]** Suitable storage devices include magnetic media such as a hard disk drive (HDD), solid state memory devices including flash drives, ROM and RAM and optical media. The storage device can contain data as well as software code for executing the functions of the computing system and the functions in accordance with the methods described herein. Therefore, the computing system 600 can be
30 used to implement the methods described above associated with the calculation of the induced source shot gather. Hardware, firmware, software or a combination thereof may be used to perform the various steps and operations described herein.

[0044] The disclosed exemplary embodiments provide a computing device, software and method for determining well drilling operational parameters. It should be understood that this description is not intended to limit the invention. On the contrary, the exemplary embodiments are intended to cover alternatives, modifications and equivalents, which are included in the spirit and scope of the invention. Further, in the detailed description of the exemplary embodiments, numerous specific details are set forth in order to provide a comprehensive understanding of the invention. However, one skilled in the art would understand that various embodiments may be practiced without such specific details.

[0045] Although the features and elements of the present exemplary embodiments are described in the embodiments in particular combinations, each feature or element can be used alone without the other features and elements of the embodiments or in various combinations with or without other features and elements disclosed herein. The methods or flowcharts provided in the present application may be implemented in a computer program, software, or firmware tangibly embodied in a computer-readable storage medium for execution by a geoscience dedicated computer or a processor.

[0046] This written description uses examples of the subject matter disclosed to enable any person skilled in the art to practice the same, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the subject matter is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims.

WHAT IS CLAIMED IS:

1. A method for determining well drilling operational parameters (100), the method comprising:

identifying at least one well data set describing a previous well drilling

5 operation (102);

using the well data set to obtain at least one probability that a given borehole condition occurs based on prescribed values in one or more well drilling operation parameters (104); and

10 using the obtained probability to determine target operational parameters that yield an acceptable borehole condition value in an indicator of borehole conditions, the indicator of borehole conditions comprising a function of well drilling operational parameters (106).

2. The method of claim 1, wherein the at least one well data set
15 comprises at least one of previous well drilling operational parameters, well borehole condition data and geological formation data.

3. The method of claim 2, wherein the previous well drilling operational parameters include caliper, density log correction, tension, weight on bit, rate of
20 penetration, torque, mud weight, deviation from vertical, equivalent circulation density or combinations thereof.

4. The method of claim 2, wherein the well borehole condition data
25 comprise pressure, hole diameter, stuck pipe, sticking tool string, borehole stability, formation blowout, borehole wall collapse or combinations thereof.

5. The method of claim 2, wherein the geological formation data comprise lithology, formation tops, porosity, saturation, physical location or combinations thereof.

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6. The method of claim 1, wherein:

identifying the at least one well data set further comprises identifying a plurality of well data sets describing a plurality of previous well drilling operations; and

5 using the well data set further comprises using the plurality of well data sets to obtain a plurality of probabilities of a plurality of given borehole conditions occurring based on prescribed values in one or more well drilling operation parameters.

10 7. The method of claim 1, wherein the indicator of borehole conditions comprises differential caliper.

8. The method of claim 1, wherein using the obtained probability to determine current operational parameters further comprises:

determining current operational parameters for a current well drilling operation;

15 determining a current value for the indicator of borehole conditions using the current operational parameters; and

determining a transformation in one or more current operational parameters to change the current value of the indicator of the borehole conditions to the acceptable value.

20 9. The method of claim 8, wherein using the obtained probability to determine current operational parameters further comprises:

25 associating the transformation with a given probability of occurrence of a selected borehole condition based on prescribed values in one or more well drilling operation parameters;

assigning a severity level that is associated with the selected borehole condition; and

modifying the one or more current operation parameters if the assigned severity level is greater than a pre-determined level.

30 10. The method of claim 9, wherein using the obtained probability to determine current operational parameters further comprises using a chart to express

the association of the transformation with the given probability of occurrence of the selected borehole condition, the assigned severity level and the transformation.

11. The method of claim 10, wherein using the chart further comprises
5 associating the chart with a given geological formation.

12. The method of claim 1, further comprising:
using the target operational parameters to determine a drilling plan;
and
10 conducting a current well drilling operation in accordance with the
drilling plan.

13. A method for drilling a well (100), the method comprising:
identifying at least one well data set describing a previous well drilling
15 operation (102);

using the well data set to obtain at least one probability that a given borehole
condition occurs based on prescribed values in one or more well drilling operation
parameters (104);

using the obtained probability to determine target operational parameters that
20 yield an acceptable borehole condition value in an indicator of borehole conditions,
the indicator of borehole conditions comprising a function of well drilling operational
parameters (106); and

conducting a current well drilling operation in accordance with the target
operational parameters (108).

14. The method of claim 13, further comprising:
using the target operational parameters to determine a drilling plan;
and
conducting the current well drilling operation in accordance with the
30 drilling plan.

15. The method of claim 13, wherein using the obtained probability to
determine current operational parameters further comprises:

determining current operational parameters for the current well drilling operation;

determining a current value for the indicator of borehole conditions using the current operational parameters; and

- 5 determining a transformation in one or more current operational parameters to change the current value of the indicator of the borehole conditions to the acceptable value.

10 16. The method of claim 15, wherein using the obtained probability to determine current operational parameters further comprises:

associating the transformation with a given probability of occurrence of a selected borehole condition based on prescribed values in one or more well drilling operation parameters;

- 15 assigning a severity level associated with the selected borehole condition; and
modifying the one or more current operation parameters if the assigned severity level is greater than a pre-determined level.

20 17. The method of claim 16, wherein using the obtained probability to determine current operational parameters further comprises using a chart to express the association of the transformation with the given probability of occurrence of the selected borehole condition, the assigned severity level and the transformation;
wherein the chart is associated with a given geological formation in which the current drilling operation is conducted.

25 18. A computer-readable storage medium containing a computer-readable code that when read by a computer causes the computer to perform a method for determining well drilling operational parameters (100), the method comprising:

- identifying at least one well data set describing a previous well drilling operation (102);
30 using the well data set to obtain at least one probability that a given borehole condition occurs based on prescribed values in one or more well drilling operation parameters (104); and

using the obtained probability to determine target operational parameters that yield an acceptable borehole condition value in an indicator of borehole conditions, the indicator of borehole conditions comprising a function of well drilling operational parameters (106).

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19. The computer readable storage medium of claim 18, wherein using the obtained probability to determine current operational parameters further comprises:

determining current operational parameters for a current well drilling operation;

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determining a current value for the indicator of borehole conditions using the current operational parameters;

determining a transformation in one or more current operational parameters to change the current value of the indicator of the borehole conditions to the acceptable value;

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associating the transformation with a given probability of occurrence of a selected borehole condition based on prescribed values in one or more well drilling operation parameters;

assigning a severity level associated with the selected borehole condition; and

modifying the one or more current operation parameters if the assigned

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severity level is greater than a pre-determined level.

20. The computer readable storage medium of claim 18, wherein the method further comprises:

using the target operational parameters to determine a drilling plan;

25

and

conducting a current well drilling operation in accordance with the drilling plan.

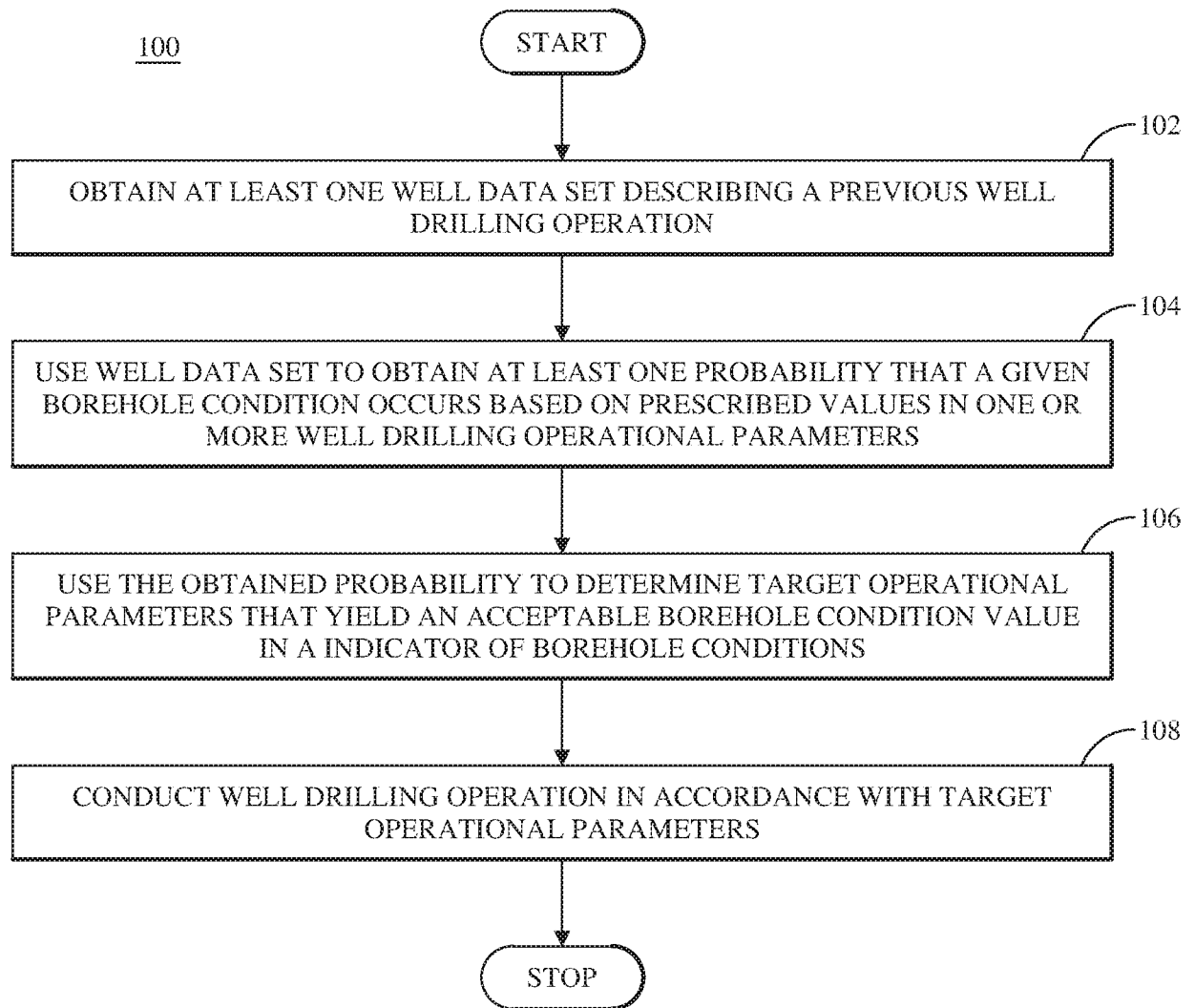


FIG. 1

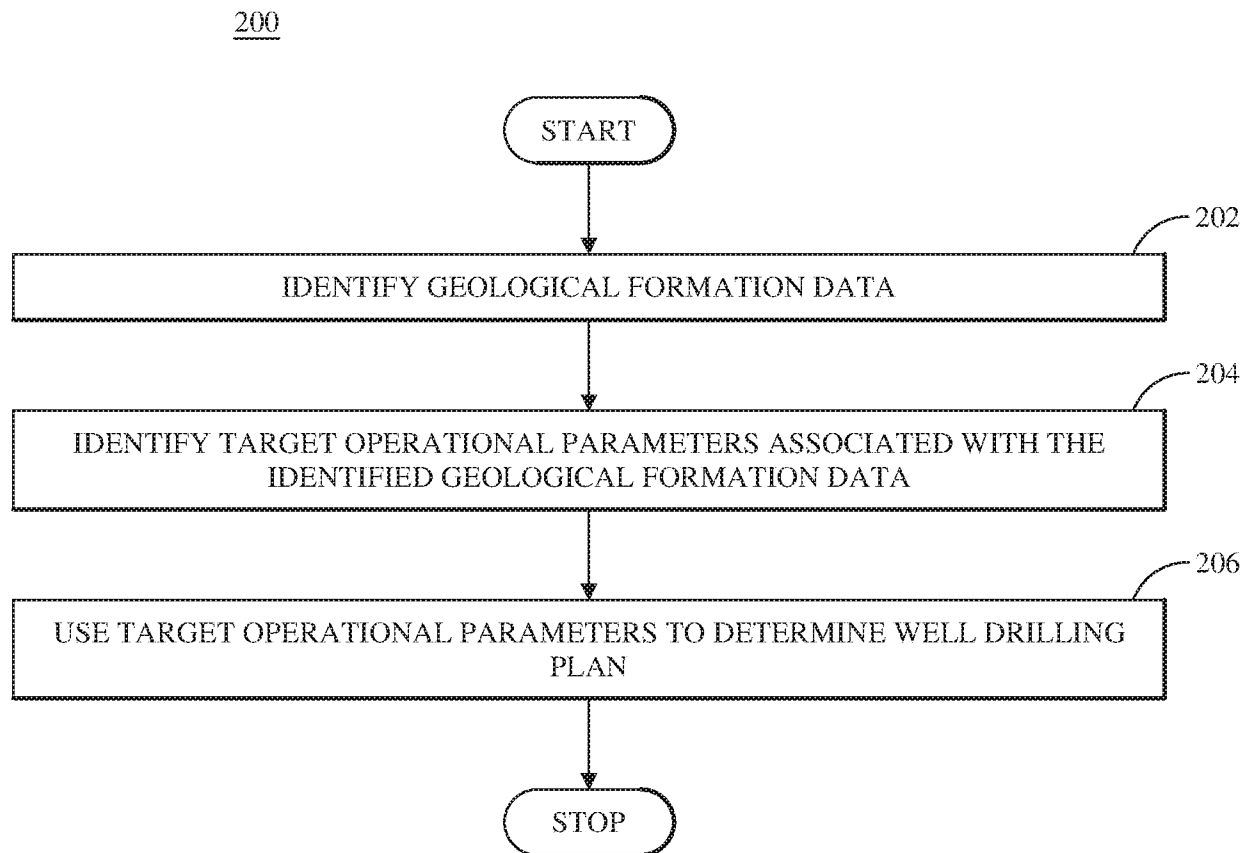


FIG. 2

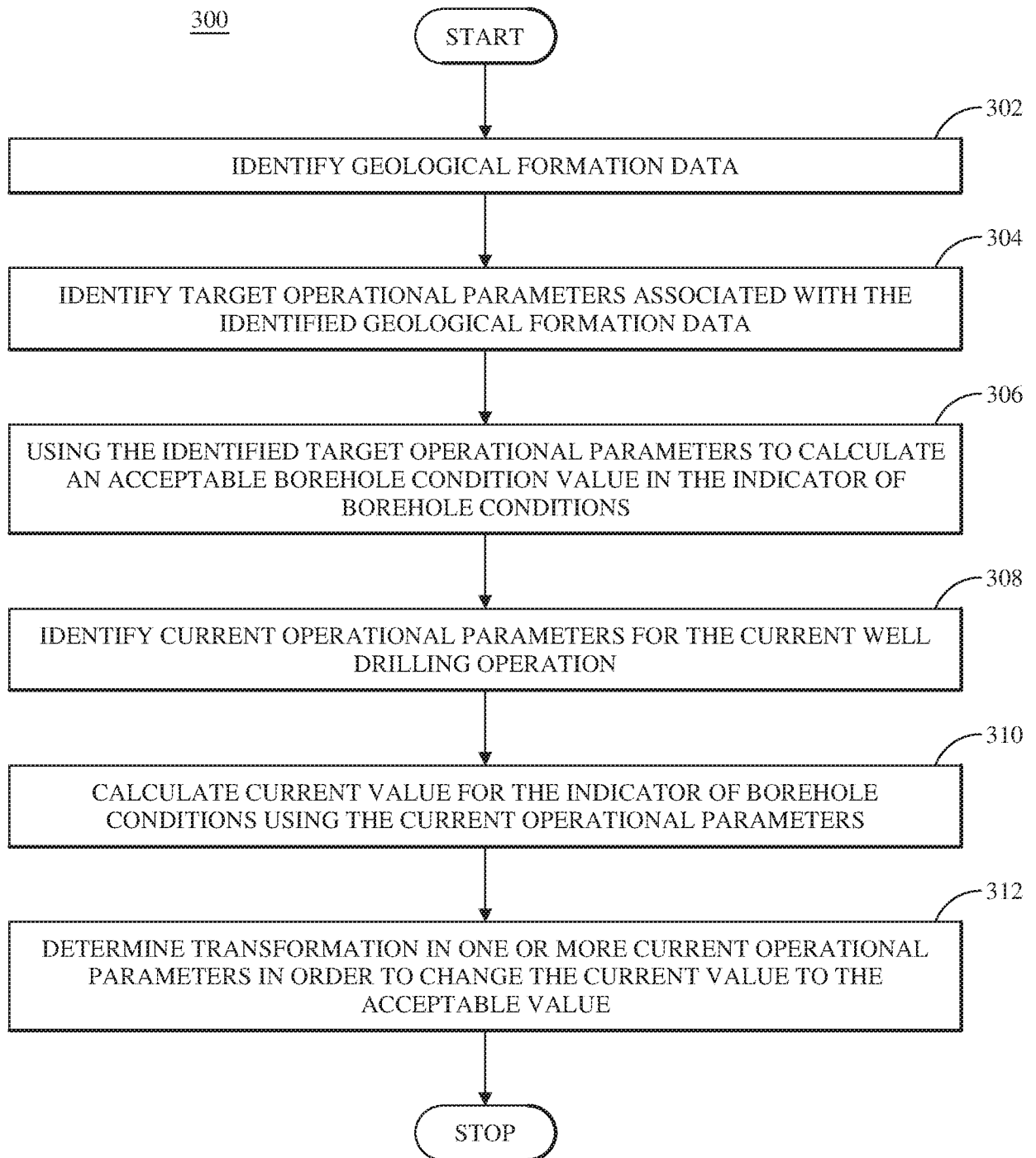


FIG. 3

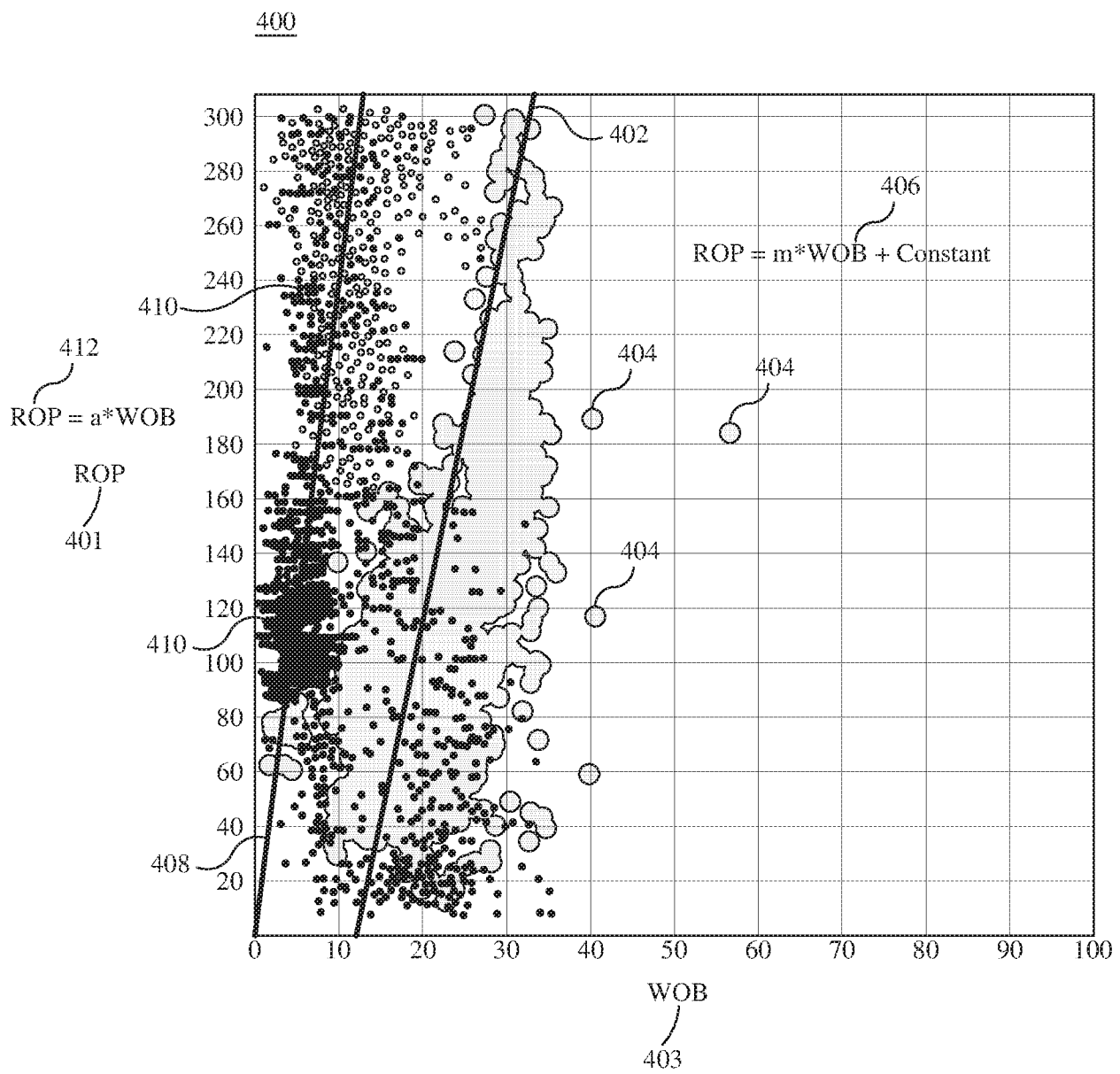


FIG. 4

Drilling Analysis Chart

Region: North Zardoz 500
 Sector, Southern Ocean
 Block 1

502 Formation	504 Deviation	506 Potential problem areas/probabilities	508 Transforms	510 Severity
Penguin	<10	if mud weight is above 12lb/gal 25% probability of stuck pipe	none, insufficient data	Low
	10 - 30	if WOB > 20 and Torque increases above 250 hole size increase 75% probable	$DCALg = 0.9 * WOB, 0.8 * Torque$	High
	30 - 50	if Deviation increases by more than 1 degree per 200 ft. stuck pipe probability 10% and hole size increase 25%	$DCALg = 1.0 * WOB, 1.0 * Torque, 0.9 * Deviation$ (when $Dev > 1/200ft$, else $1 * Deviation$)	Medium
	>50	Torque increase by more than 10% gives hole size increase probability 80%	$DCALg = 1.8 * WOB, 0.9 * Torque^2$ or $0.9 * Deviation$	High
Emperor	<10	borehole unstable at WOB >10 < 20	$DCALg = 1.2 * (WOB > 20)$ or $0.8 * (WOB < 10)$	High
Whitebird	any angle	Anhydrite no problems		Low
White Sand	<15	no problems unless BS >17.5" and mud weight >9.5 lb/gal	$DCALg = 0.8 * MW$ ($MW > 9.5$), $1.0 * MW$ ($MW < 9.5$) and BS >17.5"	Medium
	15 - 45	WOB increase has 67% probability of an increase in ROP with a 95% probability of hole size increases	$DCALg = 0.8 * MW$ ($MW > 9.5$), increase > 20%, Torque constant, MW constant: $DCALg = 0.9 * WOB$, if ROB increases > 35%, Torque increase >15%, $0.85 * MW$	High

FIG. 5

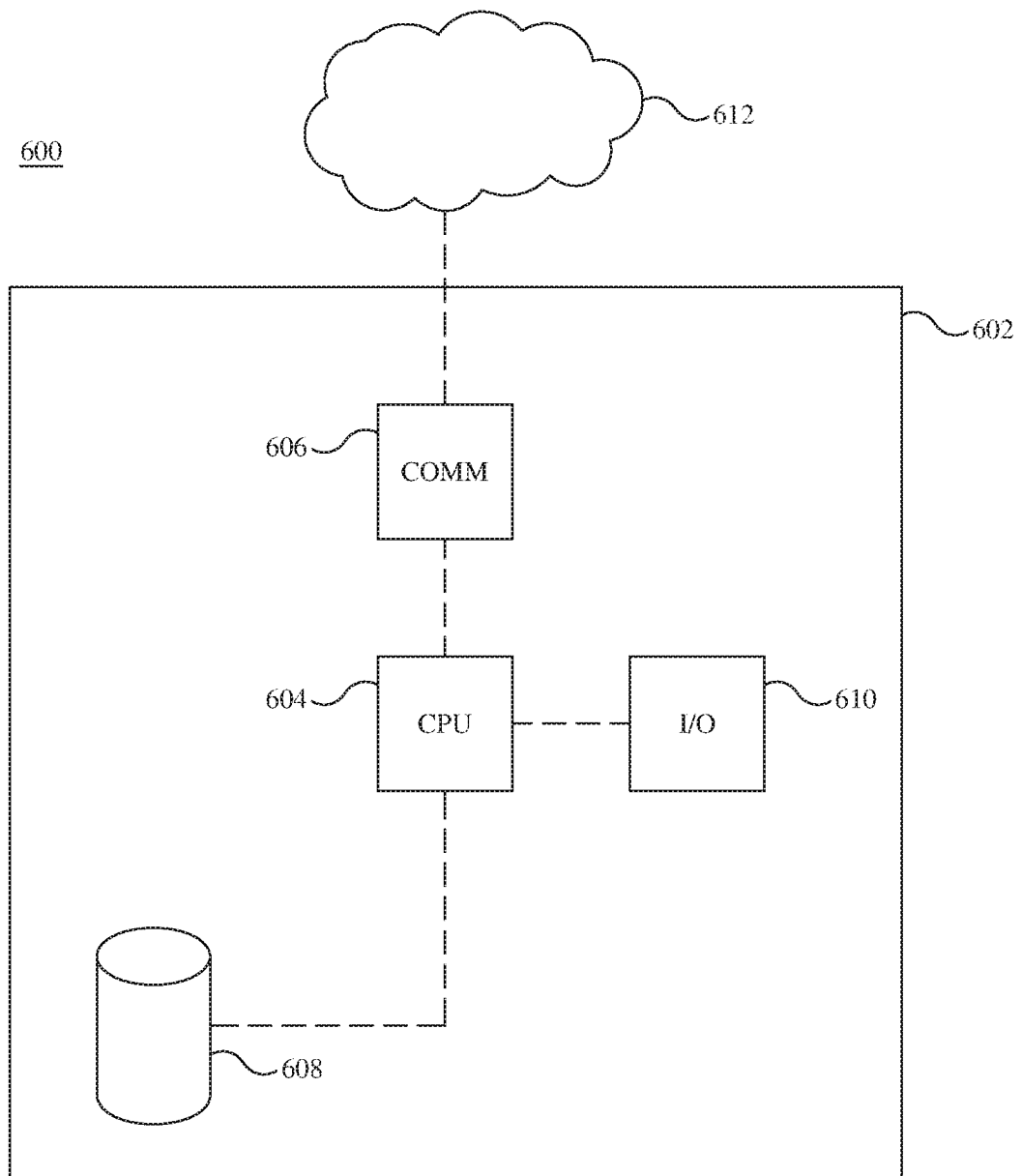


FIG. 6