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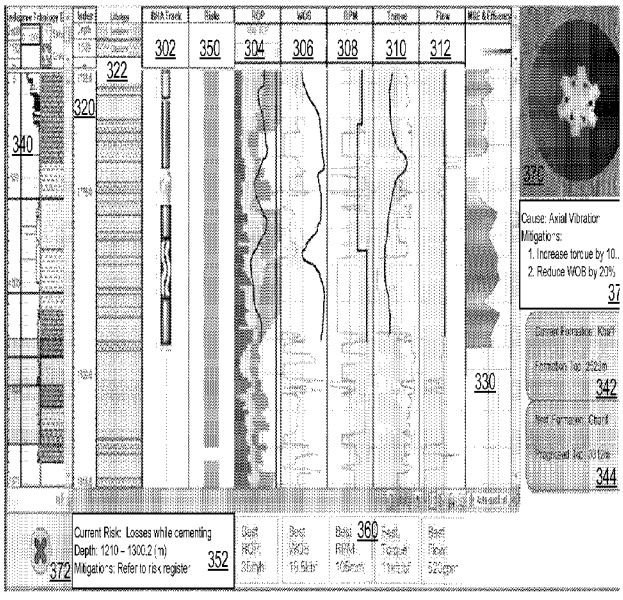


FIGURE 12

(57) Abstract: A well advisor system and console for monitoring and managing well drilling and production operations. The system may be accessed through one or more workstations, or other computing devices, which may be located at a well site or remotely. The system is in communication with and receives input from various sensors. It collects real-time sensor data sampled during operations at the well site. The system processes the data, and provides nearly instantaneous numerical and visual feedback through a variety of graphical user interfaces ("GUIs"), which are presented in the form of an operation-specific console. The input and data provides information related to rate of penetration concerning a well being drilled, and present the information for related parameters in real time against a plotted "fairway" of determined maximum and minimum values, with a focus on the safety of the drilling operation.

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SYSTEM AND CONSOLE FOR MONITORING AND MANAGING WELL SITE OPERATIONS

This application claims benefit of and priority to U.S. Provisional Application No. 61/987,803, filed May 2, 2014, and is entitled to benefit of that priority date. The specification, figures, appendices and complete disclosure of U.S. Provisional Application No. 61/987,803 are incorporated herein in their entireties by specific reference for all purposes.

FIELD OF INVENTION

This invention relates generally to oil and gas well drilling and production, and related operations. More particularly, this invention relates to a computer-implemented system for monitoring and managing the performance of well drilling operations, including, but not limited to, rate of penetration.

BACKGROUND OF THE INVENTION

It is well-known that the drilling of an oil or gas well, and related operations, is responsible for a significant portion of the costs related to oil and gas exploration and production. In particular, as new wells are being drilled into remote or less-accessible reservoirs, the complexity, time and expense to drill a well have substantially increased.

Accordingly, it is critical that drilling operations be completed safely, accurately, and efficiently. With directional drilling techniques, and the greater depths to which wells are being drilled, many complexities are added to the drilling operation, and the cost and effort required to respond to a problem during drilling are high. This requires a high level of competence from the driller or drilling engineer at the drilling rig (or elsewhere) to safely drill the well as planned.

A "well plan" specifies a number of parameters for drilling a well, and is developed, in part, based on a geological model. A geological model of various sub-surface formations is generated by a geologist from a variety of sources, including seismic studies, data from wells drilled in the area, core samples, and the like. A geological model typically includes depths to the various "tops" that define the formations (the term "top" generally refers to the top of a stratigraphic or biostratigraphic boundary of significance, a horizon, a fault, a pore pressure transition zone, change in

rock type, or the like. Geological models usually include multiple tops, thereby defining the presence, geometry and composition of subsurface features.

The well plan specifies drilling parameters as the well bore advances through the various subsurface features. Parameters include, but are not limited to, mud weight, drill bit rotational speed, and weight on bit (WOB). The drilling operators rely on the well plan to anticipate tops and changes in subsurface features, account for drilling uncertainties, and adjust drilling parameters accordingly.

In many cases, the initial geological model may be inaccurate. The depth or location of a particular top may be off by a number of feet. Further, since some geological models recite distances based on the distance between two tops, an error in the absolute depth of one top can result in errors in the depths of multiple tops. Thus, a wellbore can advance into a high pressure subsurface formation before anticipated.

Such errors thus affect safety as well as cost and efficiency. It is fundamental in the art to use drilling "mud" circulating through the drill string to remove cuttings, lubricate the drill bit (and perhaps power it), and control the subsurface pressures. The drilling mud returns to the surface, where cuttings are removed, and is then recycled.

In some cases, the penetration of a high pressure formation can cause a sudden pressure increase (or "kick") in the wellbore. If not detected and controlled, a "blowout" can occur, which may result in failure of the well. Blowout preventers ("BOP") are well known in the art, and are used to protect drilling personnel and the well site from the effects of a blowout. A variety of systems and methods for BOP monitoring and testing are known in the art, including "Blowout Preventer Testing System and Method," U.S. Pat. No. 7,706,890, and "Monitoring the Health of Blowout Preventer," US 2012/0197527, both of which are incorporated herein in their entireties by specific reference for all purposes.

Conversely, if the mud weight is too heavy, or the wellbore advances into a particularly fragile or fractured formation, a "lost circulation" condition may result where drilling mud is lost into the formation rather than returning to the surface. This leads not only to the increased cost to replace the expensive drilling mud, but can also result in more serious problems, such as stuck drill pipe, damage to the formation or reservoir, and blowouts.

Similar problems and concerns arise during other well operations, such as running and cementing casing and tubulars in the wellbore, wellbore completions, or subsurface formation characterizations.

Drills strings and drilling operations equipment include a number of sensors and devices to measure, monitor and detect a variety of conditions in the wellbore, including, but not limited to, hole depth, bit depth, mud weight, choke pressure, and the like. This data can be generated in real-time, but can be enormous, and too voluminous for personnel at the drilling site to review and interpret in sufficient detail and time to affect the drilling operation. Some of the monitored data may be transmitted back to an engineer or geologist at a remote site, but the amount of data transmitted may be limited due to bandwidth limitations. Thus, not only is there a delay in processing due to transmission time, the processing and analysis of the data may be inaccurate due to missing or incomplete data. Drilling operations continue, however, even while awaiting the results of analysis (such as an updated geological model).

A real-time drilling monitor (RTDM) workstation is disclosed in "Drilling Rig Advisor Console," U.S. App. No. 13/312,646, which is incorporated herein by specific reference for all purposes. The RTDM receives sensor signals from a plurality of sensors and generates single graphical user interface with dynamically generated parameters based on the sensor signals.

Likewise, an intelligent drilling advisor system is disclosed in "Intelligent Drilling Advisor," U.S. Pat. No. 8,121,971, which is incorporated herein by specific reference for all purposes. The intelligent advisor system comprises an information integration environment that accesses and configures software agents that acquire data from sensors at a drilling site, transmit that data to the information integration environment, and drive the drilling state and the drilling recommendations for drilling operations at the drilling site.

SUMMARY OF INVENTION

In various embodiments, the present invention comprises a well advisor system for monitoring and managing well drilling and production operations. The system may be accessed through one or more workstations, or other computing devices. A workstation comprises one or more computers or computing devices, and may be located

at a well site or remotely. The system can be implemented on a single computer system, multiple computers, a computer server, a handheld computing device, a tablet computing device, a smart phone, or any other type of computing device.

The system is in communication with and receives input from various sensors. In general, the system collects real-time sensor data sampled during operations at the well site, which may include drilling operations, running casing or tubular goods, completion operations, or the like. The system processes the data, and provides nearly instantaneous numerical and visual feedback through a variety of graphical user interfaces ("GUIs").

The GUIs are populated with dynamically updated information, static information, and risk assessments, although they also may be populated with other types of information. The users of the system thus are able to view and understand a substantial amount of information about the status of the particular well site operation in a single view, with the ability to obtain more detailed information in a series of additional views.

In one embodiment, the system is installed at the well site, and thus reduces the need to transmit date to a remote site for processing. The well site can be an offshore drilling platform or land-based drilling rig. This reduces delays due to transmitting information to a remote site for processing, then transmitting the results of that processing back to the well site. It also reduces potential inaccuracies in the analysis due to the reduction in the data being transmitted. The system thus allows personnel at the well site to monitor the well site operation in real time, and respond to changes or uncertainties encountered during the operation. The response may include comparing the real time data to the current well plan, and modifying the well plan.

In yet another embodiment, the system is installed at a remote site, in addition to the well site. This permits users at the remote site to monitor the well-site operation in a similar manner to a user at the well-site installation.

In some exemplary embodiments, the system is a web-enabled application, and the system software may be accessed over a network connection such as the Internet. A user can access the software via the user's web browser. In some embodiments, the system performs all of the computations and processing described herein and only display data is transmitted to the remote browser or client for rendering screen displays on the

remote computer. In another embodiment, the remote browser or software on the remote system performs some of the functionality described herein.

Sensors may be connected directly to the workstation at the well site, or through one or more intermediate devices, such as switches, networks, or the like. Sensors may comprise both surface sensors and downhole sensors. Surface sensors include, but are not limited to, sensors that detect torque, revolutions per minute (RPM), and weight on bit (WOB). Downhole sensors include, but are not limited to, gamma ray, pressure while drilling (PWD), and resistivity sensors. The surface and downhole sensors are sampled by the system during drilling or well site operations to provide information about a number of parameters. Surface-related parameters include, but are not limited to, the following: block position; block height; trip/running speed; bit depth; hole depth; lag depth; gas total; lithography percentage; weight on bit; hook load; choke pressure; stand pipe pressure; surface torque; surface rotary; mud motor speed; flow in; flow out; mud weight; rate of penetration; pump rate; cumulative stroke count; active mud system total; active mud system change; all trip tanks; and mud temperature (in and out). Downhole parameters include, but are not limited to, the following: all FEMWD; bit depth; hole depth; PWD annular pressure; PWD internal pressure; PWD EMW; PWD pumps off (min, max and average); drill string vibration; drilling dynamics; pump rate; pump pressure; slurry density; cumulative volume pumped; leak off test (LOT) data; and formation integrity test (FIT) data. Based on the sensed parameters, the system causes the processors or microprocessor to calculate a variety of other parameters, as described below.

In several embodiments, the system software comprises a database/server, a display or visualization module, one or more smart agents, one or more templates, and one or more "widgets." The database/server aggregates, distributes and manages real-time data being generated on the rig and received through the sensors. The display or visualization module implements a variety of GUI displays, referred to herein as "consoles," for a variety of well site operations. The information shown on a console may comprise raw data and calculated data in real time.

Templates defining a visual layout may be selected or created by a user to display information in some portions of or all of a console. In some embodiments, a template

comprises an XML file. A template can be populated with a variety of information, including, but not limited to, raw sensor data, processed sensor data, calculated data values, and other information, graphs, and text. Some information may be static, while other information is dynamically updated in real time during the well site operation. In one embodiment, a template may be built by combining one or more display "widgets" which present data or other information. Smart agents perform calculations based on data generated through or by one or more sensors, and said calculated data can then be displayed by a corresponding display widgets.

In one exemplary embodiment, the system provides the user the option to implement a number of consoles corresponding to particular well site operations. In one embodiment, consoles include, but are not limited to, rig-site fluid management, BOP management, cementing, and casing running. A variety of smart agents and other programs are used by the consoles. Smart agents and other programs may be designed for use by a particular console, or may be used by multiple consoles. A particular installation of the system may comprise a single console, a sub-set of available consoles, or all available consoles.

Agents can be configured, and configuration files created or modified, using the agent properties display. The same properties are used for each agent, whether the agent configuration is created or imported. The specific configuration information (including, but not limited to, parameters, tables, inputs, and outputs) varies depending on the smart agent. Parameters represent the overall configuration of the agent, and include basic settings including, but not limited to, start and stop parameters, tracing, whether data is read to a log, and other basic agent information. Tables comprise information appearing in database tables associated with the agent. Inputs and outputs are the input or output mnemonics that are being tracked or reported on by the agent. For several embodiments, in order for data to be tracked or reported on, each output must have an associated output. This includes, but is not limited to, log and curve information.

In one embodiment, the system comprises a Rate of Penetration (ROP) console that provides real-time ROP performance benchmarking, drilling parameter guidance, and subsurface drillability characteristics (e.g., formation name, rock type, rock strength, interface severity, and the like) from constantly updated, normalized offset well datasets.

Offset well data includes, but is not limited to, data relating to the ROP, including surface and downhole drilling information. Offset parameters can be based on historical offset data, outputs from drilling models that provide parameter recommendations, or combinations thereof. Additional information about the type and size of drill bit, drilling assembly, and other components associated with the drilling project also are considered. The data is processed and converted to a concise, comprehensive format. Key data that describes performance benchmarks extracted from the offset data is presented in a numeric and graphical manner to allow a user to easily compare this information to the real-time data from the well being drilled (e.g., a user can quickly and easily examine the current, real-time ROP of the present well as compared to the corresponding ROPs for offset wells). If the comparison indicates sub-par performance, the user can consider and implement changes in drilling parameters based upon the associated offset well parameters used to achieve the performance benchmark. Thus, the user can respond, in real-time, to attempt to improve the ROP of the well being drilled, and possibly surpass the pre-determined performance benchmark.

Offset well datasets should be relevant to the active well. Factors to consider in determining relevancy include, but are not limited to, type of well, type of drilling platform, subsurface formations, region, BHA configurations, bit types, well trajectories, and similar factors.

In several exemplary embodiments, the relevant offset data, including, but not limited to, ROP benchmark performance, drilling parameter guidance, and prognosed lithology characterization, are processed and converted, and an appropriate display range determined. The data is then normalized to prognosed formation tops for the well to be drilled (i.e., the target well). The comparative ROP and other parameters and drillability characteristics (such as weight-on-bit (WOB), revolutions per minute (RPM), and torque) are graphically displayed on linear tracks as "fairways," along with the downhole assembly track. The parameters and data displayed can include surface drilling information, downhole drilling information, or combinations thereof.

An amalgamated maximum and minimum ROP can be calculated as well as the average ROP. Comparative data and recommendations for WOB, RPM, torque, flow in, and), revolutions per minute (RPM), torque and flow may be determined using relevant

offset data (depth shifted to the current well), model calculations, and third party recommendations, or combinations thereof. The data ranges can be shaded or colored, and the ranges may be sub-divided. The actual real-time data (ROP, WOB, RPM, torque, and the like) from the target well are displayed overlaying the fairways, and the historical actual data forms a black line. The offset data may be actively depth shifted or adjusted as actual formation tops or markers are encountered (i.e., the offset set data is corrected "on the fly" to reflect the actual formation lithology). At any point, the console thus allows a direct ROP comparison, as well as the parameter combination that achieved that ROP, as well as information on formation name, rock type, hardness, and related information. A lithology (rock properties) track may be added, as well as other tracks. Drilling efficiency may be derived from mechanical specific energy (MSE) and average rock strength.

If the actual ROP is not within the optimal range, thereby indicating sub-par performance, the user can reference the associated offset parameters used to achieve the performance benchmark, and adjust or modify the operating parameters of the well being drilled so as to improve the actual ROP. Subnormal ROP or parameters exceeding those from the offset data also may indicate a variety of other conditions of concern, such as a prematurely dulled drill bit, or other drilling disfunctions.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows a view of a system in accordance with an embodiment of the present invention.

Figure 2 shows a software architecture in accordance with various embodiments of the present invention.

Figure 3 shows a smart agent management toolbar.

Figure 4 shows a smart agent management menu.

Figure 5 shows a smart agent configuration file import menu.

Figure 6 shows a smart agent configuration display screen.

Figure 7 shows a smart agent configuration file export menu.

Figure 8 shows a smart agent configuration file download display screen.

Figure 9 shows a smart agent configuration file copy menu.

Figures 10-11 shows examples of a ROP "fairway" display screen.

Figure 12 shows an example of a driller's ROP console dashboard display screen.

Figure 13 shows another embodiment of a ROP console dashboard display screen.

Figure 14 shows an example of a detailed vibration display screen.

Figure 15 shows an example of a well site leader's ROP console dashboard display screen.

Figure 16 shows an example of a correlation display

Figure 17 shows an example of a comparative depth vs. days chart.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

Computing Environment Context

The following discussion is directed to various exemplary embodiments of the present invention, particularly as implemented into a situationally-aware distributed hardware and software architecture in communication with one or more operating drilling rigs. However, it is contemplated that this invention may provide substantial benefits when implemented in systems according to other architectures, and that some or all of the benefits of this invention may be applicable in other applications. For example, while the embodiments of the invention may be described herein in connection with wells used for oil and gas exploration and production, the invention also is contemplated for use in connection with other wells, including, but not limited to, geothermal wells, disposal wells, injection wells, and many other types of wells. One skilled in the art will understand that the examples disclosed herein have broad application, and that the discussion of any particular embodiment is meant only to be exemplary of that embodiment, and not intended to suggest that the scope of the disclosure, including the claims, is limited to that embodiment.

In order to provide a context for the various aspects of the invention, the following discussion provides a brief, general description of a suitable computing environment in which the various aspects of the present invention may be implemented. A computing system environment is one example of a suitable computing environment, but is not intended to suggest any limitation as to the scope of use or functionality of the invention. A computing environment may contain any one or combination of components

discussed below, and may contain additional components, or some of the illustrated components may be absent. Various embodiments of the invention are operational with numerous general purpose or special purpose computing systems, environments or configurations. Examples of computing systems, environments, or configurations that may be suitable for use with various embodiments of the invention include, but are not limited to, personal computers, laptop computers, computer servers, computer notebooks, hand-held devices, microprocessor-based systems, multiprocessor systems, TV set-top boxes and devices, programmable consumer electronics, cell phones, personal digital assistants (PDAs), network PCs, minicomputers, mainframe computers, embedded systems, distributed computing environments, and the like.

Embodiments of the invention may be implemented in the form of computer-executable instructions, such as program code or program modules, being executed by a computer or computing device. Program code or modules may include programs, objections, components, data elements and structures, routines, subroutines, functions and the like. These are used to perform or implement particular tasks or functions. Embodiments of the invention also may be implemented in distributed computing environments. In such environments, tasks are performed by remote processing devices linked via a communications network or other data transmission medium, and data and program code or modules may be located in both local and remote computer storage media including memory storage devices.

In one embodiment, a computer system comprises multiple client devices in communication with at least one server device through or over a network. In various embodiments, the network may comprise the Internet, an intranet, Wide Area Network (WAN), or Local Area Network (LAN). It should be noted that many of the methods of the present invention are operable within a single computing device.

A client device may be any type of processor-based platform that is connected to a network and that interacts with one or more application programs. The client devices each comprise a computer-readable medium in the form of volatile and/or nonvolatile memory such as read only memory (ROM) and random access memory (RAM) in communication with a processor. The processor executes computer-executable program

instructions stored in memory. Examples of such processors include, but are not limited to, microprocessors, ASICs, and the like.

Client devices may further comprise computer-readable media in communication with the processor, said media storing program code, modules and instructions that, when executed by the processor, cause the processor to execute the program and perform the steps described herein. Computer readable media can be any available media that can be accessed by computer or computing device and includes both volatile and nonvolatile media, and removable and non-removable media. Computer-readable media may further comprise computer storage media and communication media. Computer storage media comprises media for storage of information, such as computer readable instructions, data, data structures, or program code or modules. Examples of computer-readable media include, but are not limited to, any electronic, optical, magnetic, or other storage or transmission device, a floppy disk, hard disk drive, CD-ROM, DVD, magnetic disk, memory chip, ROM, RAM, EEPROM, flash memory or other memory technology, an ASIC, a configured processor, CDROM, DVD or other optical disk storage, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, or any other medium from which a computer processor can read instructions or that can store desired information. Communication media comprises media that may transmit or carry instructions to a computer, including, but not limited to, a router, private or public network, wired network, direct wired connection, wireless network, other wireless media (such as acoustic, RF, infrared, or the like) or other transmission device or channel. This may include computer readable instructions, data structures, program modules or other data in a modulated data signal such as a carrier wave or other transport mechanism. Said transmission may be wired, wireless, or both. Combinations of any of the above should also be included within the scope of computer readable media. The instructions may comprise code from any computer-programming language, including, for example, C, C++, C#, Visual Basic, Java, and the like.

Components of a general purpose client or computing device may further include a system bus that connects various system components, including the memory and processor. A system bus may be any of several types of bus structures, including, but not limited to, a memory bus or memory controller, a peripheral bus, and a local bus

using any of a variety of bus architectures. Such architectures include, but are not limited to, Industry Standard Architecture (ISA) bus, Micro Channel Architecture (MCA) bus, Enhanced ISA (EISA) bus, Video Electronics Standards Association (VESA) local bus, and Peripheral Component Interconnect (PCI) bus.

Computing and client devices also may include a basic input/output system (BIOS), which contains the basic routines that help to transfer information between elements within a computer, such as during start-up. BIOS typically is stored in ROM. In contrast, RAM typically contains data or program code or modules that are accessible to or presently being operated on by processor, such as, but not limited to, the operating system, application program, and data.

Client devices also may comprise a variety of other internal or external components, such as a monitor or display, a keyboard, a mouse, a trackball, a pointing device, touch pad, microphone, joystick, satellite dish, scanner, a disk drive, a CD-ROM or DVD drive, or other input or output devices. These and other devices are typically connected to the processor through a user input interface coupled to the system bus, but may be connected by other interface and bus structures, such as a parallel port, serial port, game port or a universal serial bus (USB). A monitor or other type of display device is typically connected to the system bus via a video interface. In addition to the monitor, client devices may also include other peripheral output devices such as speakers and printer, which may be connected through an output peripheral interface.

Client devices may operate on any operating system capable of supporting an application of the type disclosed herein. Client devices also may support a browser or browser-enabled application. Examples of client devices include, but are not limited to, personal computers, laptop computers, personal digital assistants, computer notebooks, hand-held devices, cellular phones, mobile phones, smart phones, pagers, digital tablets, Internet appliances, and other processor-based devices. Users may communicate with each other, and with other systems, networks, and devices, over the network through the respective client devices.

By way of further background, the term "software agent" refers to a computer software program or object that is capable of acting in a somewhat autonomous manner to carry out one or more tasks on behalf of another program or object in the system.

Software agents can also have one or more other attributes, including mobility among computers in a network, the ability to cooperate and collaborate with other agents in the system, adaptability, and also specificity of function (e.g., interface agents). Some software agents are sufficiently autonomous as to be able to instantiate themselves when appropriate, and also to terminate themselves upon completion of their task.

The term "expert system" refers to a software system that is designed to emulate a human expert, typically in solving a particular problem or accomplishing a particular task. Conventional expert systems commonly operate by creating a "knowledge base" that formalizes some of the information known by human experts in the applicable field, and by codifying some type of formalism by way the information in the knowledge base applicable to a particular situation can be gathered and actions determined. Some conventional expert systems are also capable of adaptation, or "learning", from one situation to the next. Expert systems are commonly considered to be in the realm of "artificial intelligence."

The term "knowledge base" refers to a specialized database for the computerized collection, organization, and retrieval of knowledge, for example in connection with an expert system. The term "rules engine" refers to a software component that executes one or more rules in a runtime environment providing among other functions, the ability to: register, define, classify, and manage all the rules, verify consistency of rules definitions, define the relationships among different rules, and relate some of these rules to other software components that are affected or need to enforce one or more of the rules. Conventional approaches to the "reasoning" applied by such a rules engine in performing these functions involve the use of inference rules, by way of which logical consequences can be inferred from a set of asserted facts or axioms. These inference rules are commonly specified by means of an ontology language, and often a description language. Many reasoners use first-order predicate logic to perform reasoning; inference commonly proceeds by forward chaining and backward chaining.

The present invention may be implemented into an expert computer hardware and software system, implemented and operating on multiple levels, to derive and apply specific tools at a drilling site from a common knowledge base, including, but not limited to, information from multiple drilling sites, production fields, drilling equipment, and

drilling environments. At a highest level, a knowledge base is developed from attributes and measurements of prior and current wells, information regarding the subsurface of the production fields into which prior and current wells have been or are being drilled, lithology models for the subsurface at or near the drilling site, and the like. In this highest level, an inference engine drives formulations (in the form of rules, heuristics, calibrations, or a combination thereof) based on the knowledge base and on current data. An interface to human expert drilling administrators is provided for verification of these rules and heuristics. These formulations pertain to drilling states and drilling operations, as well as recommendations for the driller, and also include a trendologist function that manages incoming data based on the quality of that data, such management including the amount of processing and filtering to be applied to such data, as well as the reliability level of the data and of calculations therefrom.

At another level, an information integration environment is provided that identifies the current drilling sites, and drilling equipment and processes at those current drilling sites. Based upon that identification, and upon data received from the drilling sites, servers access and configure software agents that are sent to a host client system at the drilling site; these software agents operate at the host client system to acquire data from sensors at the drilling site, to transmit that data to the information integration environment, and to derive the drilling state and drilling recommendations for the driller at the drilling site. These software agents include one or more rules, heuristics, or calibrations derived by the inference engine, and called by the information integration environment. In addition, the software agents sent from the information integration environment to the host client system operate to display values, trends, and reliability estimates for various drilling parameters, whether measured or calculated.

The information integration environment is also operative to receive input from the driller via the host client system, and to act as a knowledge base server to forward those inputs and other results to the knowledge base and the inference engine, with verification or input from the drilling administrators as appropriate.

According to another aspect of the invention, the system develops a knowledge base from attributes and measurements of prior and current wells, and from information regarding the subsurface of the production fields into which prior and current wells have

been or are being drilled. According to this aspect of the invention, the system self-organizes and validates historic, real time, and/or near real time depth or time based measurement data, including information pertaining to drilling dynamics, earth properties, drilling processes and driller reactions. This drilling knowledge base suggests solutions to problems based on feedback provided by human experts, learns from experience, represents knowledge, instantiates automated reasoning and argumentation for embodying best drilling practices.

According to yet another aspect of the invention, the system includes the capability of virtualizing information from a well being drilled into a collection of metalayers, such metalayers corresponding to a collection of physical information about the layer (material properties, depths at a particular location, and the like) and also information on how to successfully drill through such a layer, such metalayers re-associating as additional knowledge is acquired, to manage real-time feedback values in optimizing the drilling operation, and in optimizing the driller response to dysfunction. Normalization into a continuum, using a system of such metalayers, enables real-time reaction to predicted downhole changes that are identified from sensor readings.

According to another aspect of the invention, the system is capable of carrying out these functions by creating and managing a network of software agents that interact with the drilling environment to collect and organize information for the knowledge base, and to deliver that information to the knowledge base. The software agents in this network are persistent, autonomous, goal-directed, sociable, reactive, non-prescriptive, adaptive, heuristic, distributed, mobile and self-organizing agents for directing the driller toward drilling optimization, for collecting data and information, and for creating dynamic transitional triggers for metalayer instantiation. These software entities interact with their environment through an adaptive rule-base to intelligently collect, deliver, adapt and organize information for the drilling knowledge base. According to this aspect of the invention, the software agents are created, modified and destroyed as needed based on the situation at the drilling rig, within the field, or at any feasible knowledge collection point or time instance within the control scope of any active agent.

According to another aspect of the invention, the software agents in the network of agents are controlled by the system to provide the recommendations to the drillers,

using one or more rules, heuristics, and calibrations derived from the knowledge base and current sensor signals from the drilling site, and as such in a situationally aware manner. In this regard, the software agents interact among multiple software servers and hardware states in order to provide recommendations that assist human drillers in the drilling of a borehole into the earth at a safely maximized drilling rate. The software "experts" dispatch agents, initiate transport of remote memory resources, and provide transport of knowledge base components including rules, heuristics, and calibrations according to which a drilling state or drilling recommendation is identified responsive to sensed drilling conditions in combination with a selected parameter that is indicative of a metalayer of the earth, and in combination with selected minimums and maximums of the drilling equipment sensor parameters. The software experts develop rules, heuristics, and calibrations applicable to the drilling site derived from the knowledge base that are transmitted via an agent to a drilling advisor application, located at the drilling site, that is coupled to receive signals from multiple sensors at the drilling site, and also to one or more servers that configure and service multiple software agents.

According to another aspect of the invention, the system is applied to circulation actors to optimize circulation, hydraulics at the drill bit point of contact with the medium being drilled, rationalization of distributed pressure and temperature measurements and to provide recommendations to avoid or recover from loss of circulation events.

In addition, while this invention is described in connection with a multiple level hardware and software architecture system, in combination with drilling equipment and human operators, it is contemplated that several portions and facets of this invention are separately and independently inventive and beneficial, whether implemented in this overall system environment or if implemented on a stand-alone basis or in other system architectures and environments. Those skilled in the art having reference to this specification are thus directed to consider this description in such a light.

Well Advisor System and Consoles

Figure 1 illustrates a workstation showing a well advisor system **100** in accordance with various exemplary embodiments of the present invention. The workstation comprises one or more computers or computing devices, and may be located at a well site or remotely. The system can be implemented on a single computer system,

multiple computers, a computer server, a handheld computing device, a tablet computing device, a smart phone, or any other type of computing device.

The system is in communication with and receives input from various sensors **120, 130**. In general, the system collects real-time sensor data sampled during operations at the well site, which may include drilling operations, running casing or tubular goods, completion operations, or the like. The system processes the data, and provides nearly instantaneous numerical and visual feedback through a variety of graphical user interfaces (GUIs).

The GUIs are populated with dynamically updated information, static information, and risk assessments, although they also may be populated with other types of information, as described below. The users of the system thus are able to view and understand a substantial amount of information about the status of the particular well site operation in a single view, with the ability to obtain more detailed information in a series of additional views.

In one embodiment, the system is installed at the well site, and thus reduces the need to transmit date to a remote site for processing. The well site can be an offshore drilling platform or land-based drilling rig. This reduces delays due to transmitting information to a remote site for processing, then transmitting the results of that processing back to the well site. It also reduces potential inaccuracies in the analysis due to the reduction in the data being transmitted. The system thus allows personnel at the well site to monitor the well site operation in real time, and respond to changes or uncertainties encountered during the operation. The response may include comparing the real time data to the current well plan, and modifying the well plan.

In yet another embodiment, the system is installed at a remote site, in addition to the well site. This permits users at the remote site to monitor the well-site operation in a similar manner to a user at the well-site installation.

The architecture of the system workstation shown in Figure 1 is only one example of multiple possible architectures. In one embodiment, the workstation comprises one or more processors or microprocessors **102** coupled to one or more input devices **104** (e.g., mouse, keyboard, touchscreen, or the like), one or more output devices **106** (e.g., display, printer, or the like), a network interface **108**, and one or more non-transitory computer-

readable storage devices **110**. In some embodiments, the input and output devices may be part of the workstation itself, while in other embodiment such devices may be accessible to the workstation through a network or other connection.

In one exemplary embodiment, the network interface may comprise a wire-based interface (e.g., Ethernet), or a wireless interface (e.g., BlueTooth, wireless broadband, IEEE 802.11x WiFi, or the like), which provides network connectivity to the workstation and system to enable communications across local and/or wide area networks. For example, the workstation can receive portions of or entire well or cementing plans or geological models **117** from a variety of locations.

The storage devices **110** may comprise both non-volatile storage devices (e.g., flash memory, hard disk drive, or the like) and volatile storage devices (e.g., RAM), or combinations thereof. The storage devices store the system software **115** which is executable by the processors or microprocessors to perform some or all of the functions describe below. The storage devices also may be used to store well plans, geological models **117**, configuration files and other data.

In some exemplary embodiments, the system is a web-enabled application, and the system software may be accessed over a network connection such as the Internet. A user can access the software via the user's web browser. In some embodiments, the system performs all of the computations and processing described herein and only display data is transmitted to the remote browser or client for rendering screen displays on the remote computer. In other embodiments, the remote browser or software on the remote system performs some of the functionality described herein.

Sensors **120, 130** may be connected directly to the workstation at the well site, or through one or more intermediate devices, such as switches, networks, or the like. Sensors may comprise both surface sensors **120** and downhole sensors **130**. Surface sensors include, but are not limited to, sensors that detect torque, revolutions per minute (RPM), and weight on bit (WOB). Downhole sensors include, but are not limited to, gamma ray, pressure while drilling (PWD), and resistivity sensors. The surface and downhole sensors are sampled by the system during drilling or well site operations to provide information about a number of parameters. Surface-related parameters include, but are not limited to, the following: block position; block height; trip/running speed; bit

depth; hole depth; lag depth; gas total; lithography percentage; weight on bit; hook load; choke pressure; stand pipe pressure; surface torque; surface rotary; mud motor speed; flow in; flow out; mud weight; rate of penetration; pump rate; cumulative stroke count; active mud system total; active mud system change; all trip tanks; and mud temperature (in and out). Downhole parameters include, but are not limited to, the following: all FEMWD; bit depth; hole depth; PWD annular pressure; PWD internal pressure; PWD EMW; PWD pumps off (min, max and average); drill string vibration; drilling dynamics; pump rate; pump pressure; slurry density; cumulative volume pumped; leak off test (LOT) data; and formation integrity test (FIT) data. Based on the sensed parameters, the system causes the processors or microprocessor to calculate a variety of other parameters, as described below.

Figure 2 provides an example of the system software architecture. The system software comprises a database/server **150**, a display or visualization module **152**, one or more smart agents **154**, one or more templates **156**, and one or more "widgets" **160**. The database/server **150** aggregates, distributes and manages real-time data being generated on the rig and received through the sensors. The display or visualization module **152** implements a variety of graphical user interface displays, referred to herein as "consoles," for a variety of well site operations. The information shown on a console may comprise raw data and calculated data in real time.

Templates **156** defining a visual layout may be selected or created by a user to display information in some portions of or all of a console. In some embodiments, a template comprises an XML file. A template can be populated with a variety of information, including, but not limited to, raw sensor data, processed sensor data, calculated data values, and other information, graphs, and text. Some information may be static, while other information is dynamically updated in real time during the well site operation. In one embodiment, a template may be built by combining one or more display "widgets" **160** which present data or other information. Smart agents **154** perform calculations based on data generated through or by one or more sensors, and said calculated data can then be displayed by a corresponding display widgets.

In one exemplary embodiment, the system provides the user the option to implement a number of consoles corresponding to particular well site operations. In one

embodiment, consoles include, but are not limited to, rig-site fluid management, BOP management, cementing, and casing running. A variety of smart agents and other programs are used by the consoles. Smart agents and other programs may be designed for use by a particular console, or may be used by multiple consoles. A particular installation of the system may comprise a single console, a sub-set of available consoles, or all available consoles.

In various embodiments, smart agents in the system can be managed with a toolbar **200** (as seen in Figure 3) or by a drop-down menu **210** (as seen in Figure 4), which may be activated by clicking on a smart agent icon, right-click on a mouse button, or the like. Functions include, but are not limited to, adding a new agent **202a**, copying an agent configuration **202b**, importing **202c** or exporting **202d** an agent configuration file, deleting an agent **202e**, refreshing the status of an agent **202f**, or starting or stopping an agent.

For certain smart agents, an agent configuration file must be imported **220** to use the smart agent, as seen in Figure 5. In one embodiment, configuration files are denominated as *.agent files. Selecting the import option provides the user the option to enter the configuration file name, or browse to a location where the configuration file is stored.

Agents can be configured, and configuration files created or modified, using the agent properties display, as seen in Figure 6. The same properties are used for each agent, whether the agent configuration is created or imported. The specific configuration information (including, but not limited to, parameters, tables, inputs, and outputs) varies depending on the smart agent. Parameters **232** represent the overall configuration of the agent, and include basic settings including, but not limited to, start and stop parameters, tracing, whether data is read to a log, and other basic agent information. Tables **234** comprise information appearing in database tables associated with the agent. Inputs **236** and outputs **238** are the input or output mnemonics that are being tracked or reported on by the agent. For several embodiments, in order for data to be tracked or reported on, each output must have an associated output. This includes, but is not limited to, log and curve information.

Users can export an agent configuration file for other users to import and use. The export configuration button in the toolbar can be used for a selected agent, or the agent can be right-clicked on and the export configuration option **240** chosen, as shown in Figure 7. The user confirms **242** the action to download the file to a local hard drive or other file storage location, as seen in Figure 8. The user may name the file as desired. Once downloaded, the file can be copied, emailed, or otherwise transferred to another user for importation and use.

Copying an agent configuration **244**, as seen in Figure 9, allows the user to copy an agent configuration file and rename it. This saves the user from having to perform an initial setup of the agent properties or create a new configuration file multiple times, if the user has agent configurations that are similar. In one embodiment, the user right clicks on the desired agent, selects the copy option, and identifies the wellbore for which the configuration is to be used. The user can name or rename the new agent configuration.

The Well Advisor system and related consoles are described more fully in "System and Console for Monitoring and Managing Well Site Operations," U.S. Pat. Application No. 14/196,307, and "System and Console for Monitoring and Managing Casing Running Operations at a Well Site," U.S. Pat. Application No. 14/208,796, which are incorporated herein in their entireties by specific reference for all purposes.

Rate of Penetration Console

The Rate of Penetration (ROP) console, examples of which are seen in Figures 10-12, provides real-time ROP performance benchmarking, drilling parameter guidance, and subsurface drillability characteristics (e.g., formation name, rock type, rock strength, interface severity, and the like) from constantly updated, normalized offset well datasets. Offset well data includes, but is not limited to, data relating to the ROP, including surface and downhole drilling information. Offset parameters can be based on historical offset data, outputs from drilling models that provide parameter recommendations, or combinations thereof. Additional information about the type and size of drill bit, drilling assembly, and other components associated with the drilling project also are considered. The data is processed and converted to a concise, comprehensive format. Key data that describes performance benchmarks extracted from the offset data is presented in a

numeric and graphical manner to allow a user to easily compare this information to the real-time data from the well being drilled (e.g., a user can quickly and easily examine the current, real-time ROP of the present well as compared to the corresponding ROPs for offset wells). If the comparison indicates sub-par performance, the user can consider and implement changes in drilling parameters based upon the associated offset well parameters used to achieve the performance benchmark. Thus, the user can respond, in real-time, to attempt to improve the ROP of the well being drilled, and possibly surpass the pre-determined performance benchmark.

Offset well datasets should be relevant to the active well. Factors to consider in determining relevancy include, but are not limited to, type of well, type of drilling platform, subsurface formations, region, BHA configurations, bit types, well trajectories, and similar factors.

In several exemplary embodiments, the relevant offset data, including, but not limited to, ROP benchmark performance, drilling parameter guidance, and prognosed lithology characterization, are processed and converted, and an appropriate display range determined. The data is then normalized to prognosed formation tops for the well to be drilled (i.e., the target well). The comparative ROP and other parameters and drillability characteristics (such as weight-on-bit (WOB), revolutions per minute (RPM), and torque) are graphically displayed on linear tracks as "fairways," along with the downhole assembly (BHA) track **302**, as seen in Figures 10-12. The parameters and data displayed can include surface drilling information, downhole drilling information, or combinations thereof.

An amalgamated maximum and minimum ROP can be calculated as well as the average ROP, and displayed in a ROP fairway track **304**. Comparative data and recommendations for WOB **306**, revolutions per minute (RPM) **308**, torque **310**, and flow **312** may be determined using relevant offset data (depth shifted to the current well), model calculations, and third party recommendations, or combinations thereof. The data ranges can be shaded or colored, and the ranges may be sub-divided (e.g., the ROP range in Figures 10, 11 and 13 has three sub-ranges, with the maximum ROP range on the right). The actual real-time data (ROP, WOB, RPM, torque, and the like) from the target well are displayed overlaying the fairways, and the historical actual data forms a black

line. The offset data may be actively depth shifted or adjusted as actual formation tops or markers are encountered (i.e., the offset set data is corrected "on the fly" to reflect the actual formation lithology). At any point, the console thus allows a direct ROP comparison, as well as the parameter combination that achieved that ROP, as well as information on formation name, rock properties, rock type, hardness, and related information. Formation, lithology **322** and rock properties **324** tracks may be added, as well as other tracks. A drilling efficiency track **330** may be provided, where drilling efficiency may be derived from mechanical specific energy (MSE) and average rock strength. While the tracks default to showing the current bottom of the hole, a user can move the tracks up and down by use of a slider.

If the actual ROP is not within the optimal range, thereby indicating sub-par performance, the user can reference the associated offset parameters used to achieve the performance benchmark, and adjust or modify the operating parameters of the well being drilled so as to improve the actual ROP. Subnormal ROP or parameters exceeding those from the offset data also may indicate a variety of other conditions of concern, such as a prematurely dulled drill bit, or other drilling disfunctions.

The fairways display also provides the user some advance warning of what is about to be drilled into in the active well, and thus gives the user some idea of what to expect.

An example of an ROP console display for a driller is shown in Figure 12. The left track **340** shows formation information and depth, with the formation names and depth of tops for the current formation being drilled **342** and the next formation **344** shown on the display (this information can be provided by a formation name widget). The depth shown here may be on a different scale from the depth used for the other tracks.

A depth index track **320** shows the depth range for the remaining tracks on the display. The lithology track **322** shows the type of lithology. The BHA track **302** shows a graphical representation of the current components of the BHA. The risk track **350** gives a graphic or color-based representation of risk for a particular depth. Further information about the current risks for a depth range, and mitigation steps, may be provided in a separate box **352**.

The ROP, WOB, RPM, Torque and Flow fairway tracks **304, 306, 308, 310, 312**, are provided as described above. Further, the "best" value for each parameter can identified in a series of boxes **360** below each track. The MSE and Drilling Efficiency track **330** also is provided.

A graphical display of a cross-section of a drill-bit and hole size also may be shown **370**, indicating the presence of axial vibration and providing remedial actions to mitigate the problem. The display also may provide an indicator of general data quality **372**, which may be provided by a data quality widget.

An example of a GUI display for a dashboard showing drilling parameters is shown in Figure 13. Information provided includes drill bit hydraulics **380**, current hookload **382**, WOB **384**, block position **386**, mud parameters **388** and a run information "snapshot" **390**.

Figure 14 shows an example of a vibration detail display. It provides the same graphical display and mitigation information **370, 372** as described above, as well as time-based tracks **374** showing overall vibration and related parameters (e.g., torsion, stick slip, and shock). The charts may be colored to draw the viewer's attention to areas of concern (e.g., green to indicate acceptable values, yellow to indicate an alert, orange or red to indicate areas of high concern). A zone chart **378** may also be used to show current (or historical) values of parameters of interest, superimposed over a normalized geometric diagram with colored regions as described above. The permits the user to see graphically which parameter values are of greatest alarm or concern.

Figure 15 shows an example of a console display for a well site leader (WSL). It should be noted that a user can switch between the various displays by clicking on a tab in the console. Clicking on the tab marked "ROP Display 1," for example, would show the display of Figure 12, while clicking on the tab marked "ROP Display 2" would show the WSL display of Figure 15. The WSL display contains several of the same tracks as Figure 12, but also contains a time-based set of tracks **410**, including, but not limited to, block position **412**, WOB **414**, rotary torque **416**, and mud flow in **418**. This display also lists the main current risk **420** (e.g., losses while cementing).

Figure 16 shows a correlations display. Figure 17 shows an example of a real-time depth vs. days chart showing actual data for the well being drilled compared to offset data.

Accordingly, the ROP console and system provides an method for improving drilling performance, enhancing the consistency of drilling performance, and reduce well construction costs, particularly in hard rock areas. It improves ROP, optimizes drill-bit performance, and reduces shock and vibration to the drilling assembly and drill string.

There are numerous advantages to the ROP console and system as compared to the prior art. Bit performance benchmarking in the prior art is typically only performed by total/daily run length (distance and time), defined using very road parameter ranges for the entire run, and may occasionally be broken down by formation. Run lengths, however, may be over thousands of meters, and formation intervals may be hundreds of meters, thereby missing subtle and dramatic ROP nuances. The present invention captures these nuances, and allows the driller to consider drilling parameter changes that coincide with intra-formation changes, or zones of high interface severity. It also allows for quick adjustment based on actual formation tops, thereby avoiding the problems caused by differences between prognosed and actual formation tops.

Optimizing the rate of penetration requires the steps of preparing to monitor the rate of penetration for a run, monitoring and controlling the rate of penetration for a run, optimizing the rate of the penetration for a run, and, in some cases, evaluating and reporting on the rate of penetration for an intermediate or section rune. The console describe above assists the rate of penetration monitors and specialists and other users to carry out these steps.

Thus, it should be understood that the embodiments and examples described herein have been chosen and described in order to best illustrate the principles of the invention and its practical applications to thereby enable one of ordinary skill in the art to best utilize the invention in various embodiments and with various modifications as are suited for particular uses contemplated. Even though specific embodiments of this invention have been described, they are not to be taken as exhaustive. There are several variations that will be apparent to those skilled in the art.

CLAIMS

What is claimed is:

1. A system for computer-based processing and monitoring of rate of penetration data in well drilling operations, comprising:

a plurality of sensors to sample or detect parameters related to the rate of penetration of drilling operations in a well, said plurality of sensors comprising surface sensors or downhole sensors or a combination thereof;

one or more computing devices adapted to receive parameter information in real time from said plurality of sensors, said one or more computing devices each further comprising a processor or microprocessor, said processor or microprocessor adapted to process the received parameter information to calculate derived parameters related to the rate of penetration;

at least one computer-readable storage medium for storing some or all of said received parameter information and said derived parameters; and

a visual display, coupled to said one or more computing devices, for displaying in real time some or all of the received parameter information and said derived parameters.

2. The system of claim 1, wherein the visual display of some or all of the received parameter information and said derived parameters is in real time.

3. The system of claim 1, said one or more computing devices further comprising at least one software smart agent having one or more formulations applicable to said drilling operations.

4. The system of claim 1, wherein the visual display of some or all of the received parameter information and said derived parameters for the well further comprises comparable parameter information from offset wells.

5. The system of claim 4, wherein the offset well parameter information comprises historical offset data, parameter recommendations from drilling models, or combinations thereof.

6. The system of claim 4, wherein the visual display comprises at least one track, said track comprising a plotline of a certain parameter for the well in real time versus depth, wherein the real time parameter data for the well is presented overlaying a fairway, the fairway comprising the area between a plotline for a first value and a plotline for a second value at each depth for that parameter.

7. The system of claim 6, wherein the first value is a maximum value for the parameter for a given depth in the well calculated from offset well parameter information, and the second value is a minimum value for the parameter for the same depth calculated from offset well parameter information,

8. The system of claim 7, wherein the first values and second values have been normalized to anticipated formation tops for the well.

9. The system of claim 8, wherein the first values and second values may be updated in real time based on actual formation tops as encountered in the well.

10. The system of claim 6, wherein the fairway for a given parameter may be divided into two or more ranges by one or more plotlines located between the first value plotline and the second value plotline.

11. The system of claim 6, wherein the parameter being mapped comprises one or more of rate of penetration, weight-on-bit, revolutions per minute, and torque.

12. The system of claim 6, further comprising a track displaying the bottom hole assembly matched to the actual drilling depth.

13. The system of claim 6, further comprising one or more tracks displaying corresponding lithology data, drilling efficiency data, drill bit performance data, or combinations thereof.

14. A method for improving computer-based processing and monitoring of rate of penetration data in well drilling operations, comprising the steps of:

receiving, using a processor or microprocessor, rate of penetration parameter information from a plurality of sensors, said plurality of sensors comprising surface sensors or downhole sensors or a combination thereof;

calculating, in real time, using said processor or microprocessor, one or more derived parameters from the received pressure testing parameter information; and

displaying in real time, on a visual display, some or all of the received parameter information and the one or more derived parameters.

15. The method of claim 14, wherein the step of displaying comprises displaying at least one track of parameter information, said track comprising a plotline of a certain parameter for the well in real time versus depth, wherein the real time parameter data for the well is presented overlaying a fairway, the fairway comprising the area between a plotline for a first value and a plotline for a second value at each depth for that parameter.

16. The method of claim 15, wherein the first value is a maximum value for the parameter for a given depth in the well calculated from offset well parameter information, and the second value is a minimum value for the parameter for the same depth calculated from offset well parameter information,

17. The method of claim 15, wherein the fairway for a given parameter may be divided into two or more ranges by one or more plotlines located between the first value plotline and the second value plotline.

18. The method of claim 14, wherein the parameter being mapped comprises one or more of rate of penetration, weight-on-bit, revolutions per minute, and torque.

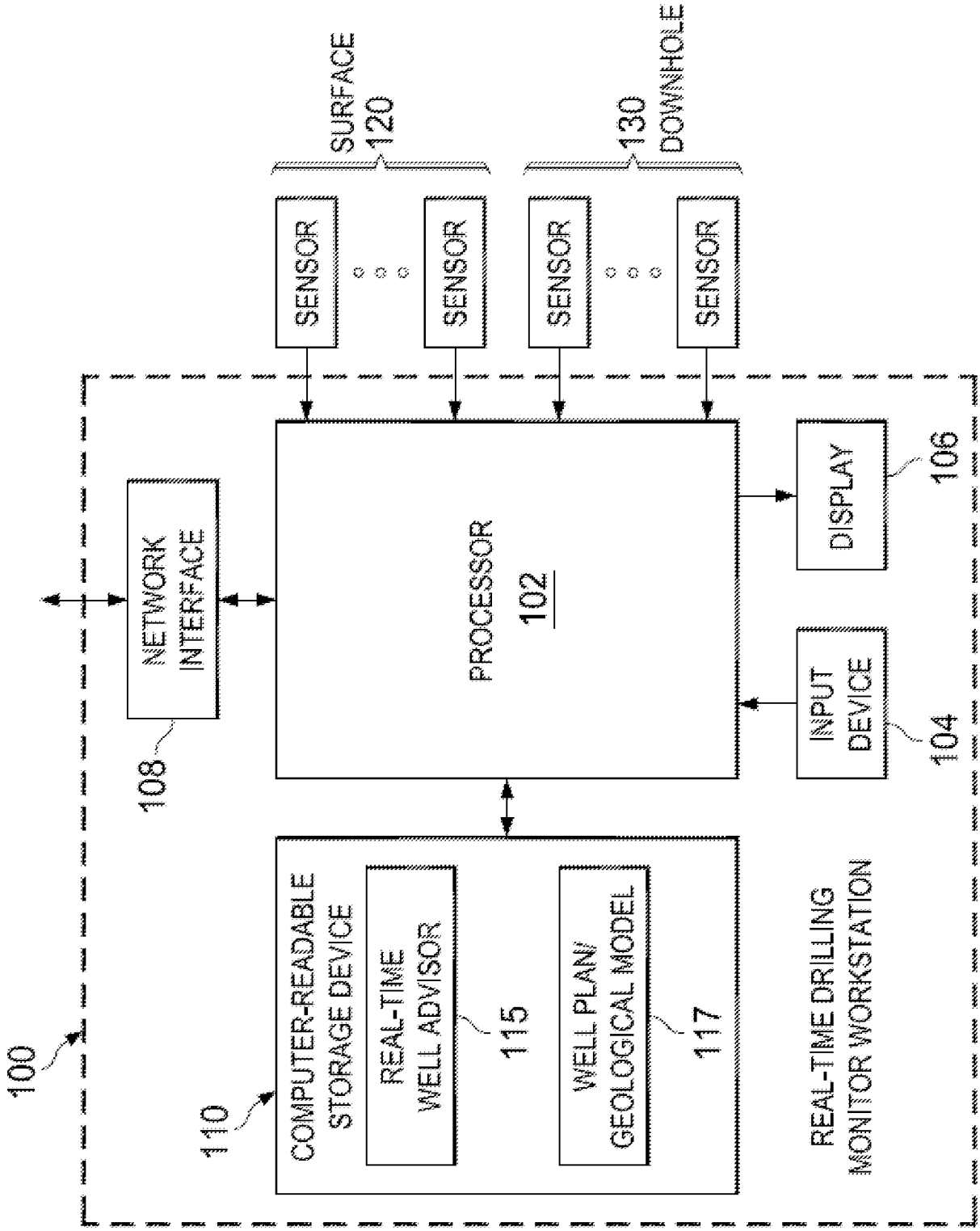

SURFACE
120
DOWNHOLE
130
SENSOR
SENSOR
SENSOR
SENSOR
NETWORK INTERFACE
108
PROCESSOR
102
DISPLAY
106
INPUT DEVICE
104
100
110
COMPUTER-READABLE STORAGE DEVICE
REAL-TIME WELL ADVISOR
115
WELL PLAN/ GEOLOGICAL MODEL
117
REAL-TIME DRILLING MONITOR WORKSTATION

FIGURE 1

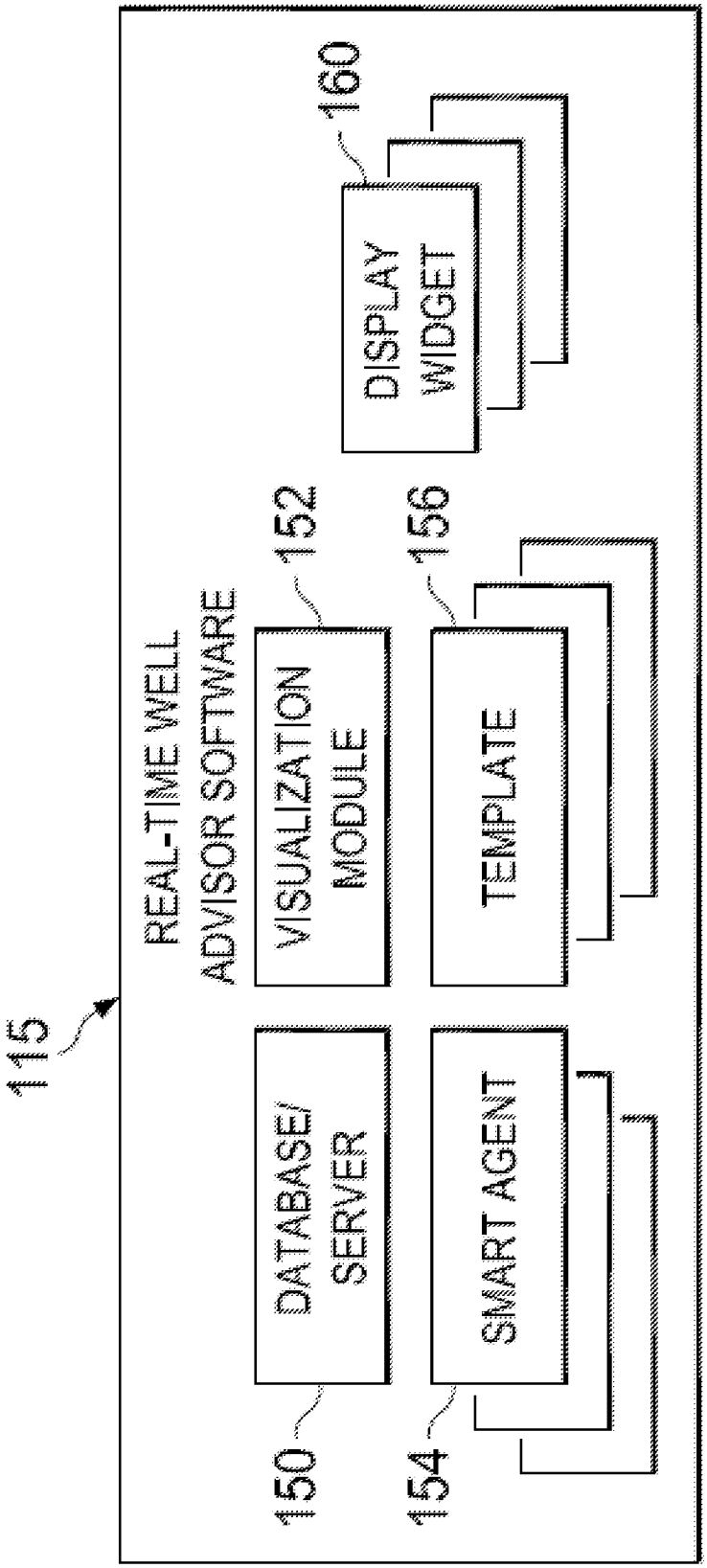

115
REAL-TIME WELL ADVISOR SOFTWARE
DATABASE/ SERVER
150
VISUALIZATION MODULE
152
SMART AGENT
154
TEMPLATE
156
DISPLAY WIDGET
160

FIGURE 2

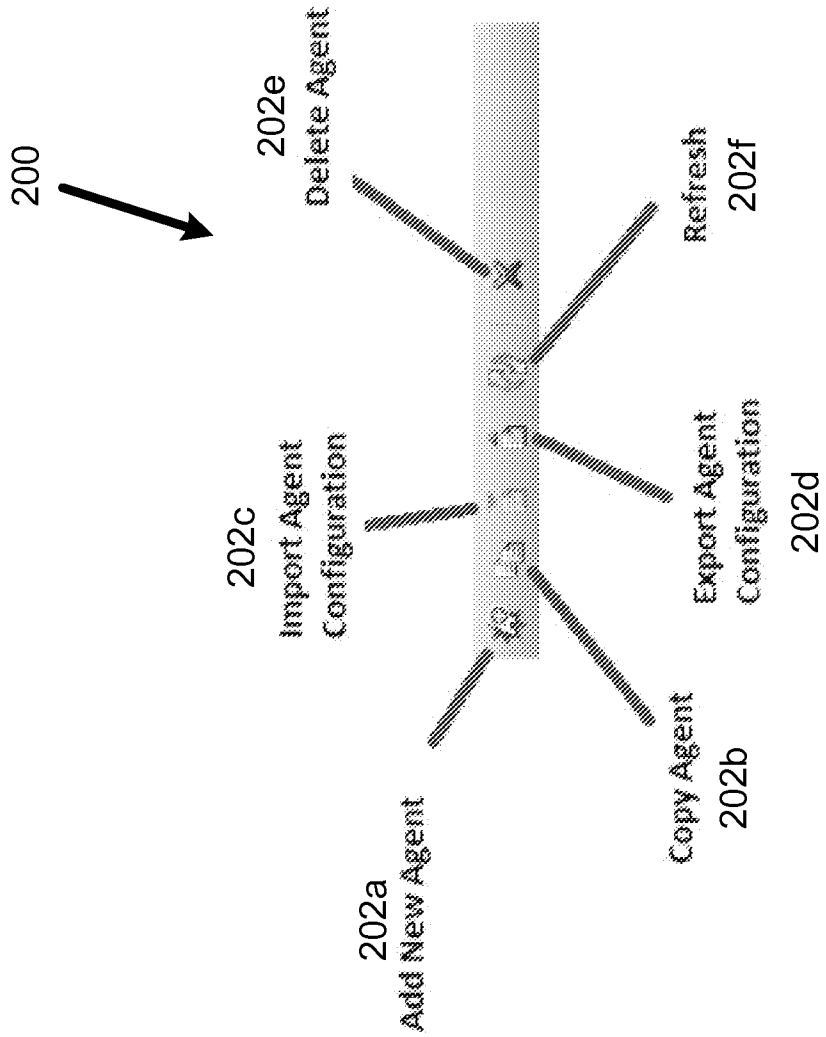

200
202e
Delete Agent
Refresh
202f
202c
Import Agent
Configuration
Export Agent
Configuration
202d
202a
Add New Agent
Copy Agent
202b

FIGURE 3

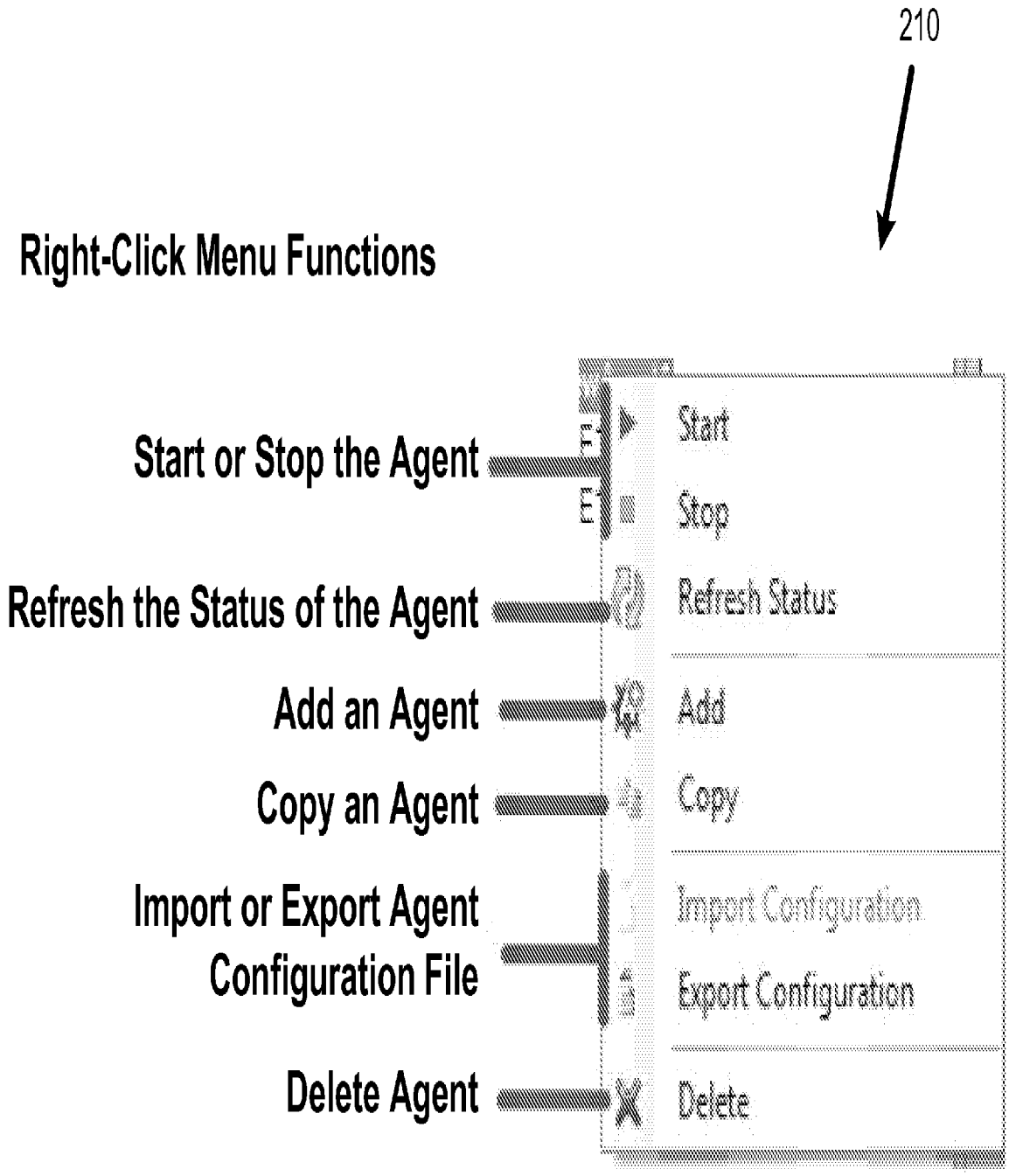

210
Right-Click Menu Functions
Start or Stop the Agent
Refresh the Status of the Agent
Add an Agent
Copy an Agent
Import or Export Agent Configuration File
Delete Agent
Start
Stop
Refresh Status
Add
Copy
Import Configuration
Export Configuration
Delete

FIGURE 4

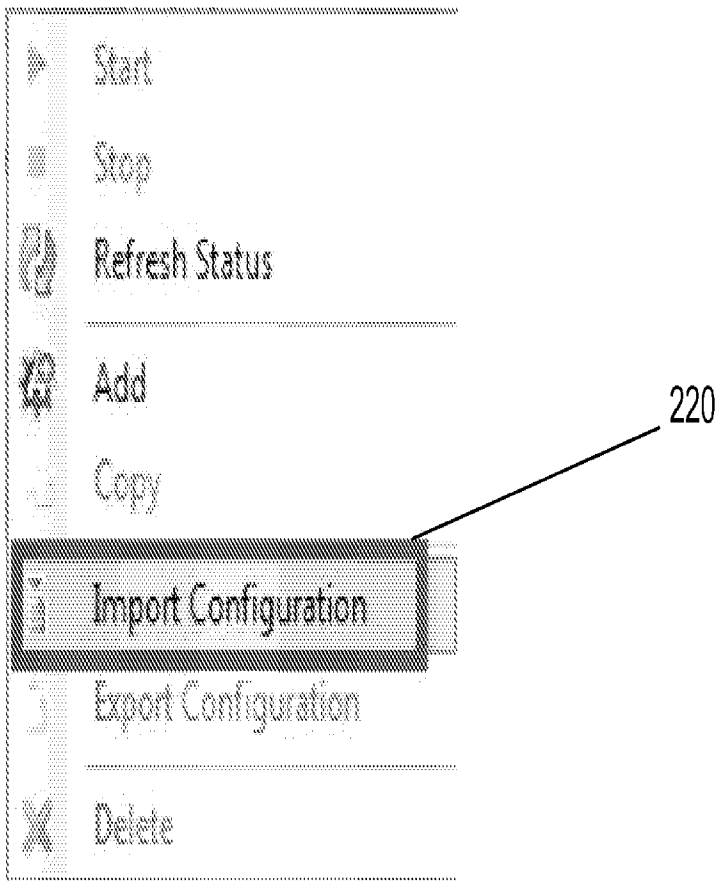

Start
Stop
Refresh Status
Add
Copy
Import Configuration
Export Configuration
Delete
220

FIGURE 5

	E15N-O	Description:	TCRc Hookload Signature Smart Agent
Agent Type:	TrippingCasingRunning SmartAgent Hookload Signature Agent		
Well/Wellbore:	E15TestGroupNJ\E15_SourceWellbore		

Parameters 232

Key	Data type	Value
AgentUtcStart	string	10/11/15 00:00:00
AgentUtcStop	string	
RushOutputLogs	bool	False
TravelingAssemblyWeight	string	115
EnableTracing	bool	True

Tables 234

Table Key	Key	Value

Inputs 236

Key	Mnemonic	Log Name	Index Type
HookloadSignatureInput	DBTM	GENERAL TIME_BASED (...	Time
HookloadSignatureInput	BPOS	GENERAL TIME_BASED (...	Time
HookloadSignatureInput	HKLA	GENERAL TIME_BASED (...	Time

Inputs 238

Key	Mnemonic	Log Name	Index Type	Index Curve	Index c
HookloadSignature	Start	HookloadSignature	Time	Time	Date Ti
HookloadSignature	Stop	HookloadSignature	Time	Time	Date Ti

FIGURE 6

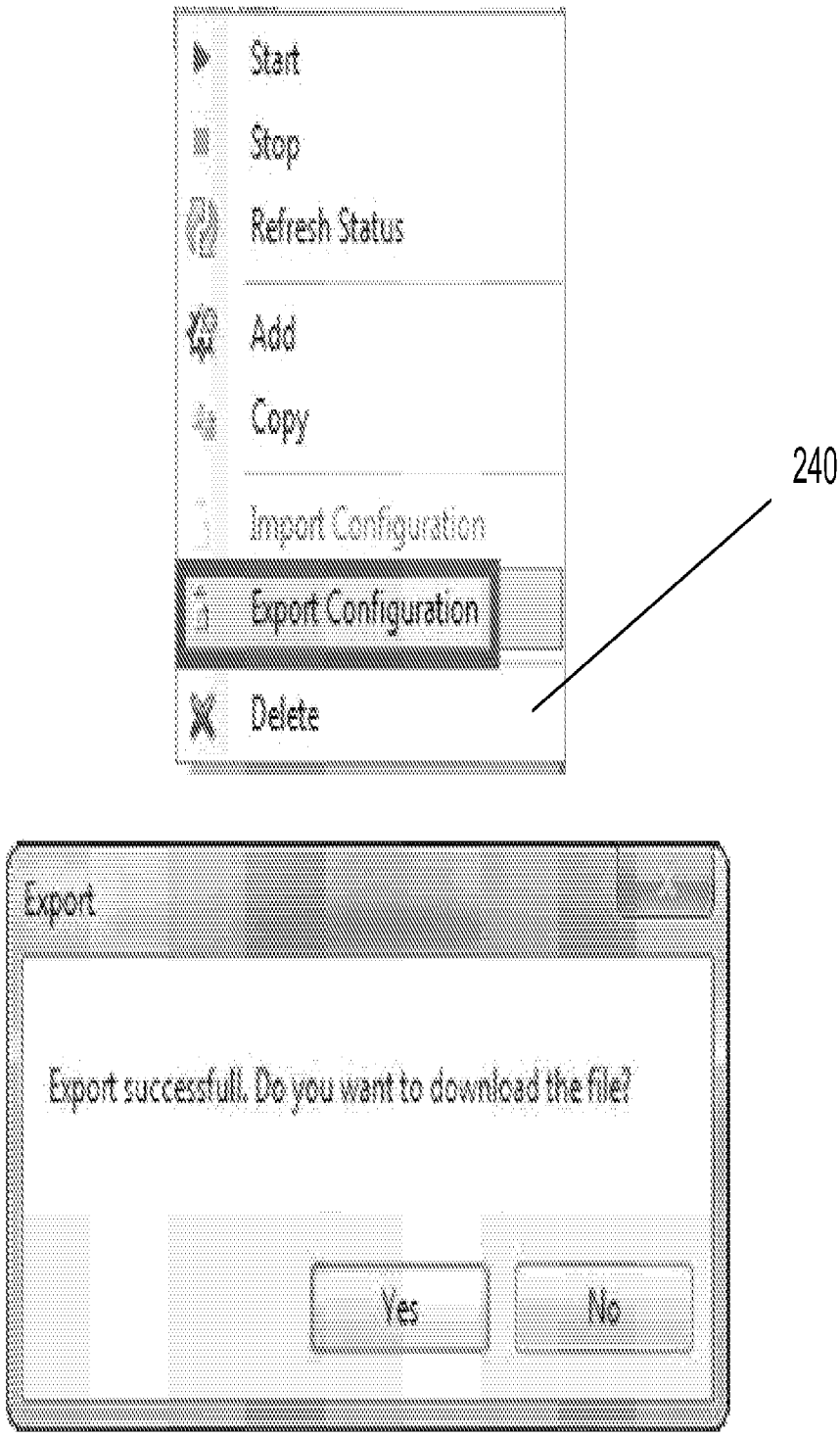

Start
Stop
Refresh Status
Add
Copy
Import Configuration
Export Configuration
Delete
240
Export
Export successful. Do you want to download the file?
Yes
No

FIGURE 7

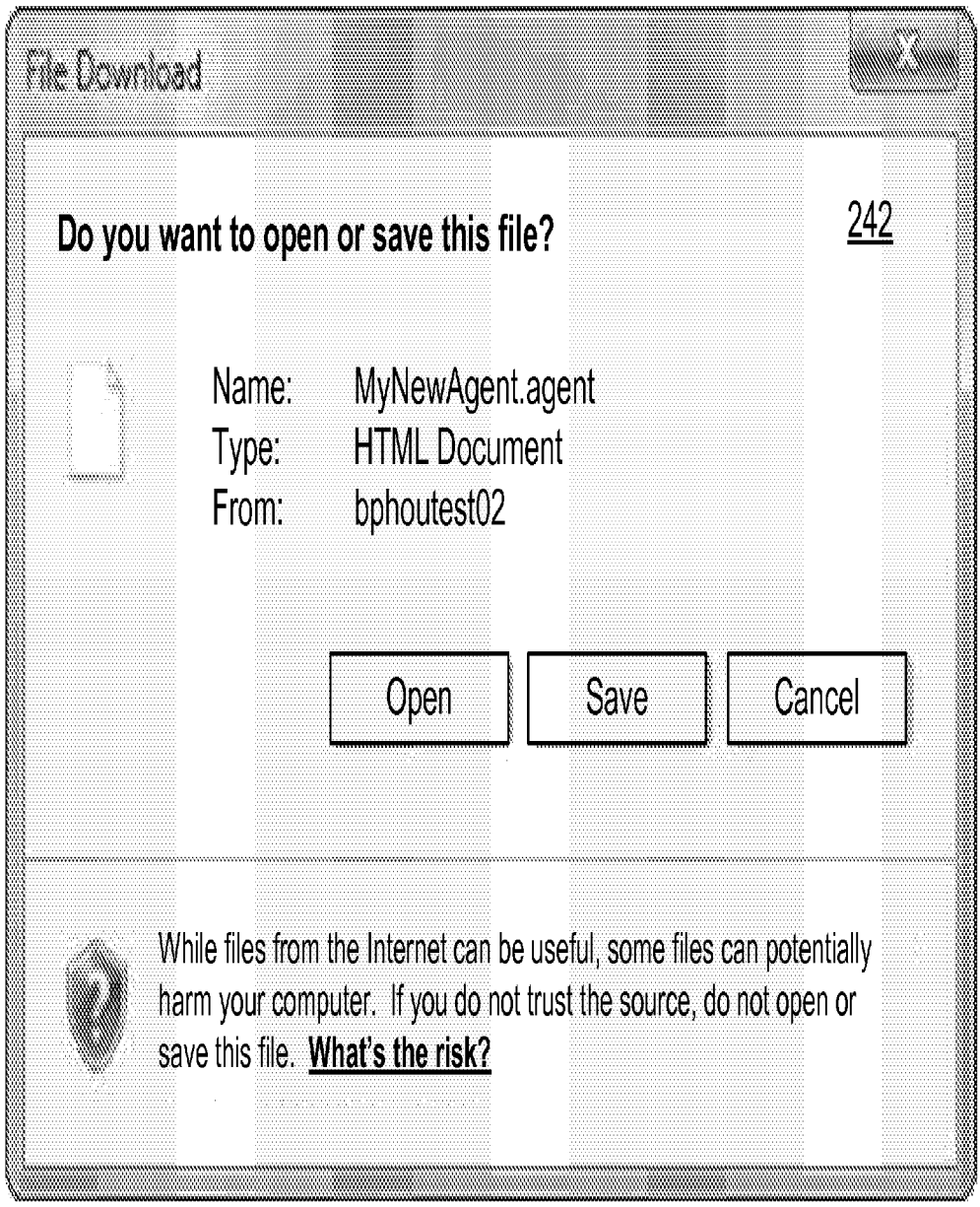

File Download
Do you want to open or save this file?
242
Name: MyNewAgent.agent
Type: HTML Document
From: bphoutest02
Open
Save
Cancel
While files from the Internet can be useful, some files can potentially harm your computer. If you do not trust the source, do not open or save this file. What's the risk?

FIGURE 8

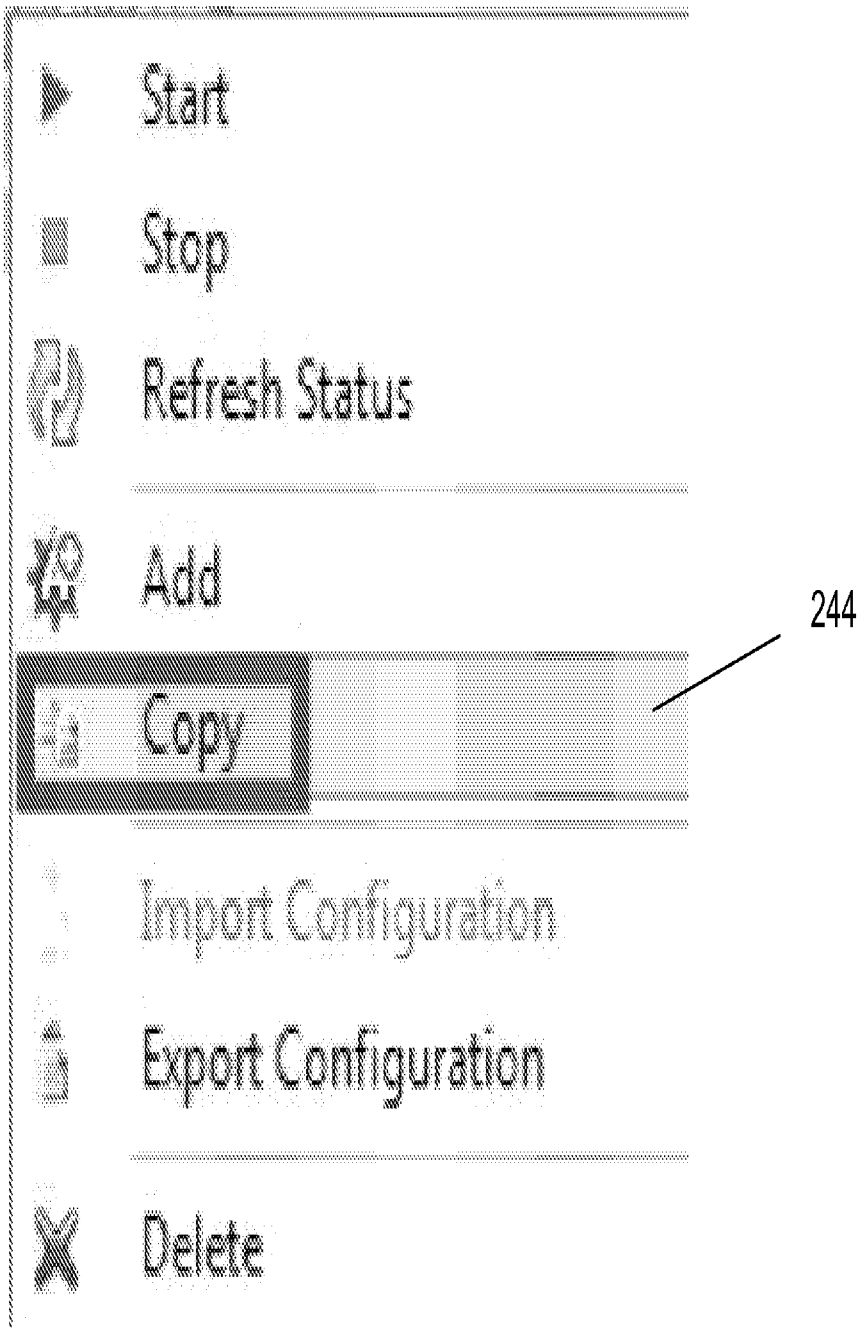

Start
Stop
Refresh Status
Add
Copy
Import Configuration
Export Configuration
Delete
244

FIGURE 9

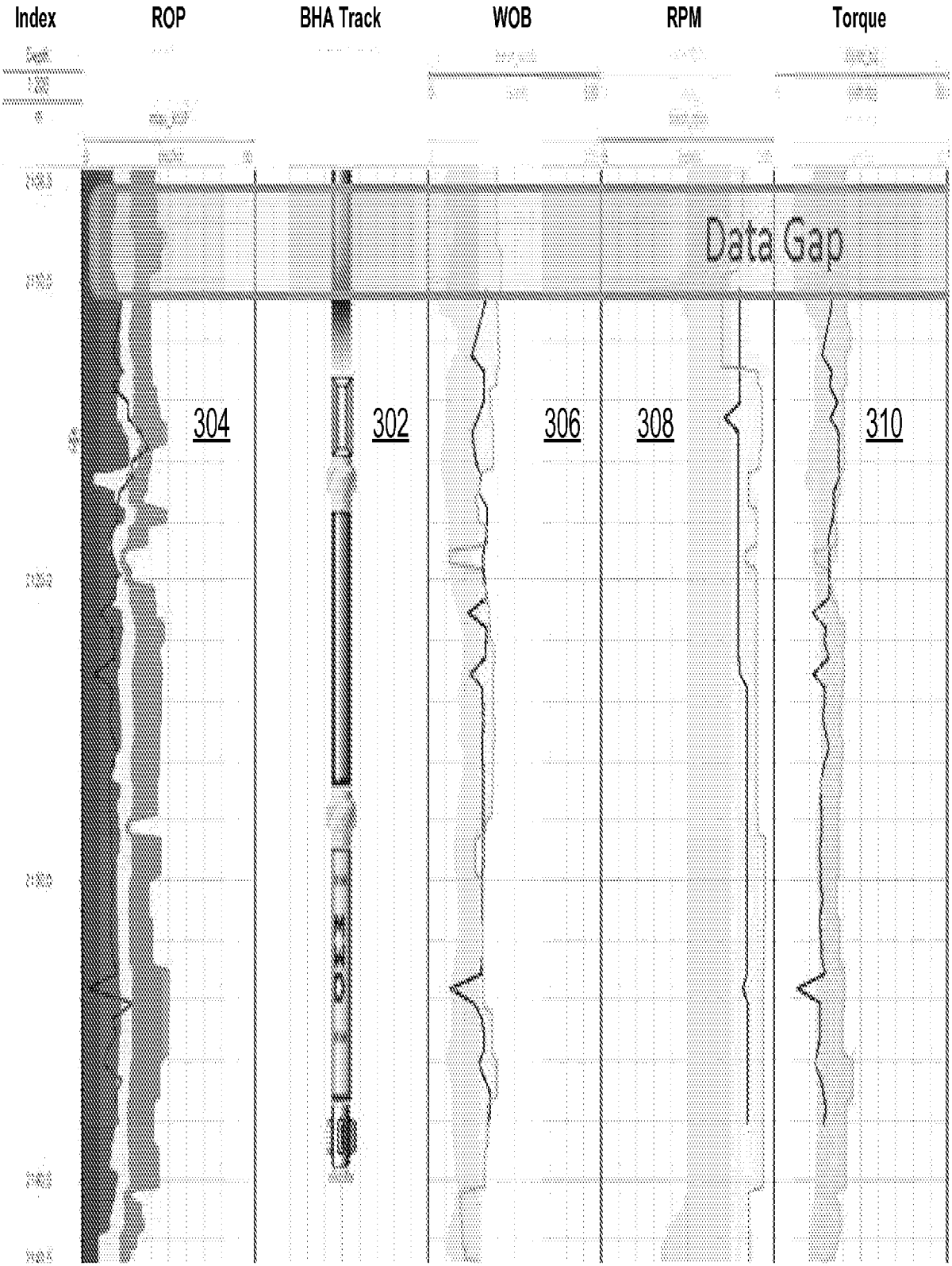
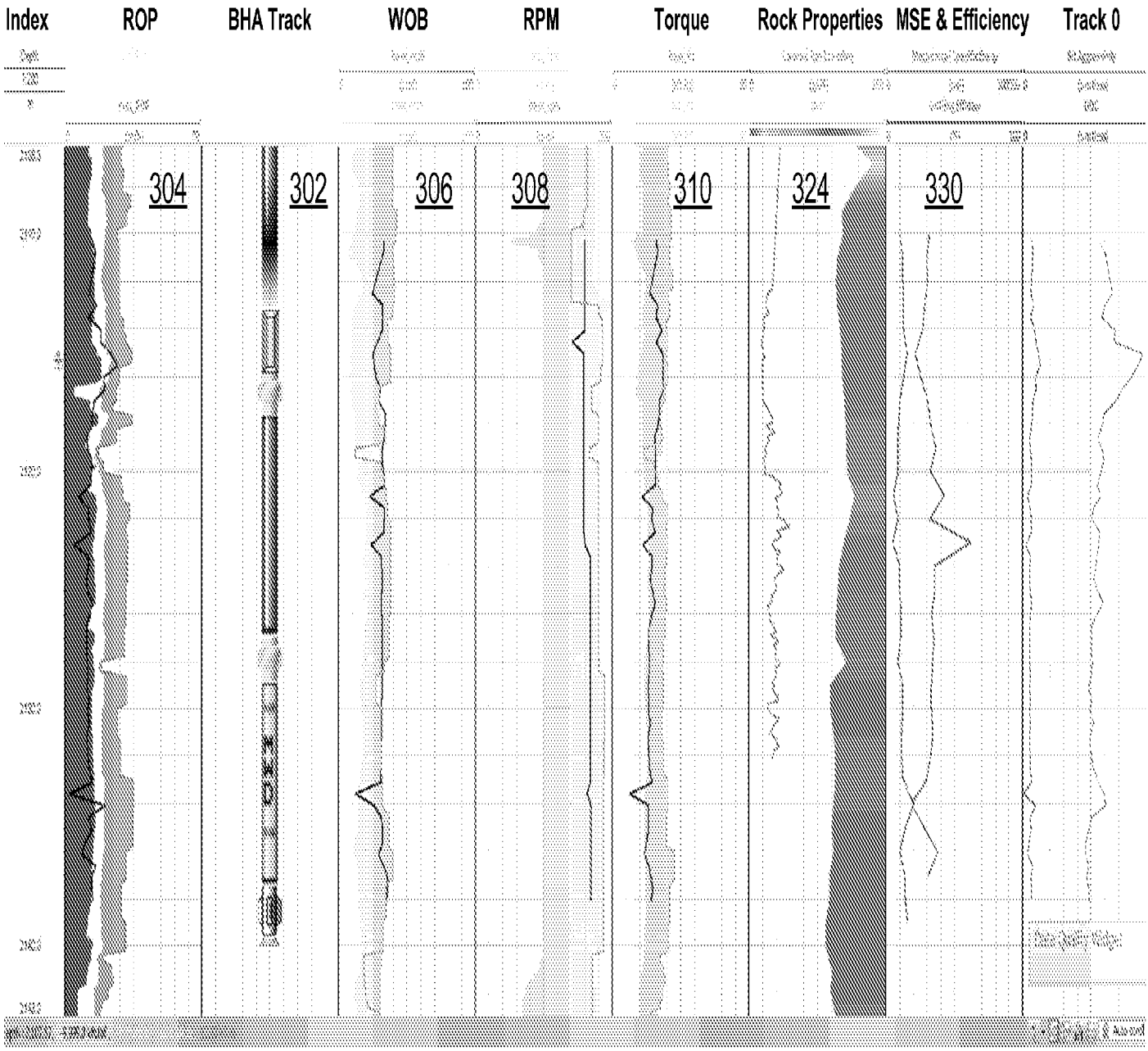

Index
ROP
BHA Track
WOB
RPM
Torque
Data Gap
304
302
306
308
310

FIGURE 10



ROP Fairway: Overlays real-time ROP (black line) on offset performance range. Current run shows below avg ROP for interval displayed.

Parameter Fairways: Overlays real-time parameters of WOB, RPM & Torque (black line) on offset performance range. Green line indicates parameter value that delivered best ROP

Rock Properties: Real-time Gamma Ray and Rock Strength (UCS) derived from offsets

Mechanical Specific Energy and Drilling Efficiency

Drill Bit Performanc Indicators

FIGURE 11

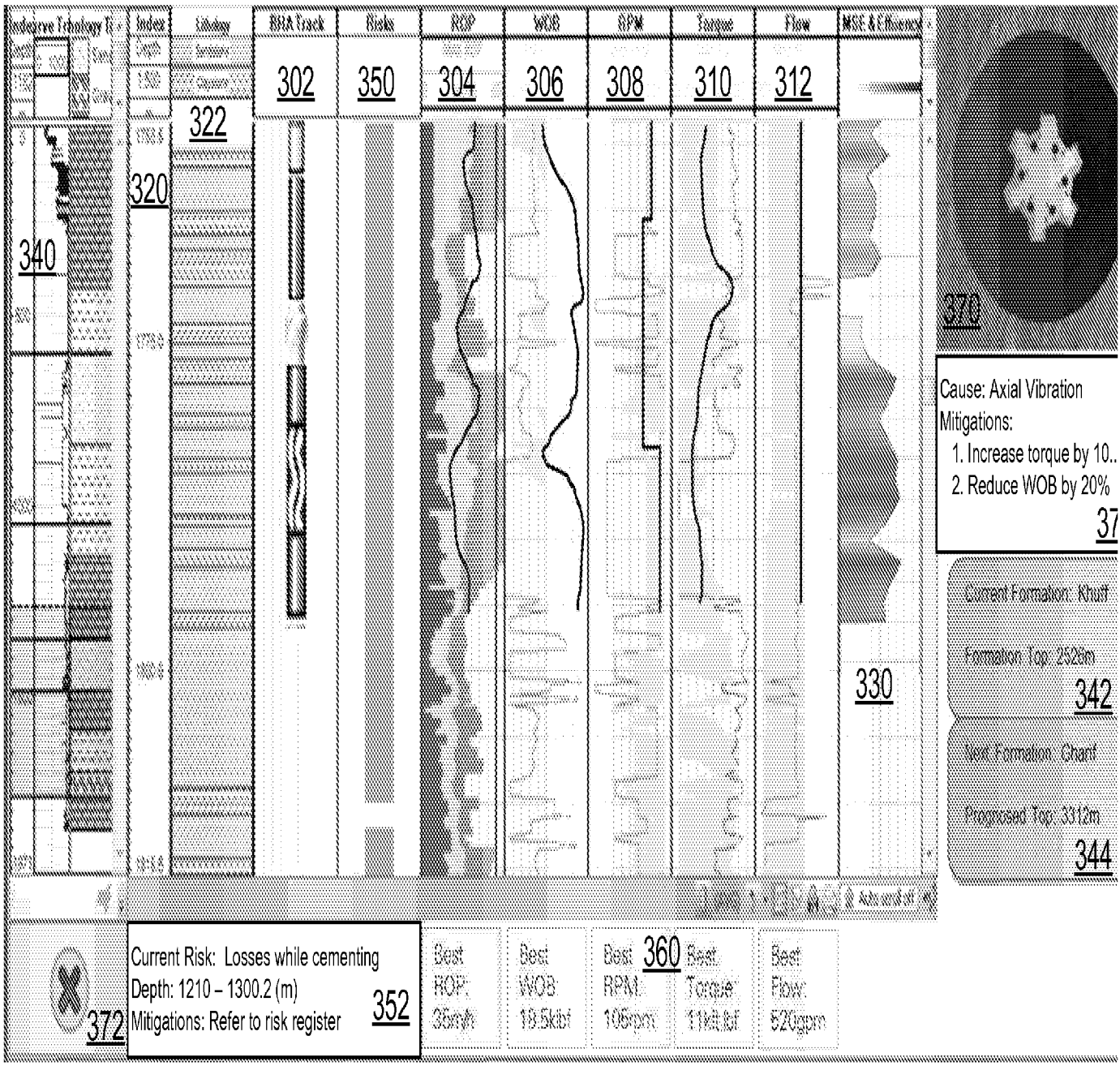

302
350
304
306
308
310
312
322
320
340
330
370
Cause: Axial Vibration
Mitigations:
1. Increase torque by 10..
2. Reduce WOB by 20%
37
Current Formation: Khuff
Formation Top: 252m
342
Next Formation: Chant
Prognosed Top: 3312m
344
Current Risk: Losses while cementing
Depth: 1210 – 1300.2 (m)
Mitigations: Refer to risk register
352
372
360
Best ROP: 35m/h
Best WOB: 18.5klbf
Best RPM: 105rpm
Best Torque: 11kft.lbf
Best Flow: 520gpm

FIGURE 12

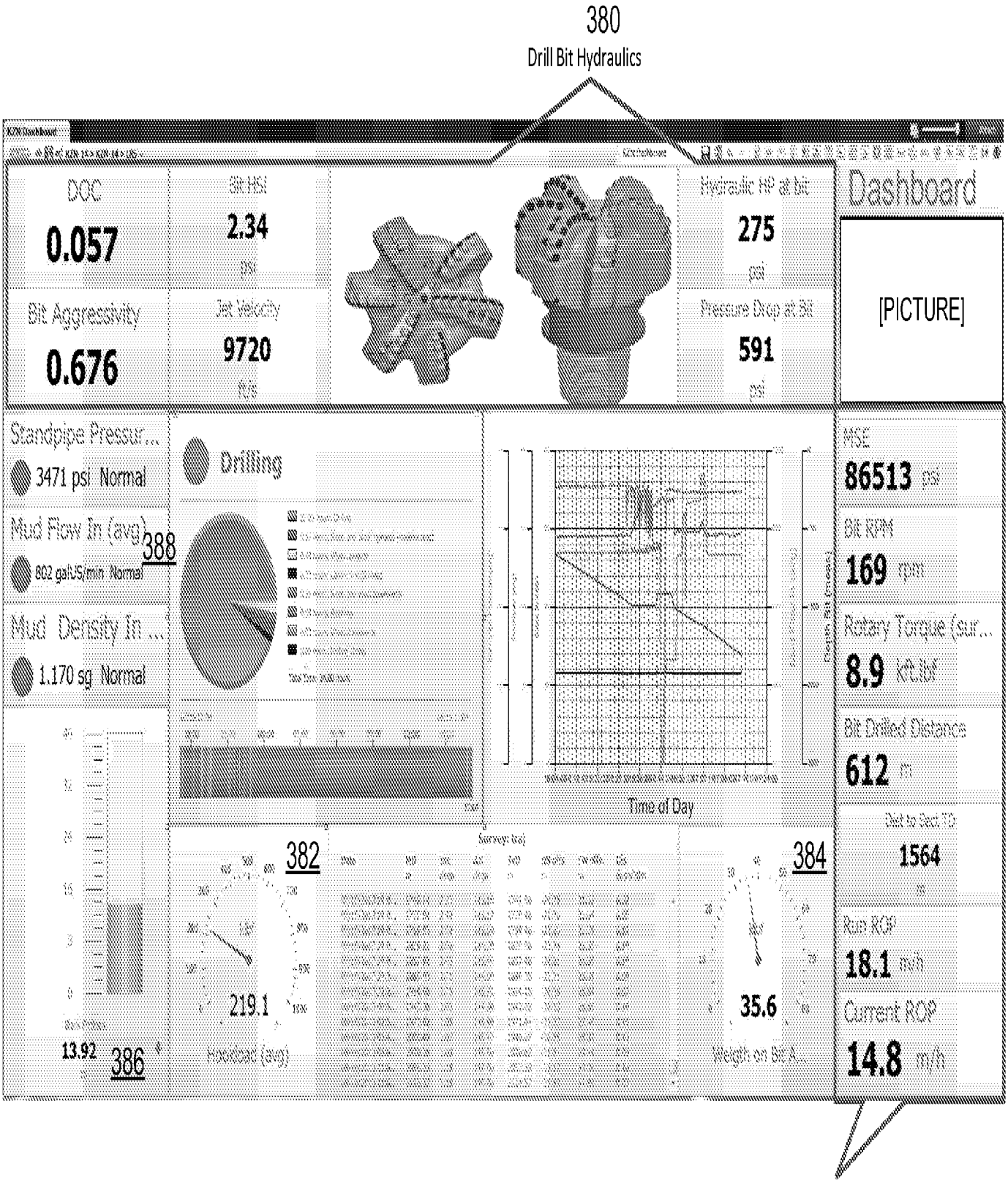

380
Drill Bit Hydraulics
DOC
0.057
Bit HSI
2.34
Bit Aggressivity
0.676
Jet Velocity
9720
Hydraulic HP at bit
275
Pressure Drop at Bit
591
Dashboard
[PICTURE]
Standpipe Pressur...
3471 psi Normal
Drilling
Mud Flow In (avg)
388
802 gal/US/min Normal
Mud Density In ...
1.170 sg Normal
MSE
86513 psi
Bit RPM
169 rpm
Rotary Torque (sur...
8.9 Kft.lbf
Bit Drilled Distance
612 m
Dist to Sect TD
1564
Run ROP
18.1 m/h
Current ROP
14.8 m/h
Time of Day
382
384
219.1
35.6
13.92
386
Run Snapshot
390

FIGURE 13

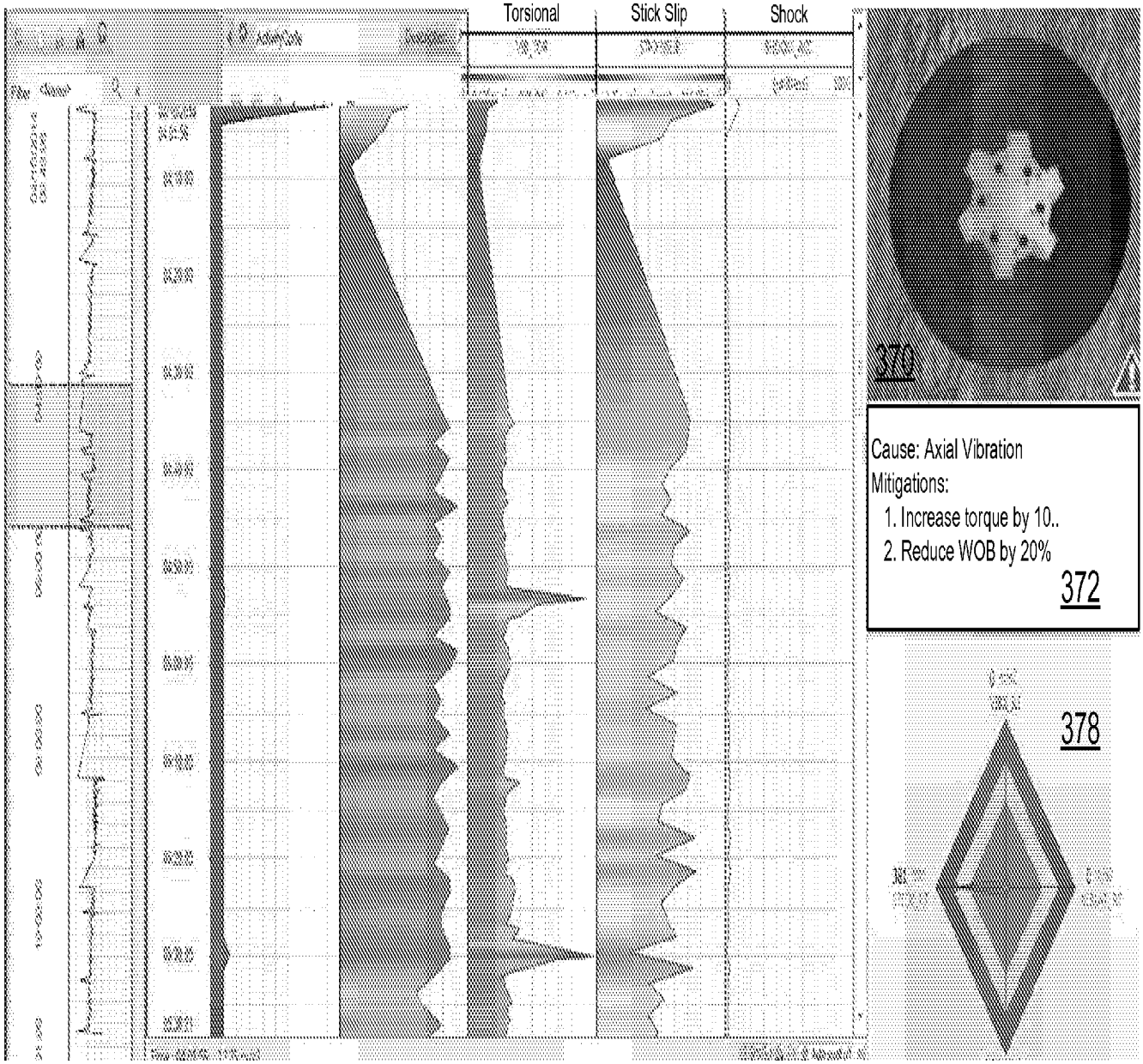

Torsional
Stick Slip
Shock
370
Cause: Axial Vibration
Mitigations:
1. Increase torque by 10..
2. Reduce WOB by 20%
372
378

FIGURE 14

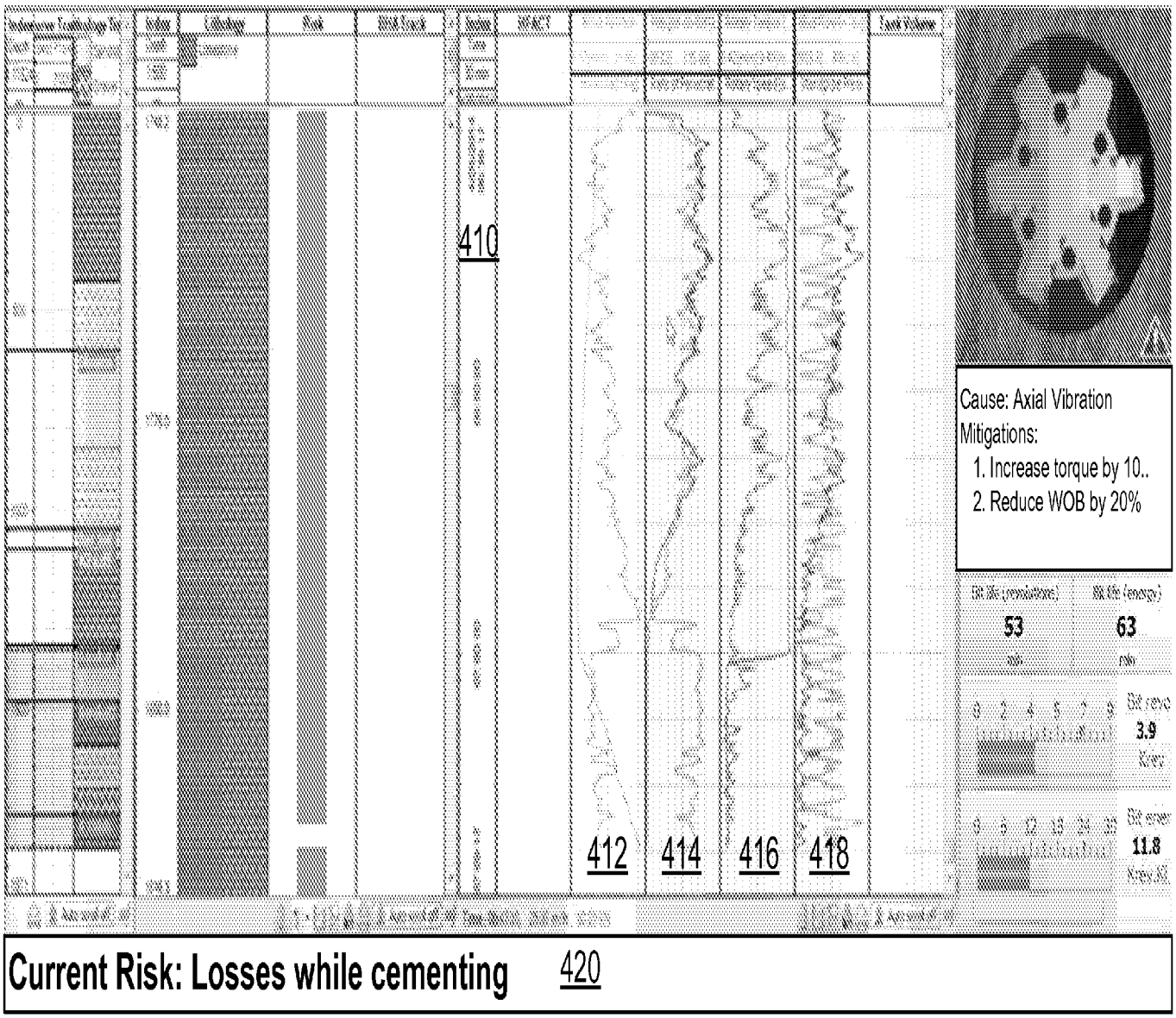
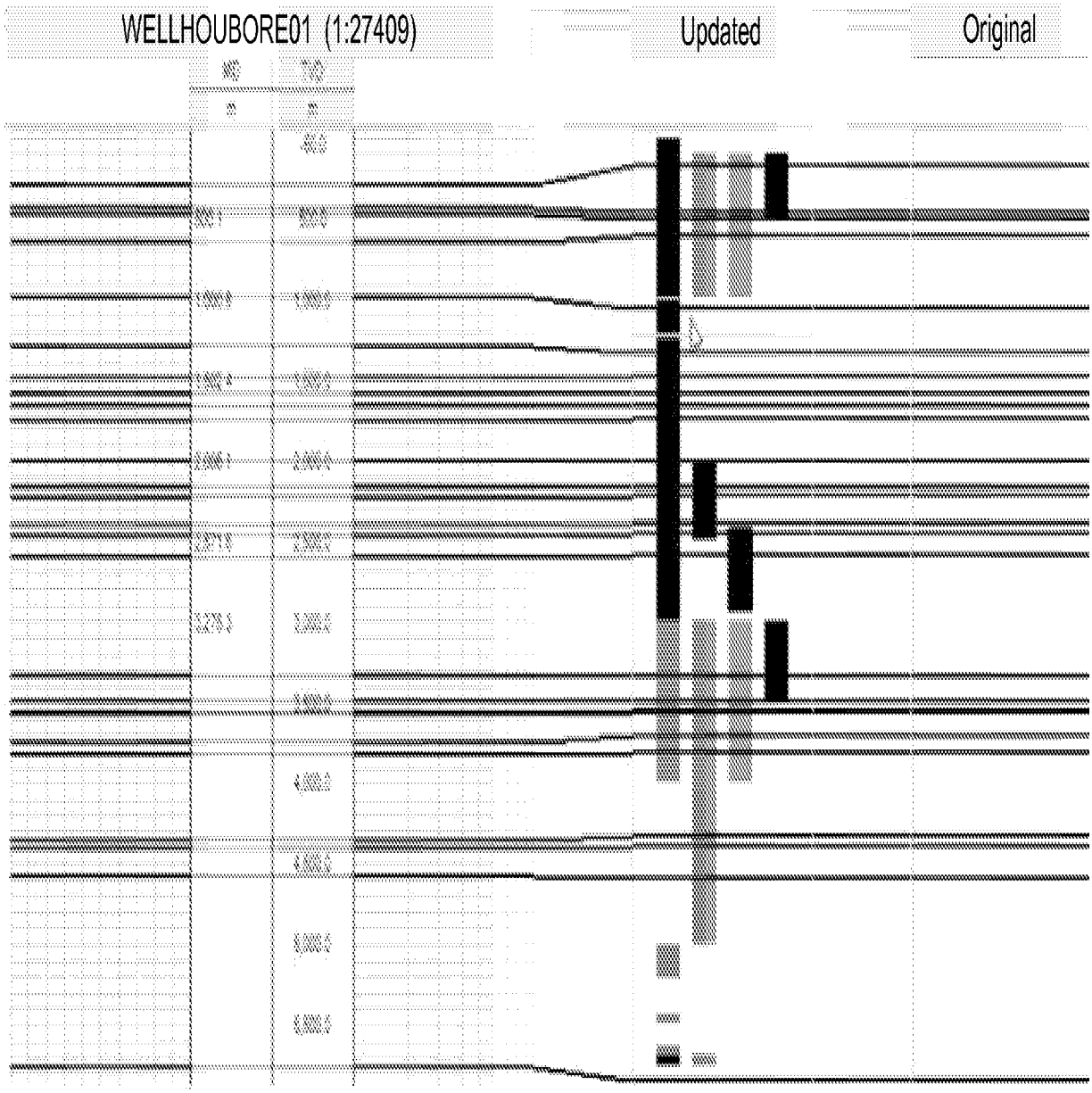

410
412
414
416
418
Cause: Axial Vibration
Mitigations:
1. Increase torque by 10..
2. Reduce WOB by 20%
53
63
3.9
11.8
Current Risk: Losses while cementing
420

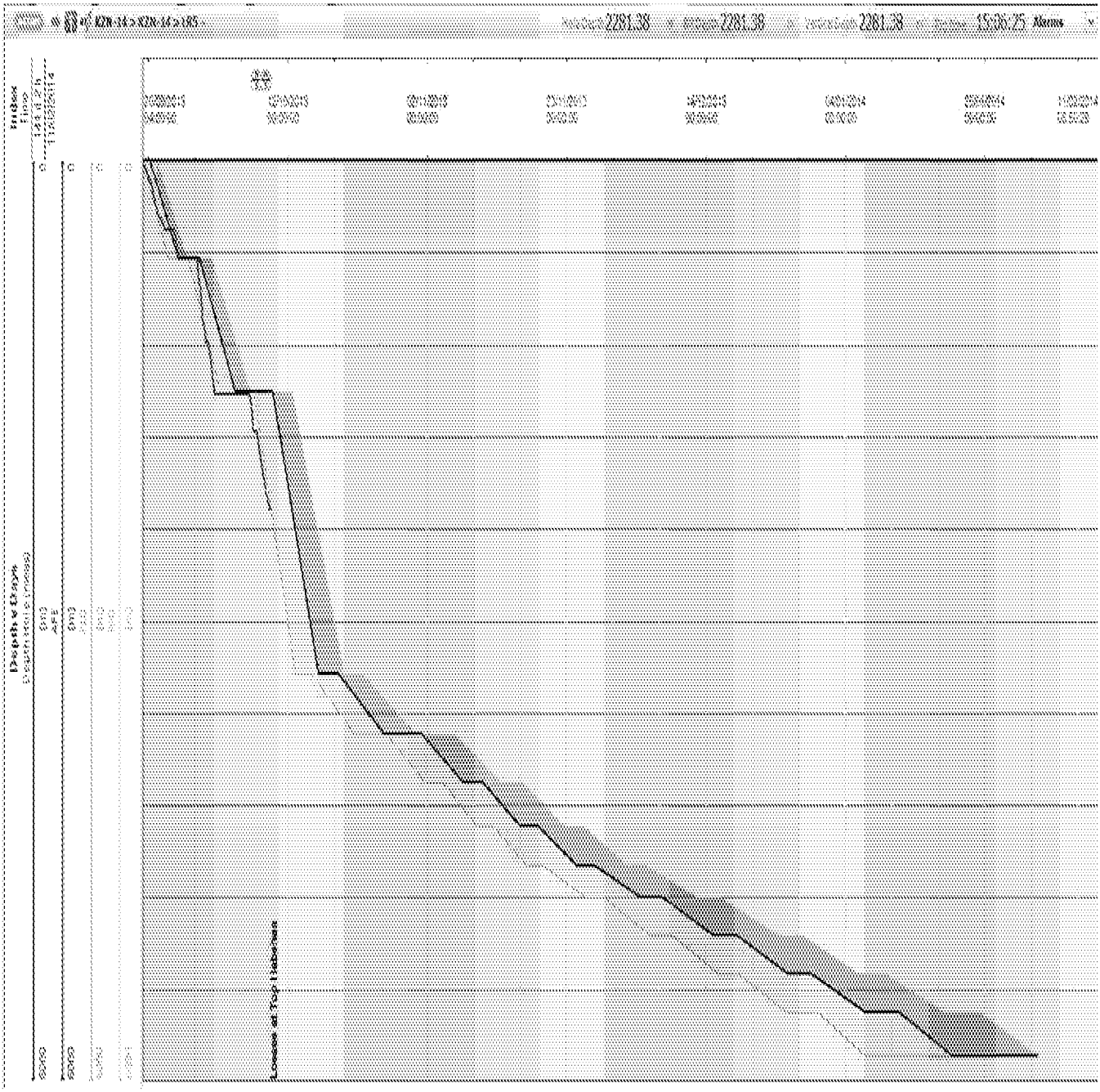
FIGURE 15



Well: WELLHOUBORE01, Track: Updated, MD: 1229.70 m, TVD: 1228.22 m,
Name: Ledges/Rugose hole, Depth: 1001.00 (m) – 1500.00 (m)

FIGURE 16

Drill Bit Hydraulics



Real Time Depth vs. Days Plot
Blue = actual
Black = AFE days
Lower bound of Green = P10 days
Upper bound of Red = P90 days

FIGURE 17