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- (71) Applicant (for all designated States except US): **HAL-LIBURTON ENERGY SERVICES, INC.** [US/US];
10200 Bellaire Blvd., Houston, Texas 77072 (US).
- (72) Inventor; and
- (75) Inventor/Applicant (for US only): **GREENWOOD, Jeremy Alexander** [GB/US]; 1615 Hermann Drive, Apt. 1428, Houston, Texas 77004 (US).
- (74) Agent: **EDWARDS, Gary J.**; Haynes and Boone, LLP, IP Section, 2323 Victory Avenue, Suite 700, Dallas, Texas 75219 (US).
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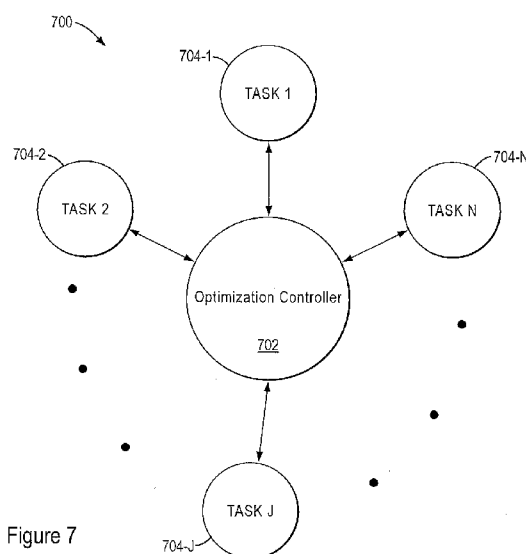


Figure 7

(57) Abstract: In accordance with aspects of the present invention, a method well design is presented. The method of well design can include identifying a plurality of task workflows related to a well design; identifying links between individual tasks in the plurality of task workflows; and performing tasks in the plurality of task workflows in order to optimize the well design according to optimization criteria.

PCT APPLICATION

Drilling Optimization

Jeremy Alexander Greenwood

Related Applications

[0001] This application claims priority to U.S. Provisional Application No. 61/438,589, filed on February 1, 2011, which is herein incorporated by reference in its entirety.

Technical Field

[0002] The present invention relates to optimization of the drilling environment through integrated planning performed by multiple technical disciplines.

Discussion of Related Art

[0003] Many parameters are considered when planning or drilling a well. These parameters involve many technical disciplines, for example, well trajectory, wellbore integrity, drilling fluids, drill bit design, Bottom Hole Assembly design, drillstring design, and hydraulics design. Currently, each of those areas is considered independently by different specialists to arrive at a drilling solution. However, factors that affect the operation of one of the many areas may also affect other areas of the well drilling and well construction process. Therefore, the current methods utilized to plan and drill a well are not optimized.

[0004] Therefore, there is a need to develop better methods of optimizing the well drilling process as a whole.

Summary

[0005] In accordance with aspects of the present invention, a method of optimizing the well drilling process is enclosed. A method of creating the well drilling design according to some embodiments of the present invention includes identifying a plurality of task workflows related to a well drilling design; identifying links between individual tasks in the plurality of task workflows; and performing tasks in the plurality of task workflows in order to optimize the well

design according to an optimization criteria. The plurality of task workflows for the drilling design can be chosen from a set of task workflows that includes Well Trajectory, Wellbore Integrity Analysis, Drilling Fluids Design, Drill Bit and Hole Opener Design, Bottom Hole Assembly Design, Drillstring Design, and Hydraulics Management.

[0006] These and other embodiments are further discussed below with respect to the following figures.

Brief Description of the Drawings

[0007] Figure 1 illustrates diagrammatically the well construction performance optimization according to some embodiments of the present invention.

[0008] Figure 2 illustrates an optimization scheme according to some embodiments of the present invention.

[0009] Figure 3 illustrates a well drilling planning scheme and shows interconnections according to some embodiments of the present invention.

[00010] Figure 4 illustrates drilling optimization across separate technology areas according to some embodiments of the present invention.

[00011] Figure 5 illustrates a particular example of optimizing drilling fluids design while considering parameters from other technology designs.

[00012] Figure 6 illustrates a particular example of optimizing the well trajectory design while considering parameters from other technology designs.

[00013] Figure 7 illustrates an optimization system according to some embodiments of the present invention.

[00014] In the figures, elements that have the same designation have the same or similar functions.

Detailed Description

[00015] In the following description, specific details are set forth describing some embodiments of the present invention. It will be apparent, however, to one skilled in the art that some embodiments may be practiced without some or all of these specific details. The specific embodiments disclosed herein are meant to be illustrative but not limiting. One skilled in the art may realize other material that, although not specifically described here, is within the scope and the spirit of this disclosure.

[00016] Figure 1 illustrates schematically well construction performance optimization 100 according to some embodiments of the present invention. As illustrated in Figure 1, several tasks involved in a well construction plan are being optimized. As shown in Figure 1, a reservoir analysis 112, drilling performance 110, casing and cementing performance 108, completions 106, and production 104 each have optimization criteria. Additionally, through interaction 102, the combination of reservoir analysis 112, drilling performance 110, casing and cementing performance 108, completions 106, and products 104 are all optimized. Optimization may take several forms and may differ depending on the particular drilling situation. An optimum environment may, for example, emphasize drilling speed while another optimization may emphasize equipment longevity. Consequently, optimization may involve choosing the best products and drilling parameters to solve a particular defined problem, picking the best combination of products, and continually implementing and refining methods of solving the problems. Figure 1 illustrates an example of performance optimization through the integration of workflows and services from different technology groups and different responsible parties.

[00017] As is further illustrated in Figure 1, the optimization process can be performed on computers for each optimized task running at remote sites. Each of optimization processes 104, 106, 108, 110, and 112 can be optimization tools operating on individual computer systems that are in contact with a central server, represented by performance optimization 102. Each of optimization processes 104, 106, 108, 110, and 112 may fall within the responsibility of different engineering groups that are responsible for the design of certain aspects of the drilling process. As such, once one optimization process is completed, parameters that affect others of the optimization process are transferred through performance optimization 102 to each of the other

processes. The well construction optimization process is complete when, through a loop of each of optimization processes 104, 106, 108, 110, and 112, no further changes in drilling parameters and design are completed. In some embodiments, a subset of all of the tasks utilized in a well drilling design can be optimized.

[00018] Therefore, well construction performance optimization 102 can be an optimization and design tools operating on a central server. Each of optimization processes 104, 106, 108, 110, and 112 can be individual computer systems that are coupled to performance optimization 102 and which operate design tools for designing a particular portion of the drilling construction process.

[00019] Figure 2, then, illustrates an optimization flow 200 according to some embodiments of the invention. As shown in Figure 2, individual tasks, which often operate as separate silos or stages during the well construction process, are integrated into one workflow. Planning 202, preparation 204, mobilization 206, execution 208, and knowledge capture 210, for example, can be integrated and optimized as a single workflow. For example, equipment delivery and system solutions can be chosen for optimal performance to minimize the impact on the drilling operation. Wellbore trajectories and integrity, rock destruction, drilling dynamics, and hydraulics management can be integrated. Finally, solutions and the results of those solutions can be captured through communications, knowledge management, and data storage and access facilities.

[00020] Figure 3 illustrates a portion of the work flow environment 300. Optimization flow 202 can be depicted as a workflow environment 300. As shown in Figure 3, workflow environment 300 can include individual design tasks. As illustrated in Figure 3, the example of workflow environment 300 includes individual tasks 302-340, the final task 340 being to drill the well. Table 1 illustrates individual tasks 302-340: Task 302 represents the task "Obtain Target Location"; Task 304 represents the task "Determine Well Type"; Task 306 represents the task "Determine Reservoir Type, Extent of Reservoir, and Required Exposure"; Task 308 represents the task "Determine Production Requirements"; Task 310 represents the task "Determine Stimulation Requirements"; Task 312 represents the task "Determine Completion Hole Size";

Task 314 represents “Obtain Geological Information”; Task 316 represents the task “Reservoir Geomechanical Analysis”; Task 318 represents the task “Obtain Surface Location”; Task 320 represents the task “Obtain Environmental Limitations at Surface Location”; Task 322 represents “Design Well Trajectory”; Task 324 represents the task “Wellbore Integrity Analysis”; Task 326 represents the task “Casing Point Selection and Casing Point Design”; Task 328 represents the task “Cement Design”; Task 330 represents the task “Drilling Fluids Design”; Task 332 represents the task “Drill Bit and Hole Enlargement Design”; Task 334 represents the task “Bottom Hole Assembly (BHA) Design”; Task 336 represents the task “Drillstring Design”; Task 338 represents the task “Hydraulics Design”; and task 340 represents the task “Well Drilling”.

[00021] As is further illustrated in Figure 3, each of tasks 302 through 340 includes one or more sub-tasks (designated by individual dots associated with the individual task). As tasks 302 through 340 are labeled tasks A through T, the subtasks are labeled with the task letter and a number. Table 1 provides a list of subtasks for each of tasks 302 through 340 illustrated in workflow environment 300 illustrated in Figure 3. As indicated in the table, and illustrated in Figure 3, task 302 includes subtasks A1-A2; task 304 includes subtask B1; task 306 includes subtasks C1-C2; task 308 includes subtasks D1-D2; task 310 includes subtask E1; task 312 includes subtask F1; task 314 includes subtasks G1-G5; task 316 includes subtask F1; task 318 includes subtasks I1-I4; task 320 includes subtask J1; task 322 includes subtasks K1-K35; task 324 includes subtasks L1-L36; task 326 includes subtasks M1-M4; task 328 includes subtasks N1-N2; task 330 includes subtasks O1-O26; task 332 includes subtasks P1-P30; task 334 includes subtasks Q1-Q36; task 336 includes tasks R1-R20; task 338 includes tasks S1-S26; and task 340 includes task T1.

[00022] As is further illustrated in Figure 3, design choices and parameters utilized in the steps leading to a particular design task affect other steps in other design tasks. Subtasks from each of tasks 302 through 340 can be defined by the technical group that completes that task. Further, each technical group, in defining workflow 300, indicates data and parameters that are utilized or determined in other subtasks or tasks in workflow 300. Before optimization of the well construction process, subtasks for each of tasks 302 through 340 and their linkages to other subtasks of tasks 302 through 340 are determined.

[00023] In performing the optimization, multiple iterations arrive at a design that optimizes the entire well drilling process rather than concentrating on designs that optimize particular design tasks. Figure 3 illustrate the interlinking parameters that can be utilized in optimization of tasks 322 (Design Well Trajectory), 324 (Wellbore Integrity Analysis), 330 (Drilling Fluids Design), 332 (Drill Bit and Hole Enlargement Design), 334 (Bottom Hole Assembly Design), 336 (Drillstring Design), and 338 (Hydraulics Design). Figure 3 illustrates links between subtasks of the tasks that include parameters that are utilized to optimize the entire workflow. For clarity, the links are also provided in Table 1.

[00024] Therefore, referring back to Figure 3 and the drilling workflow 202 defined by the tasks 322 (Design Well Trajectory), 324 (Wellbore Integrity Analysis), 330 (Drilling Fluids Design), 332 (Drill Bit and Hole Enlargement Design), 334 (Bottom Hole Assembly Design), 336 (Drillstring Design), and 338 (Hydraulics Design) illustrated in Figure 3, workflow 300 can optimize the drilling environment for optimal equipment and equipment delivery solutions as well as system solutions. As is understood, workflow 300 can be utilized to optimize the drilling environment for any optimization goal or set of optimization goals.

[00025] Optimization can have many definitions. As is understood, workflow 300 can be utilized to optimize the drilling environment for any optimization goal or set of optimization goals. Every drilling design has a unique optimum configuration where the well construction includes, but is not limited to, the following minimum criteria: The path the well will take from the surface through the overburden rock and through the reservoir rock; Knowledge of the overburden rock and reservoir rock mechanical properties, in situ stresses, formation fluid pressure and formation collapse and fracture pressure; The selection and design of the drilling fluid and its rheological properties to maintain the wellbore pressures, clean the hole, cool the bit and transmit hydraulic energy; The selection and design of the drill bits appropriate for drilling the overburden rock and reservoir rock; The design of the Bottom Hole Assembly (BHA) to deliver the directional drilling performance required by the trajectory design and to convey downhole measurement tools; The design of the drillstring to transmit mechanical energy from surface to the bit withstand the static and dynamic frictional drag in the well bore due to the movement of the drill string; the design of the hydraulics requirements for the drilling fluid flow

rate, flow regime and pressure regime inside drillstring, through the bit and through the annulus between the drillpipe and the wellbore and between the drillpipe and the casing and the marine riser if present. Each of these criteria places restrictions on the wellbore constructions. The optimal well design falls within each of the restrictions that are placed on the wellbore constructions.

[00026] As illustrated in Figures 1 and 2, workflow 300 can be iterated based on the linked parameters to optimize the designed drilling environment for a particular set of optimization goals. In some embodiments, not all drilling workflow tasks may be included in the optimization process. For example, the workflow may include tasks 322 (Design Well Trajectory), 324 (Wellbore Integrity Analysis), 332 (Drill Bit and Hole Enlargement Design), and 334 (Bottom Hole Assembly Design) and not include other tasks in the optimization. Another workflow may integrate and optimize 330 (Drilling Fluids Design), 332 (Drill Bit and Hole Enlargement Design), 334 (Bottom Hole Assembly Design), and 336 (Drillstring Design). Yet another may optimize a combination of all of the individual workflows: task 322 (Design Well Trajectory), task 324 (Wellbore Integrity Analysis), task 330 (Drilling Fluids Design), task 332 (Drill Bit and Hole Enlargement Design), task 334 (Bottom Hole Assembly Design), task 336 (Drillstring Design), and task 338 (Hydraulics Design).

[00027] Optimization of workflows in accordance with some embodiments of the present invention may result in higher performance and less drilling time. Optimization may result in bonuses for completion, contract deliveries, extended and improved contract terms, increased market share at better margins, performance bonuses, better footage rates, and increased equipment lifetimes. Optimization criteria may be based on rate of penetration, lessening of non-productive time, meeting of production targets, meeting of AFE, or other requirements. Optimization criteria may be based on combinations of factors. The results of the optimization process provides for a drilling design for that optimization criteria.

[00028] Table 1 illustrates particular tasks in workflow 300, the entity that usually performs that task (although the task may be formed by others as well), and which other tasks included in workflow 300 provide inputs to or receive outputs from the performance of the particular tasks.

The example of workflow 300 provided in Figure 3 and Table 1 is exemplary only. Other workflows can be utilized with embodiments of the present invention.

Table 1

Sub-Task	Description	Responsible Entity	Links
A. Task 302: Obtain Target Location			
A1	Obtain Geographic Coordinates and coordinate system for the target		
A2	Carry out a database search for offset wells already drilled and review relevant well designs, plots, logs and end of well reports.		K6, K12, K31, L1, L2, L3, L4, L6, L7, L8, L9, L16, O7, O15, O16, P11, R15
B. Task 304: Determine Well Type			P3
B1	Exploration, Production, Injection, Re-entry		
C. Task 306: Determine Reservoir Type, Extent of Reservoir, and Required Exposure			K7
C1	Vertical, Hz, Length		
C2	Obtain Reservoir Type and trapping mechanism		
D. Task 308: Determine Production Requirements			
D1	Determine Hydrocarbon requirements, Oil, Gas, Condensate, Water, Ratios and Production Volumes		
D2	Determine production method Flowing, Pumping, Artificial Lift, determine Longevity of production and required production hole size		
E. Task 310: Determine Stimulation Requirements			
E1	Fracturing, Acidization, Steam assisted gravity drainage (Sagd), Pressure maintenance (injection)		
F. Task 312: Determine Completion Hole Size			
F1	Obtain required hole size at TD for required completion		
G. Task 314: Obtain Geological Information			O3, O13

G1	Obtain Formation Tops		
G2	Obtain Formation Types		
G3	Obtain Depositional Environment		
G4	Obtain Formation Temperature Profile		Q10, Q15
G5	Obtain Reservoir formation type and properties		O2
H. Task 316: Reservoir Geomechanical Analysis			O2, O13
H1	Perform geomechanical analysis on the reservoir for sanding, and fracturing requirements		
H2	Review well path design based on results of reservoir geomechanics analysis		
I. Task 318: Obtain Surface Location			K32, L12
I1	Onshore or Offshore	Obtained from customer by DD Coordinator, Well Planner updates plans	
I2	Obtain Geographic Coordinates and coordinate system for the surface location	Obtained from customer by DD Coordinator, Well Planner checks when starting on new plan	
I3	Obtain reference Datum elevations. Ensure it is the correct system Vertical datum.	Obtained from customer by DD Coordinator, Well Planner checks when starting on new plan	
I4	For Offshore Locations obtain planned water depth, determine if well is deepwater / ultra-deepwater	Obtained from customer by DD Coordinator, Drilling Fluid Specialist	
J. Task 320: Obtain Environmental Limitations at Surface Location			O5
J1	Zero discharge, drilling fluid limitations, Noise restrictions	Obtained from customer	
K. Task 322: Design Well Trajectory			O12, Q2
K1	Obtain Customer Reference Documentation. Tool instrument performance model files, anti-collision practices, drilling and surveying practices	DD Coordinator, Well Planner, Survey Manager	
K2	Determine Single / Multi well path design	DD Coordinator, Well Planner, Survey Manager	
K3	Determine Geological Target (s)	Obtained from customer by DD Coordinator, Well Planner updates	

		plans	
K4	Determine Drillers Target(s)	Obtained from customer by DD Coordinator, Well Planner updates plans	R4
K5	Determine the boundaries of any lease line or block	Customer / Well Planner	
K6	Obtain offset well survey information and QA type of surveys to determine correct instrument performance model .	Obtained by DD Coordinator, Well Planner updates plans	A2
K7	Determine any zones to avoid penetrating, (Injection / production / cuttings injection/ subsidence).	Customer, DD Coordinator, Well Planner	C, O7, Q2,
K8	Determine inclination limitations for Top hole section, riserless section or entire wellbore.	Customer, DD Coordinator, Well Planner	
K9	Determine inclination and azimuth sensitivities for borehole stability	Customer, DD Coordinator, Well Planner	L
K10	Determine inclination and azimuth sensitivities for Torque and Drag limitations.	Customer, DD Coordinator, Well Planner	R
K11	Determine formation tendencies for build / drop / turn rates.	Customer, DD Coordinator, Well Planner	Q3
K12	Identify formations that are difficult / impossible to steer in or have 'natural' formation tendencies	DD Coordinator, Well Planner	A2, L5
K13	Plan Well Path aiming to continually diverge from all existing wells from the kick off point.	DD Coordinator, Well Planner	
K14	Plan to minimize Doglegs in top hole sections.	DD Coordinator, Well Planner	
K15	Perform Anti collision Analysis, review high risk wells and report to the customer.	DD Coordinator, Well Planner	
K16	Determine if gyro or steering tools are required because of magnetic interference.	DD Coordinator, Well Planner	
K17	Establish the effect of TVD uncertainties especially when	DD Coordinator, Well Planner, Survey Manager	Q

	planning horizontal The effect of TVD uncertainty, due to both geology and survey error should be accounted for in the plan so that well can still be landed within the dogleg capability of the equipment.		
K18	Establish the effect of drilling close to magnetic east west and close to horizontal, based on the latitude of the well.	DD Coordinator, Well Planner, Survey Manager	
K19	Determine length of Rat hole required at TD for logging tools	Customer /DD Coordinator, Well Planner, Survey Manager	L5
K20	Determine differential sticking risk. Compensate within wellplan for build and drop above and below the risk zone as sliding may result in stuck pipe.	Customer	Q
K21	Perform Anti collision Analysis, review high risk wells and report to the customer.	Customer, DD Coordinator, Well Planner	Q7
K22	Consider options for collision avoidance should the directional plan not be achieved	DD Coordinator, Well Planner	Q
K23	Determine if sidetracks are Planned	Customer, DD Coordinator, Well Planner	
K24	When sidetracking an existing wellbore review QA information of main bore and generate definitive survey listing	DD Coordinator/Well Planner	
K25	When sidetracking an existing wellbore determine if the location of the KOP is in open hole or inside casing and obtain hole diameter	DD Coordinator/Customer	
K26	When sidetracking an existing wellbore determine the top of the cement in open hole or behind casing.	DD Coordinator/Customer	N
K27	When sidetracking an existing wellbore determine the Kick off method,(open hole, cement plug, whipstock)	DD Coordinator/Customer	

K28	When Sidetracking an existing wellbore produce Ladder plots or travelling cylinder and clearance listings in sufficient detail to show the planned divergence from the parent well, casing stumps and the zones of magnetic interference.	DD Coordinator/Well Planner/Survey Manager	
K29	When sidetracking determine the requirement for gyro singles shots, gyro multishots, or gyro MWD over the zone of magnetic interference Any risk of collision shall be documented	DD Coordinator/Well Planner/Survey Manager	
K30	When Sidetracking Perform Anti collision Analysis, review high risk wells and report to the customer.	DD Coordinator/survey management	
K31	QA check proposed well design with offset well performance	DD Coordinator	A2
K32	Review surface location position to determine if well path design can be improved by modifying it.	Customer/DD Coordinator	I
K33	Review Torque and Drag for Drillstring and Casing to determine if well path design can be improved by modifying it.	Customer/DD Coordinator	R
K34	Review Fluid Design, Hydraulics and hole cleaning to determine if well path design can be improved by modifying it.	Customer/DD Coordinator	O, S
K35	Review Bottom Hole Assembly Designs to determine if directional performance can be optimized by modifying the well path design	Customer/DD Coordinator	Q
L. Task 324: Wellbore Integrity Analysis			K9, K32, M1, O1, O3, O13, Q4
L1	Obtain locations of offset wells with Latitude and Longitude	Pore Pressure Engineer/ Geomechanics Specialist	A2
L2	Obtain offset data sets	Pore Pressure Engineer/	A2

	(resistivity, sonic, gamma ray, SP, RHOB, porosity) for all analogue wells including surveys for directional wells and image logs sufficient to perform Pore pressure prediction and rock property calculations.	Geomechanics Specialist	
L3	Obtain any pore pressure calibration data from offset wells such as MDTs, kicks, mud weights or actual offset reservoir pressures.	Pore Pressure Engineer/ Geomechanics Specialist	A2
L4	Obtain simple geologic cross-sections with major formation ages, paleo markers, any major structural features, key horizons and targets.	Pore Pressure Engineer/ Geomechanics Specialist	A2
L5	Perform Hazard identification (salt, Rubble zones, faults, fractured zones, vuggy or karst formations)	Pore Pressure Engineer/ Geomechanics Specialist	K19, K12, O16
L6	Obtain Seismic cross-sections showing targets and relationships to analogue wells along with depth vs. two-way time conversions.	Pore Pressure Engineer/ Geomechanics Specialist	A2
L7	Obtain Stacking velocities and/or original CDP gathers and RMS volumes if a seismic pore pressure volume from reprocessed seismic is requested.	Geomechanics Specialist	A2
L8	Obtain Drilling data (gas, torque and drag, Dxc, mud temp, conductivity, etc) and histories of offset wells with any hole problems, lost circulation, LOTs, casing points, sidetracks, etc. Mud logs or End of Well reports	Pore Pressure Engineer/ Geomechanics Specialist	A2
L9	From structural and stratigraphic geological information evaluate the potential pore pressure	Pore Pressure Engineer/ Geomechanics Specialist	O21

	mechanisms active within the prospect. Determining pressure in permeable and impermeable formations and driven by compaction, temperature, chemical and hydrodynamic effects		
L10	Obtain rig Datums for offset wells	Pore Pressure Engineer, Geomechanics Specialist	A2
L11	Obtain Water depths for offset offshore wells	Pore Pressure Engineer, Geomechanics Specialist	A2
L12	Obtain Planned rig Datums and for offshore wells the planned water depth and air gap	Pore Pressure Engineer, Geomechanics Specialist	I
L13	Determine any potential zones of under pressure or depletion	Pore Pressure Engineer, Geomechanics Specialist	K19
L14	Establish Shallow Gas and Shallow water flow risk, presence of hydrates and estimate pressures within centroids.	Pore Pressure Engineer, Geomechanics Specialist	
L15	Determine if 1d, 3d or basin modelling is required and can be performed	Pore Pressure Engineer, Geomechanics Specialist	
L16	Determine lithology column on offset wells	Pore Pressure Engineer, Geomechanics Specialist	A2
L17	Generate Overburden Gradient from composite bulk density profile	Pore Pressure Engineer, Geomechanics Specialist	
L18	For 1d analysis perform shale discrimination, shale volume and shale index calculations on offset data.	Pore Pressure Engineer, Geomechanics Specialist	
L19	For 1d analysis establish compaction trend lines through the offset log data	Pore Pressure Engineer, Geomechanics Specialist	
L20	For 1d analysis Calculate Pore Pressure from each data source	Pore Pressure Engineer, Geomechanics Specialist	
L21	For 1d analysis Examine Qualitative pore pressure data sets	Pore Pressure Engineer, Geomechanics Specialist	
L22	Compare pore pressure predictions to offset MW, ECD and PWD information	Pore Pressure Engineer, Geomechanics Specialist	

L23	Determine Definitive Pore Pressure from offset wells	Pore Pressure Engineer, Geomechanics Specialist	
L24	Calculate Fracture Pressure using available methods, lithology information and LOT measurements	Pore Pressure Engineer, Geomechanics Specialist	
L25	Determine Definitive Fracture Pressure from offset wells	Pore Pressure Engineer, Geomechanics Specialist	
L26	For 3d Analysis obtain seismic cube	Geomechanics Specialist	
L27	For 3d Analysis analyze seismic cube to calculate Density profile, Overburden gradient, Pore Pressure and Fracture pressure.	Geomechanics Specialist	
L28	Extract PP, FP, OB for proposed well path from Seismic cube	Geomechanics Specialist	
L29	For Basin Pore Pressure model obtain stratigraphy, sedimentation rates and fault locations.	Geomechanics Specialist	
L30	Calibrate basin PP model to offset well pore pressure data.	Geomechanics Specialist	
L31	For Wellbore Stability Calculations determine Shmin from LOT and Fracture information	Geomechanics Specialist	O16, P11
L32	For Wellbore Stability Calculations constrain Shmax from evidence of wellbore failure	Geomechanics Specialist	O16, P11
L33	For Wellbore Stability Calculations determine Rock properties (UCS, CCS, Friction Angle, Vshale) from offset log data and regionally established correlations	Geomechanics Specialist	O16, P11
L34	For Wellbore Stability Calculations determine chemical sensitivities between the drilling fluid and formations	Geomechanics Specialist / Drilling Fluid Specialist	
L35	For Wellbore Stability Calculations calculate collapse pressure using most applicable	Geomechanics Specialist	

	failure criteria, PP, OB, Shmin, Shmax and rock properties.		
L36	Review well path design based on results of wellbore integrity analysis		J9
M. Task 326: Casing Point Selection/ Casing Design			O3
M1	Define Required Mud Windows from Pore Pressure / Collapse Pressure / Fracture Pressure limits		L, O21, O26, S2
M2	Determine Casing sizes and shoe depths		
M3	Determine Casing Yield / Collapse Requirements		
M4	Determine MAASP / Kick Tolerance		
N. Task 328: Cement Design			K26
N1	Design Slurry and spacer requirements		
N2	Determine Requirements: Single / Multistage Cement job		
O. Task 330: Drilling Fluids Design			K34, S5
O1	Obtain reservoir requirements, geological objectives, reservoir description (lithology column for well path), fault formation, temperature profile, casing design, PP/FG plots	Drilling Fluid Specialist/Customer	A2, L
O2	Determine if the reservoir calls for a drill-in fluid or other specialized system	Drilling Fluid Specialist/Customer/ Drilling Fluid Technical Group	H, G5
O3	Determine the appropriate fluid types and technologies for the specific well/project and sections/intervals	Drilling Fluid Specialist/Customer/ Drilling Fluid Technical Group	L, M, G
O4	Determine the completion fluid requirements	Drilling Fluid Specialist/Customer/ Drilling Fluid Technical Group	
O5	Determine the local environment regulations	Drilling Fluid Specialist/Customer/Health, Safety and Environment Specialist	J
O6	Determine what the drilling waste profile associated with the project is	Drilling Fluid Specialist/Drilling Fluid Surface Solutions Tech Professional/Customer	

O7	Determine if there are special challenges of this well (e.g., deepwater, HPHT, logistical issues, depleted zones, formation damage, etc) that affects the fluid design.	Drilling Fluid Specialist/Well Planner/Customer	A2, K7
O8	Determine need for customized solutions/new technology	Drilling Fluid Specialist/ Drilling Fluid Technical Group	
O9	Determine if this is a critical first well	Drilling Fluid Specialist/ Drilling Fluid Technical Group	
O10	Determine if the well calls for specialized lab equipment	Drilling Fluid Specialist/Customer	
O11	Determine if wellbore stability modeling is required	Drilling Fluid Specialist/Customer	L
O12	Determine if there are any challenges with regard to the hole cleaning, angle of well that requires modification to the drilling fluid	Drilling Fluid Specialist/Customer	K, K34
O13	Evaluate need for lab testing to determine if the mud system is suited for drilling under the planned well conditions	Drilling Fluid Specialist/Drilling Fluid Technical Group	G, H, L
O14	Perform lab tests to determine composition of LCM pills or Wellset treatment if required.	Drilling Fluid Specialist/Drilling Fluid Technical Group	
O15	Obtain data from offset wells or wells that have been drilled under similar conditions to get an understanding of what could be expected for the next well to be drilled.	Drilling Fluid Specialist	A2
O16	Design LCM decision trees or matrix based on formations to be drilled.	Drilling Fluid Specialist/Drilling Fluid Technical Group	A2, L5, L31, L32, L33
O17	Determine stuck pipe procedures and required treatments	Drilling Fluid Specialist/Drilling Fluid Technical Group	
O18	Create a Basis of Design	Drilling Fluid Specialist	
O19	Create a Total Fluid Management Program	Drilling Fluid Specialist	
O20	Create Drilling Fluid Program	Drilling Fluid Specialist	
O21	Perform mud formulation based on given formation pressure /		M1, L9

	anticipated hole problems		
O22	Select mud type / properties for each hole section		
O23	Specify mud properties mud wt / yield point / gel strength / pH / MBT / Chloride / Solid content / Filtrate		
O24	Run hydraulic analysis for each hole section and estimate the Optimum ROP / gpm to minimize cutting load in the annulus		K34, S, Q9
O25	Determine mud wt schedule for each hole section.		M1, Q1, Q10, Q15, Q26, Q35, R4, R12
O26	Obtain reservoir requirements, geological objectives, reservoir description (lithology column for well path), fault formation, temperature profile, casing design, PP/FG plots	Drilling Fluid Specialist/Customer	A2, L
P. Task 332: Drill Bit and Hole Enlargement Design			
P1	Obtain offset data and bit performance information	Bit Sales rep/ Bit Applications Engineer	A2
P2	Determine operational constraints (i.e. type of rig, pump capacity)	Customer	
P3	Determine type of well and casing design	Customer	B, M
P4	Study offset data from bit database and identify potential improvements	Bit Sales rep/ Applications Engineer	
P5	Formulate bit selection based on existing designs or if new design is required	Bit Sales rep/ Bit Applications Engineer	P17
P6	Obtain ROP targets	Bit Sales rep/ Bit Applications Engineer / DD Coordinator	
P7	Determine directional requirements	Bit Applications Engineer / DD Coordinator	
P8	Obtain rock strength and overbalance (MW-PP)	Bit Applications Engineer	L33
P9	Obtain formation properties	Bit Sales rep/ Applications Engineer	
P10	Obtain formation tops and	BitSales rep/ Applications	

	amount of interbedding	Engineer	
P11	Obtain offset Log data, Pore Pressure and Perform Bit performance Analysis	Bit Performance Engineer / Sales rep	A2, L31, L32, L33
P12	Bit Type Selection	Bit Sales rep/ Bit Applications Engineer / DD Coordinator	
P13	Match Bit Selection to Bottom Hole Assembly and drive system (Motor / RST / Rotary)	Bit Specialist / DD Coordinator	Q
P14	Determine hole enlargement requirements and ratio of pilot hole to opened hole diameter	Bit Sales rep/ Applications Engineer	
P15	Select the hole opener or reamer to meet hole opening requirements	Bit Applications Engineer	S9
P16	Match the hole opener or reamer to Bottom Hole Assembly and drive system (Motor / RST / Rotary)	Bit Applications Engineer / DD Coordinator	Q
P17	Match the bit and hole opener cutting structures to balance the penetration rates	Bit Applications Engineer / DD Coordinator	
P18	For new bit design perform rock strength analysis using offset log data	Bit Applications Engineer / Applications Design Engineer	
P19	For new bit design Obtain bit FRR with dull bit photos	Bit Applications Engineer	
P20	For new bit design Determine areas for improvement and define design criteria	Bit Applications Engineer / Applications Design Engineer	
P21	For new bit design optimum cutting structure and gage configuration	Applications Design Engineer	
P22	Recommend best drilling practice for selected bit and hole enlargement	Bit Applications Engineer / Applications Design Engineer	
P23	Perform bench mark analysis of selected equipment to target ROP	Applications Design Engineer	
P24	Determine ROP Capability	Applications Design Engineer	
P25	Determine Bit / hole enlargement Torque requirements	Bit Applications Design Engineer	R3
P26	Determine bit / hole	Bit Applications Engineer / Bit	S, S7

	enlargement hydraulics requirements HSI / IF	Applications Design Engineer	
P27	Determine Bit / hole enlargement Weight requirements	Bit Applications Engineer / Bit Applications Design Engineer	Q
P28	Determine Bit / hole enlargement Speed requirements	Bit Applications Engineer / Bit Applications Design Engineer	Q, Q35
P29	Determine Bit / hole enlargement nozzle selection and Flow rate requirements	Bit Applications Engineer / Bit Applications Design Engineer	S, S26
P30	Determine flow rates / pressures to activate reamers	Bit Applications Engineer	S
Q. Task 334: Bottom Hole Assembly Design			K17, K20, K22, K35, P13, P16, P27, P28, R9, S24
Q1	Obtain Wellbore trajectory, wellbore schematic with hole size start and end depths and mud weight schedule	DD Coordinator	K, O26
Q2	Obtain Build / Drop / Equilibrium Rate Requirements/Limitations and target tolerances	DD Coordinator	K, K7, K11
Q3	Obtain formation tendencies	DD Coordinator/Well Planner	K11
Q4	Obtain information on known borehole stability issues	DD Coordinator / Pore Pressure Engineer	L
Q5	Determine hole opening / reaming requirements	Customer/Fluid Specialist/Well Planner/DD Coordinator	P14
Q6	Obtain TVD uncertainties to ensure sufficient dogleg capability is available from the design	DD Coordinator	K17
Q7	Obtain Anti-collision program	DD Coordinator/Well Planner	K21
Q8	Obtain Rig Limitations - Tubular handling maximum length, Torque Limitations, RPM Capacity, Derrick Load Capacity, Crane Capacity	Customer/DD Coordinator	
Q9	Obtain minimum flow rate required for hole cleaning		S, O24
Q10	Determine maximum pressure and temperature requirements	DD Coordinator / M/LWD Coordinator	G4, O26

	of the equipment		
Q11	Determine bit drive system	DD Coordinator/Bit Specialist	
Q12	Rotary Assembly – packed, pendulum or build	DD Coordinator	
Q13	Motor Assembly – slick or stabilized	DD Coordinator	S25
Q14	Select Motor Speed and Torque based on Bit Requirements and flow rate range	DD Coordinator / Bit Applications Engineer	S8
Q15	Select Motor Elastomer based on pressure and temperature requirements	DD Coordinator / Bit Applications Engineer	S, O26, G4
Q16	Rotary Steerable Assembly – vertical or build	DD Coordinator	
Q17	Determine M/LWD Strategy	DD Coordinator / M/LWD Coordinator / Customer	
Q18	Determine Telemetry System and Downlink requirements	M/LWD Coordinator	S10, S11
Q19	Determine Survey Requirements and magnetic spacing	DD Coordinator / Survey Manager	
Q20	Determine Survey Management options. IFR, IIFR, Multi-station Analysis		
Q21	Determine required Formation Measurements / Logging Program within each hole section	Customer/DD Coordinator/M/LWD Coordinator	
Q22	Determine required downhole Drilling Measurements within each hole section	Customer/DD Coordinator/M/LWD Coordinator	
Q23	Select equipment that meets all the measurement, steering and environmental requirements.	DD Coordinator / M/LWD Coordinator	S
Q24	Obtain M/LWD tool configuration, Tool OD, ID and stiffness information	DD Coordinator / M/LWD Coordinator	
Q25	Analysis		
Q26	Obtain mud weight schedules and calculate buoyancy factor(s)	DD Coordinator	O26
Q27	Determine the neutral point design factor or safety factor	DD Coordinator/Well Planner	
Q28	Calculate Jar Placement	DD Coordinator	

Q29	Calculate the Length of drill collars required to obtain the Maximum desired WOB.	DD Coordinator	
Q30	Obtain Hole enlargement equipment specifications for Max WOB and Torque	DD Coordinator / Applications Engineer	
Q31	Perform Bottom Hole Assembly force analysis calculations to determine contact points and forces, profile, slope, deflection, shear force and bending moment.	DD Coordinator/Well Planner	
Q32	Perform directional tendency calculations, build / drop / equilibrium rate / turn	DD Coordinator/Well Planner	
Q33	Perform Bit force analysis and balance with Bottom Hole Assembly forces	DD Coordinator	
Q34	Determine if the resulting force required to deliver directional performance fall within operating limits and adjust Bottom Hole Assembly design as necessary	DD Coordinator/Well Planner	
Q35	Obtain bit speed and weight requirements, mud weight schedule and proposed trajectory and Perform Harmonic Vibration Analysis	DD Coordinator/Well Planner/ADT	P28, O26
Q36	Determine if the resulting critical RPM will fall in the proposed operating ranges and adjust Bottom Hole Assembly design if necessary	DD Coordinator / Applications Design Engineer	
R. Task 336: Drillstring Design			K10, K33, P30, S4, S23
R1	Obtain rig hoisting limitations and derrick load limitations	DD Coordinator/Well Planner	
R2	Obtain rig Torque limitations	DD Coordinator/Well Planner	
R3	Obtain the Bit Torque requirements	DD Coordinator / Bit Applications Engineer	P25
R4	Obtain Wellbore trajectory, wellbore schematic with hole size start and end depths and mud weight schedule	DD Coordinator/Well Planner	K, O26

R5	Obtain desired Tensional safety factor or Margin of Overpull	DD Coordinator/Well Planner	
R6	Obtain desired Torsional safety factor	DD Coordinator/Well Planner	
R7	Obtain desired safety factor for pipe collapse	DD Coordinator/Well Planner	
R8	Obtain desired safety factor for pipe burst	DD Coordinator/Well Planner	
R9	Obtain Bottom Hole Assembly Specifications and weight in Air of Bottom Hole Assembly	DD Coordinator	Q
R10	For vertical wells calculate maximum length of pipe using a selected pipe class, grade, size and weight and tension safety factor.	DD Coordinator/Well Planner	
R11	Determine if a tapered string is required and calculate maximum length of pipe using a selected pipe class, grade, size and weight and tension safety factor.	DD Coordinator/Well Planner	
R13	Determine if the selected drill pipe meets the allowable collapse pressure criteria	DD Coordinator/Well Planner	
R14	Determine if the selected pipe meets the allowable internal burst pressure criteria	DD Coordinator/Well Planner	
R15	For Deviated wells obtain the coefficient of friction values for cased and open hole for each hole section	DD Coordinator/Well Planner	A2
R16	For Deviated wells determine the maximum length of pipe using a selected pipe class, grade, size and weight using trajectory, mud weight and friction factors and safety factor.	DD Coordinator/Well Planner	
R17	For Deviated wells calculate the multiaxial loading for connection stress and fatigue limits	DD Coordinator/Well Planner	
R18	For Deviated wells calculate the torque requirements at TD for	DD Coordinator/Well Planner	

	each section and determine the torque limits of the selected drill pipe.		
R19	For Deviated or ERD wells calculate the makeup torque requirements and assess if high torque connections are required	DD Coordinator/Well Planner	
R20	For Deviated wells perform buckling calculations and determine if a change in drillpipe pipe class, grade, size and weight is required or the placement of HWDP higher in the string,	DD Coordinator/Well Planner	
S. Task 338: Hydraulics Design			K34, P26, P29, P30, Q9, Q15
S1	Obtain Wellbore trajectory, wellbore schematic with hole size start and end depths, casing sizes	DD Coordinator/ Well Planner / Drilling Fluid Specialist	
S2	Obtain available mud window.	DD Coordinator/ Well Planner / Drilling Fluid Specialist	M1
S3	Obtain rig surface equipment pressure limitations and pump specifications – Maximum allowable surface pressure.	DD Coordinator/ Well Planner / Drilling Fluid Specialist	
S4	Obtain planned Drillstring design	DD Coordinator/ Well Planner / Drilling Fluid Specialist	R
S5	Obtained planned Mud weight schedule and rheology	DD Coordinator/ Well Planner / Drilling Fluid Specialist	O
S6	Obtained planned bit type / Hole Enlargement equipment specifications	DD Coordinator/ Well Planner / Drilling Fluid Specialist / Bit Applications Engineer	P
S7	Determine Bit / hole enlargement flow optimization requirements for velocity, HSI or HHP.	DD Coordinator/ Well Planner / Drilling Fluid Specialist / Bit Applications Engineer	P26
S8	Determine if a motor is planned and obtain flow rate requirements and bit pressure drop requirements for bearing lubrication	DD Coordinator/ Well Planner	Q14
S9	Determine method of activation of any hole enlargement equipment and plan for	DD Coordinator/ Well Planner / Drilling Fluid Specialist / Bit Applications Engineer	S9

	hydraulic activation if required		
S10	Determine MWD telemetry system flow rate and pressure drop requirements	M/LWD Coordinator	Q18
S11	Determine MWD downlink system flow rate and pressure drop requirements	M/LWD Coordinator/DD Coordinator	Q18
S12	Obtain MWD mass flow rate limitations	M/LWD Coordinator/DD Coordinator	Q23
S13	Determine most applicable rheology model for mud fluid type. (Herschel Bulkley, Bingham, Power law, etc.)	Drilling Fluid Specialist	
S14	Determine ROP / Flow limits for Hole cleaning	DD Coordinator/ Well Planner / Drilling Fluid Specialist	
S15	Calculate system pressure losses, bit TFA and maximum flow rate	DD Coordinator/ Well Planner / Drilling Fluid Specialist	
S16	Calculate maximum ECD at the bottom hole, shoe and zones of low fracture gradient	DD Coordinator/ Well Planner / Drilling Fluid Specialist	
S17	For ERD wells add safety factor for rotational effect increasing ECD in smaller hole sizes	DD Coordinator/ Well Planner / Drilling Fluid Specialist	
S18	Calculate annular velocities and ensure laminar flow	DD Coordinator/ Well Planner / Drilling Fluid Specialist	
S19	Estimate cutting slip velocity based on expected cuttings density and size	DD Coordinator/ Well Planner / Drilling Fluid Specialist	
S20	Estimate cuttings bed heights and locations based on expected flow rates	DD Coordinator/ Well Planner / Drilling Fluid Specialist	
S21	Determine safety margin for swab and surge pressures	DD Coordinator/ Well Planner / Drilling Fluid Specialist	
S22	Calculate swab / surge pressures and maximum tripping speeds compared to wellbore pressure boundaries	DD Coordinator/ Well Planner / Drilling Fluid Specialist	
S23	If required Determine if changes to drillstring design will allow higher flow rates to improve hole cleaning or reduce maximum surface pressures	DD Coordinator/ Well Planner	R
S24	If required Determine if	DD Coordinator/ Well Planner	Q

	changes to Bottom Hole Assembly design will allow higher flow rates to improve hole cleaning or reduce maximum surface pressures		
S25	If required Determine if motor requires a jetted rotor design to allow higher flow rates to improve hole cleaning or reduce maximum surface pressures	DD Coordinator/ Well Planner	Q13
S26	Determine if changes to Bit Nozzle selection will reduce maximum surface pressures	DD Coordinator/ Bit Applications Engineer	P29
T. Task 340: Drill Well			
T1	Drill		

[00029] Figure 4 illustrates another example workflow 400 that can be optimized according to some embodiments of the present invention. As shown in Figure 4, workflow 400 includes task 402 (Well Trajectory Design), task 404 (Wellbore Integrity Analysis), task 406 (Drilling Fluid Design and Management), task 408 (Bit/Reamer/Hole Opener Design), task 410 (Bottom Hole Assembly Design), task 412 (Drillstring Design) and task 414 (Hydraulics Management). Workflow 400 represents a simplified drilling optimization workflow according to some embodiments of the present invention, utilized for examples. As shown in Figure 4, task 402 includes subtasks. In accordance with embodiments of the present invention, tasks 402 – 414 are linked as illustrated in Figure 4 and then optimized.

[00030] Figure 5 illustrates an example of task 406 of workflow 400. Figure 6 illustrates an example of task 402 of workflow 400. As shown in Figure 5, task 406 (Drilling Fluids Design) can include subtasks 501-527 and may include inputs from other individual workflows such as task 402 (Well Trajectory Design) and task 404 (Wellbore Integrity Analysis). Table 2 defines each of subtasks 501 through 527 of task 406. Table 3 defines each of subtasks 601 through 627 of task 402 (Well Trajectory Design).

Table 2

Subtask	Description	Performance Responsibility
501	Obtain reservoir requirements, geological objectives,	Drilling Fluid Specialist/Well Planner/Customer

	reservoir description (lithology column for well path), fault formation, temperature profile, casing design, PP/FG plots as provided by the customer	
502	Determine if the reservoir call for a drill-in fluid or other specialized system	Drilling Fluid Specialist/Well Planner/Customer/ Drilling Fluid Technical Group
503	Determine the appropriate fluid types and technologies for the specific well/project and sections/intervals	Drilling Fluid Specialist/Well Planner/Customer/ Drilling Fluid Technical Group
504	Determine the completion fluid requirements	Drilling Fluid Specialist/Well Planner/Customer/ Drilling Fluid Technical Group/Completion Fluid Specialist
505	Determine the local environment regulations	Drilling Fluid Specialist/Customer/Well Planner/Health, Safety and Environment Specialist
506	Determine what the drilling waste profile associated with the project is	Drilling Fluid Specialist/BSS TP/Customer
507	Determine if there are special challenges of this well (e.g., deepwater, HPHT, logistical issues, depleted zones, formation damage, etc) that affects the fluid design.	Drilling Fluid Specialist/Well Planner/Customer
508	Determine need for customized solutions/new technology	Drilling Fluid Specialist/Drilling Fluid Technical Group
509	Determine if this is a critical first well	Drilling Fluid Specialist/Drilling Fluid Technical Group
510	Determine if the well call for specialized lab equipment	Drilling Fluid Specialist/Customer
511	Determine if wellbore stability modeling is required	Drilling Fluid Specialist/Customer
512	Determine if there are any challenges with regard to the hole cleaning, angle of well that requires modification to	Drilling Fluid Specialist/Customer

	the drilling fluid	
513	Evaluate need for lab testing to determine what/if the mud system is suited for drilling under the planned well conditions	Drilling Fluid Specialist/Drilling Fluid Technical Group
514	Perform lab tests to determine composition of LCM pills or Wellset treatment if required.	Drilling Fluid Specialist/Drilling Fluid Technical Group
515	Obtain data from offset wells or wells that have been drilled under similar conditions to get an understanding of what could be expected for the next well to be drilled.	Drilling Fluid Specialist
516	Design LCM decision trees or matrix based on formations to be drilled.	Drilling Fluid Specialist/Drilling Fluid Technical Group
517	Determine stuck pipe procedures	Drilling Fluid Specialist/Drilling Fluid Technical Group
518	Create a Basis of Design (BOD)	Drilling Fluid Specialist
519	Create a Total Fluid Management (TFM)	Drilling Fluid Specialist
520	Create Drilling Fluid Program and Completion Fluid Program if required	Drilling Fluid Specialist/Completion Fluid Specialist
521	Review together with customer and get customers approval	Drilling Fluid Specialist
522	Perform mud formulation based on given formation pressure / anticipated hole problems	
523	Select mud type / properties for each hole section	
524	Specify mud properties like mud wt / yield point / gel strength / pH / MBT / Chloride / Solid content / Filtrate quantity / filtrate analysis	
525	Run hydraulic DFG for each hole section and estimate the	

	proper ROP / gpm to minimize cutting load in the annulus	
526	Adjust ROP while drilling to minimize cutting load	
527	Determine mud wt schedule for each hole section.	

Table 3

Subtask	Description	Performance Responsibility
601	Obtain Customer Reference Documentation. Tool Instrument Performance Model files, anti-collision practices, drilling and surveying practices	DD Coordinator/Well Planner/Survey Manager
602	Determine Single / Multi well path design	DD Coordinator/Well Planner/Survey Manager
603	Determine Geological Target (s)	Obtained from customer by DD Coordinator, Well Planner updates plans
604	Determine Drillers Target(s)	Obtained from customer by DD Coordinator, Well Planner updates plans
605	Determine the boundaries of any lease line or block	Customer / Well Planner
606	Obtain offset well survey information and QA type of surveys to determine correct Instrument Performance Model .	Obtained by DD Coordinator, Well Planner updates plans
607	Determine any zones to avoid penetrating, (Injection / production / cuttings injection/ subsidence).	Customer/DD Coordinator/Well Planner
608	Determine inclination limitations for Top hole section, riserless section or entire wellbore.	Customer/DD Coordinator/Well Planner
609	Determine inclination and azimuth sensitivities for borehole stability	Customer/DD Coordinator/Well Planner
610	Determine inclination and azimuth sensitivities for	Customer/DD Coordinator/Well Planner

	Torque and Drag limitations.	
611	Determine formation tendencies for build / drop / turn rates.	Customer/DD Coordinator/Well Planner
612	Identify formations that are difficult / impossible to steer in or have 'natural' formation tendencies	DD Coordinator/Well Planner
613	Plan Well Path aiming to continually diverge from all existing wells from the kick off point.	DD Coordinator/Well Planner
614	Plan to minimize Doglegs in top hole sections.	DD Coordinator/Well Planner
615	Perform Anti collision Analysis, review high risk wells and report to the customer.	DD Coordinator/Well Planner
616	Determine if gyro or steering tools are required because of magnetic interference.	DD Coordinator/Well Planner
617	Establish the effect of TVD uncertainties especially when planning horizontal The effect of TVD uncertainty, due to both geology and survey error should be accounted for in the plan so that well can still be landed within the dogleg capability of the equipment.	DD Coordinator/Well Planner/Survey Manager
618	Establish the effect of drilling close to magnetic east west and close to horizontal, based on the latitude of the well.	DD Coordinator/Well Planner/Survey Manager
619	Determine length of Rat hole required at TD for logging tools	Customer /DD Coordinator/Well Planner/Survey Manager
620	Determine differential sticking risk. Compensate within wellplan for build and drop above and below the risk zone as sliding may result in stuck pipe.	Customer
621	Perform Anti collision Analysis, review high risk	Customer/DD Coordinator/Well Planner

	wells and report to the customer.	
622	Consider options for collision avoidance should the directional plan not be achieved	DD Coordinator/Well Planner
623	Determine if sidetracks are Planned	Customer /DD Coordinator/Well Planner
624	When sidetracking an existing wellbore review QA information of main bore and generate definitive survey listing	DD Coordinator/Well Planner
625	When sidetracking an existing wellbore determine if the location of the KOP is in open hole or inside casing and obtain hole diameter	DD Coordinator/Customer
626	When sidetracking an existing wellbore determine the top of the cement in open hole or behind casing.	DD Coordinator/Customer
627	When sidetracking an existing wellbore determine the Kick off method,(open hole, cement plug, whipstock)	DD Coordinator/Customer
628	When Sidetracking an existing wellbore produce Ladder plots or travelling cylinder and clearance listings in sufficient detail to show the planned divergence from the parent well, casing stumps and the zones of magnetic interference.	DD Coordinator/Well Planner/Survey Manager
629	When sidetracking determine the requirement for gyro singles shots, gyro multishots, or gyro MWD over the zone of magnetic interference Any risk of collision shall be documented	DD Coordinator/Well Planner/Survey Manager
630	When Sidetracking Perform Anti collision Analysis, review high risk wells and report to	DD Coordinator/survey management

	the customer.	
631	QA check proposed well design with offset well performance	DD Coordinator
632	Review surface location position to determine if well path design can be improved by modifying it.	Customer/DD Coordinator
633	Review Torque and Drag for Drillstring and Casing to determine if well path design can be improved by modifying it.	Customer/DD Coordinator
634	Review Fluid Design, Hydraulics and hole cleaning to determine if well path design can be improved by modifying it.	Customer/DD Coordinator
635	Review Bottom Hole Assembly Designs to determine if directional performance can be optimized by modifying the well path design	Customer/DD Coordinator

[00031] Figure 5 further shows some of the links to other tasks and subtasks that are utilized in subtasks 501-527 of task 406 (Drilling Fluids Design). As is shown in Figure 5, subtasks 503, 504, 507, 509, 512, 513, 518, and 519 of task 406 are each linked to subtasks 618, 624, and 630 of task 402 (Well Trajectory Design) and to task 404 (Wellbore Integrity Analysis). Subtask 505, 510, and 516 are each linked to subtasks 618 and 624 of task 402 and to task 404. Subtasks 506 and 515 of task 406 are each lined to subtask 618 of task 402 and to task 404.

[00032] Figure 6 further illustrates some links to other tasks and subtasks that are utilized in task 402 (Well Trajectory Design). As shown in Figure 7, subtask 604 is linked to subtask 650, which can be the fourth subtask in task 412 (Drillstring Design): Obtain Wellbore trajectory, wellbore schematic with hole size start and end depths and mud weight schedule. Subtask 606 is linked to subtask 652, which is a subtask of an "Obtain Target Location" task: Carry out a database search for offset wells already drilled and review relevant well designs, plots, logs and

end of well reports. Subtask 607 is linked to task 654 (Determine Reservoir Type, Extent of Reservoir and Required Exposure), subtask 507 of task 406 and subtask 658 of task 410 (Bottom Hole Assembly Design): Obtain Build/Drop/Equilibrium Rate Requirements/ Limitations and target tolerances. Subtask 609 is linked to task 404 (Wellbore Integrity Analysis). Subtask 610 is linked to task 412 (Drillstring Design). Subtask 611 is linked to subtask 670 of task 410: Obtain formation tendencies. Subtask 612 is linked to subtask 652 and subtask 672 of task 404 (Perform Hazard identification – salt, rubble zones, faults, fractured zones, vuggy or karst formations). Subtask 617 is linked to task 410. Subtask 619 is linked to subtask 672. Subtask 620 is linked to task 410. Subtask 621 is linked to subtask 674 of task 410 (Obtain Anti-collision program). Subtask 622 is linked to task 410. Subtask 626 is linked to task 676 (Cement Design). Subtask 631 is linked to subtask 652. Subtask 632 is linked to task 678 (Obtain Surface Location). Subtask 633 is linked to task 410. Subtask 634 is linked to task 406 (Drilling Fluids Design), task 414 (Hydraulics design), and subtask 512 of task 406. Subtask 635 is linked to task 410.

[00033] Similar subtask definitions and linkages can be provided for each of tasks 402 through 414. Therefore, in optimizing the drilling environment utilizing workflow 400 as illustrated in Figure 4, once task 414 is completed the optimization routine returns to perform tasks 402-414 again. The process continues until it converges onto an optimum drilling design.

[00034] Figure 7 illustrates a system 700 for optimizing N tasks in a workflow environment. As shown in Figure 7, optimization controller 702 provides the framework for performing each of the tasks in order. Once task 704-1, the resulting design can be uploaded to optimization controller 702. Optimization controller 702 can then enable performance of task 704-2. Once task 704-2 is completed and the resulting design parameters uploaded to optimization controller 702, then optimization controller proceeds to enable the next task. Once the last task, task 704-N, is performed and the resulting design is uploaded to optimization controller 702, then optimization controller 702 can begin again to enable task 704-1. In doing so, optimization controller 702 can upload design parameters that result from the linkages formed between task 704-1 and the other tasks 704-2 through 704-N as discussed above. Similarly, optimization controller 702 continues to cycle through tasks 704-1 through 704-N until convergence is

achieved. The optimization controller can perform all of the tasks 704-1 through 704-N sequentially as described above, or in some embodiments has the capability to detect only the tasks 704-1 through 704-N that need to be performed based on changes in the state of the tasks 704-1 through 704-N within the workflow so that convergence is achieved more rapidly.

[00035] As examples, tasks 704-1 through 704-N can correspond to tasks 322, 324, 330, 332, 334, 336, and 338 illustrated in Figure 3 and defined in Table 1. Similarly, tasks 704-1 through 704-N can correspond to tasks 402-414 illustrated in Figures 4-6 and Tables 1 and 2.

[00036] As discussed above, optimization controller 702 can be a central computer. Tasks 704-1 through 704-N or groupings of tasks can be performed utilizing peripheral computers controlled by the particular group with responsibility for performing that task or grouping of tasks and the results uploaded to optimization controller 702. Alternatively, all of tasks 704-1 through 704-N or groupings of tasks can be performed utilizing the central computer of optimization controller 702, which can be linked through a network with peripheral computers. In that case, all of the design parameters and results remain on optimization controller 702. Alternatively, all of tasks 704-1 through 704-N or groupings of tasks can be performed utilizing the central computer of optimization controller 702 that controls the peripheral computers to which the optimization controller 702 is linked through a network. In that case, all of the design parameters and results of the task or groupings of tasks performed on the peripheral computers remain on the peripheral computers and the results of the overall analysis are retained on the optimization controller 702.

[00037] The above detailed description is provided to illustrate specific embodiments of the present invention and is not intended to be limiting. Numerous variations and modifications within the scope of the present invention are possible. The present invention is set forth in the following claims.

Claims

What is claimed is:

1. A method of optimizing a well drilling design, comprising:
identifying a plurality of tasks to be optimized, the plurality of tasks being in a well drilling design workflow for the well drilling design;
identifying links to other tasks and subtasks in the well drilling design workflow; and
repeatedly performing tasks in the plurality of tasks until the plurality of tasks until the well drilling design is optimized according to optimization parameters.
2. The method of claim 1, wherein the plurality of tasks includes are chosen from a set of tasks consisting of Well Trajectory, Wellbore Integrity Analysis, Drilling Fluids Design, Drill Bit and Hole Opener Design, Bottom Hole Assembly Design, Drillstring Design, and Hydraulics Management.
3. The method of claim 1, wherein identifying links comprises:
determining subtasks associated with each of the plurality of tasks;
determining parameters that are affected by results of performing other tasks or subtasks;
and
defining links based on the affected parameters.
4. An optimizer, comprising:
an optimization controller; and

a plurality of peripheral computers coupled to the optimization controller, each of the plurality of peripheral computers corresponding to one of a plurality of tasks to be optimized, the plurality of tasks being in a well design workflow,

wherein the optimization controller enables each of the plurality of tasks and provides linked designs and parameters to others of the plurality of tasks.

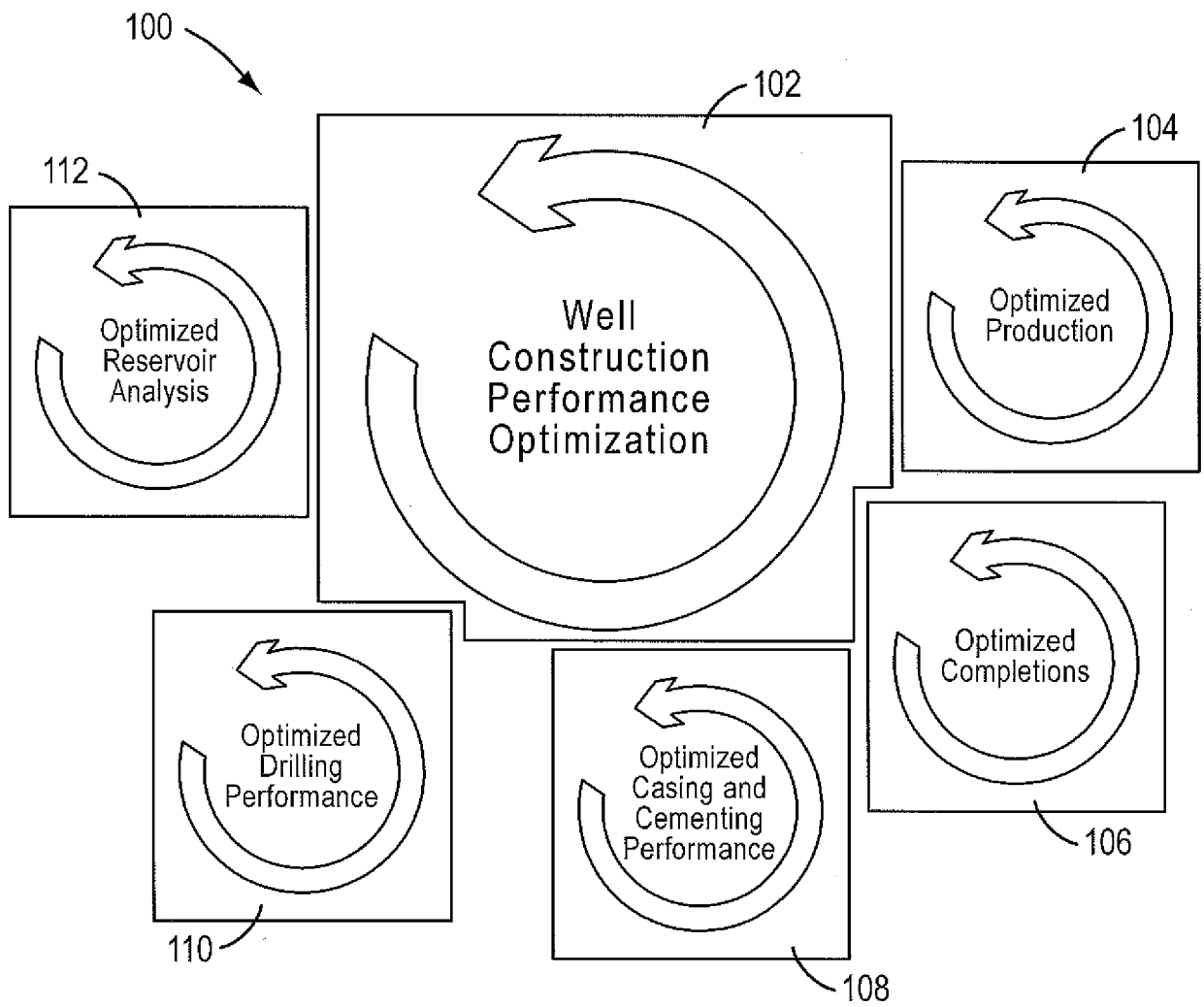


Figure 1

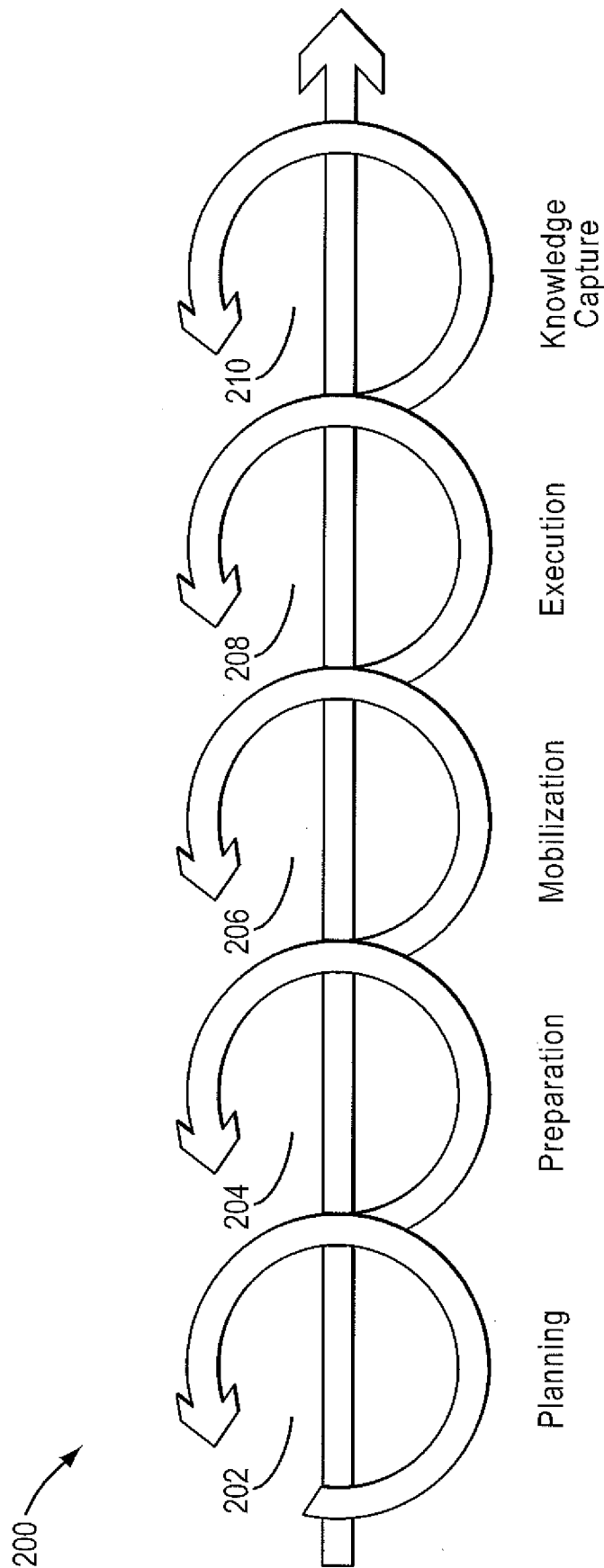


Figure 2

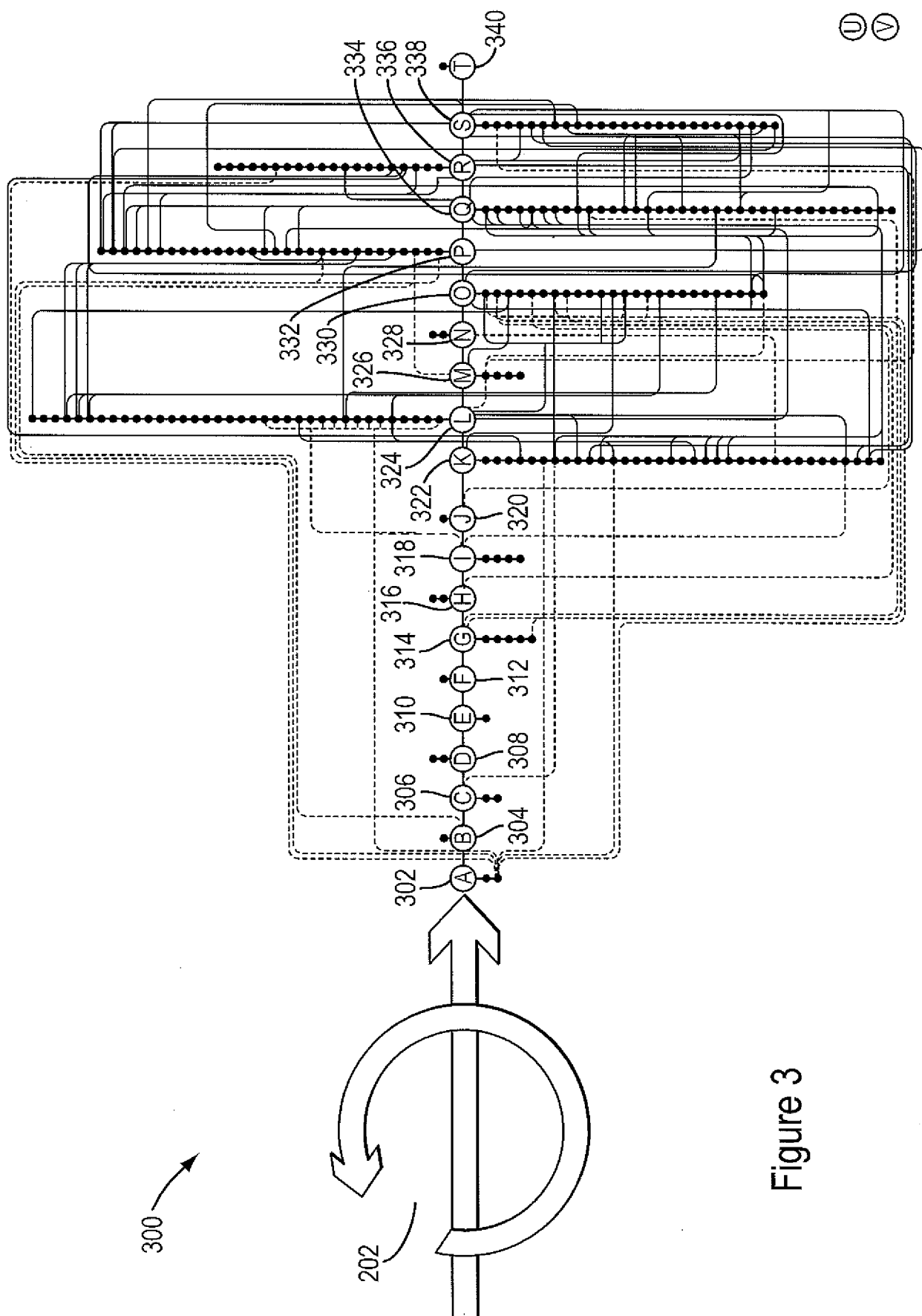


Figure 3

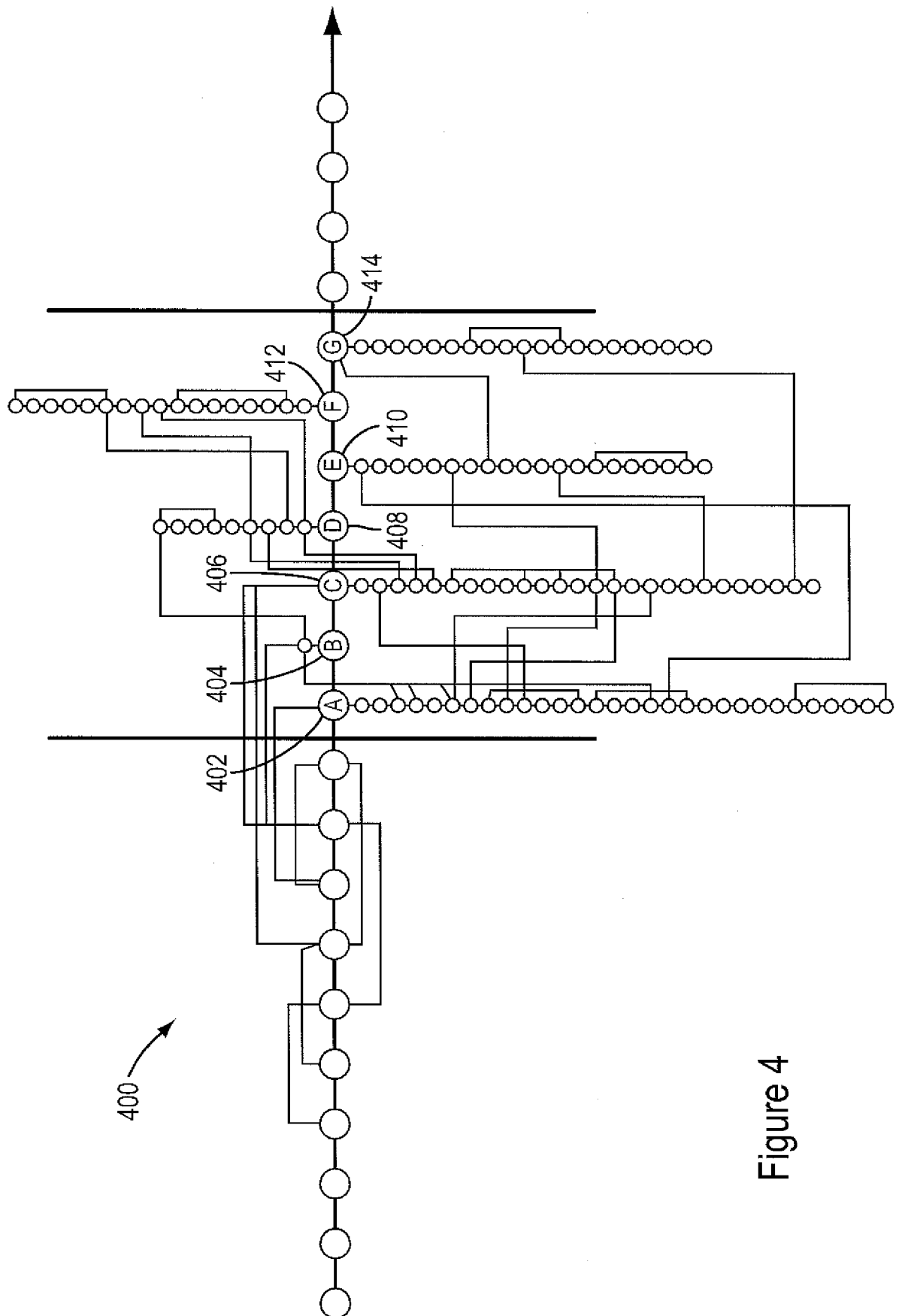


Figure 4

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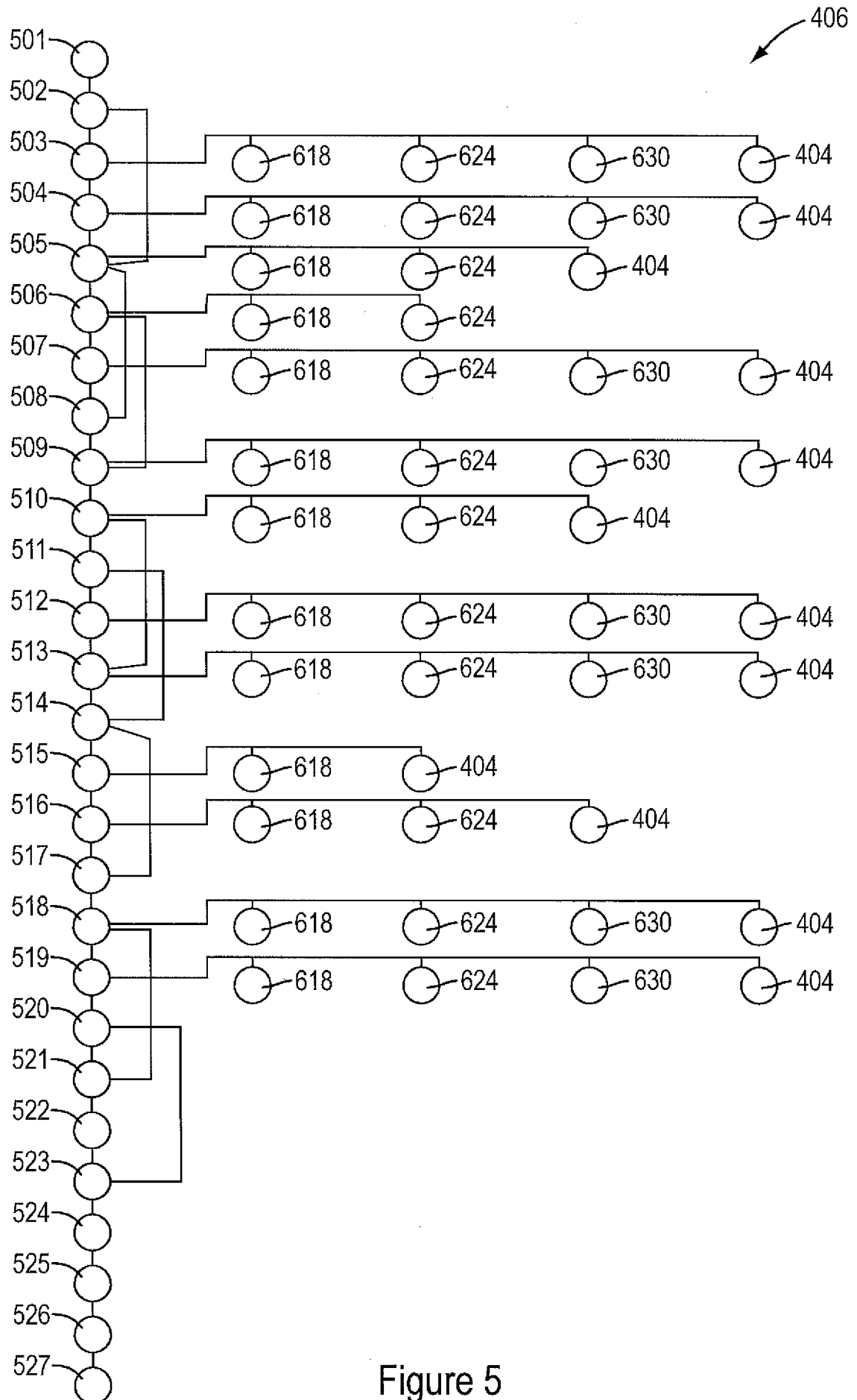


Figure 5

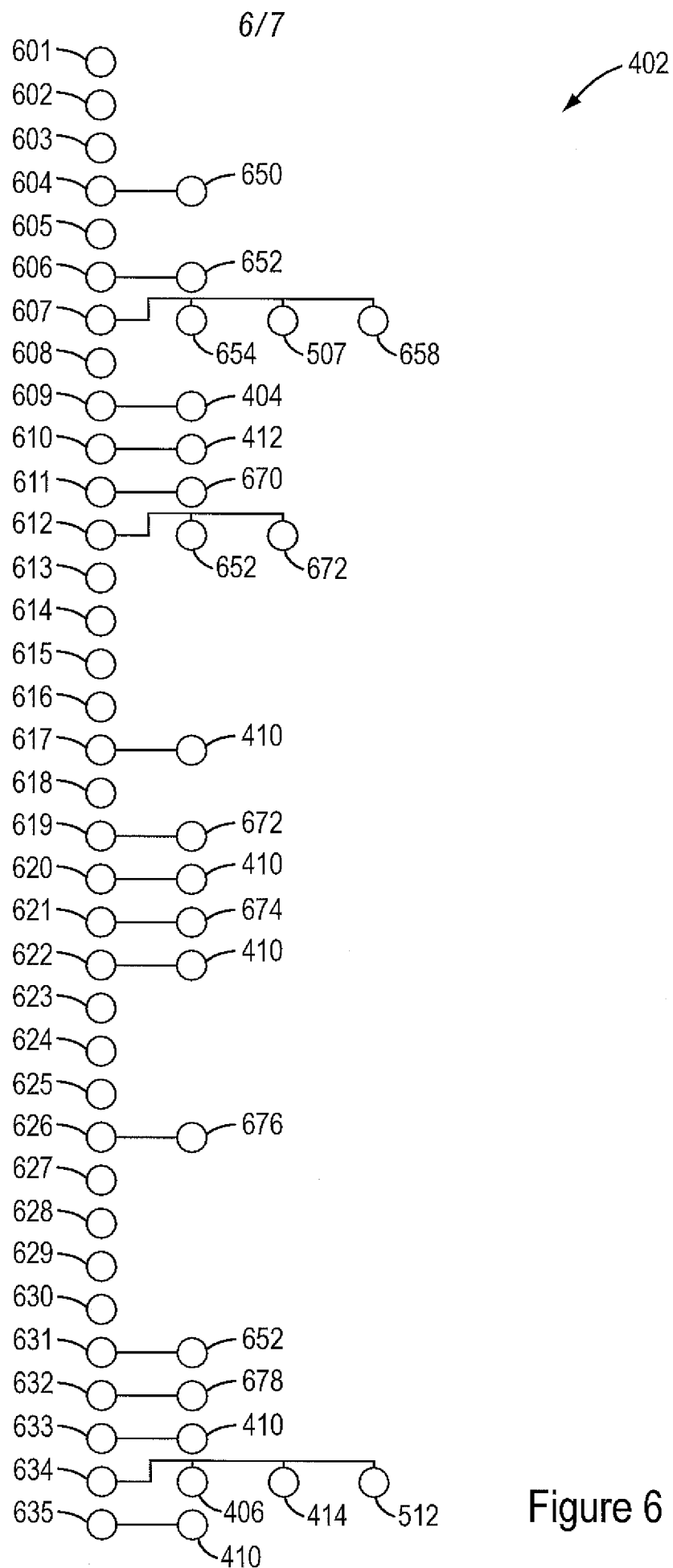


Figure 6

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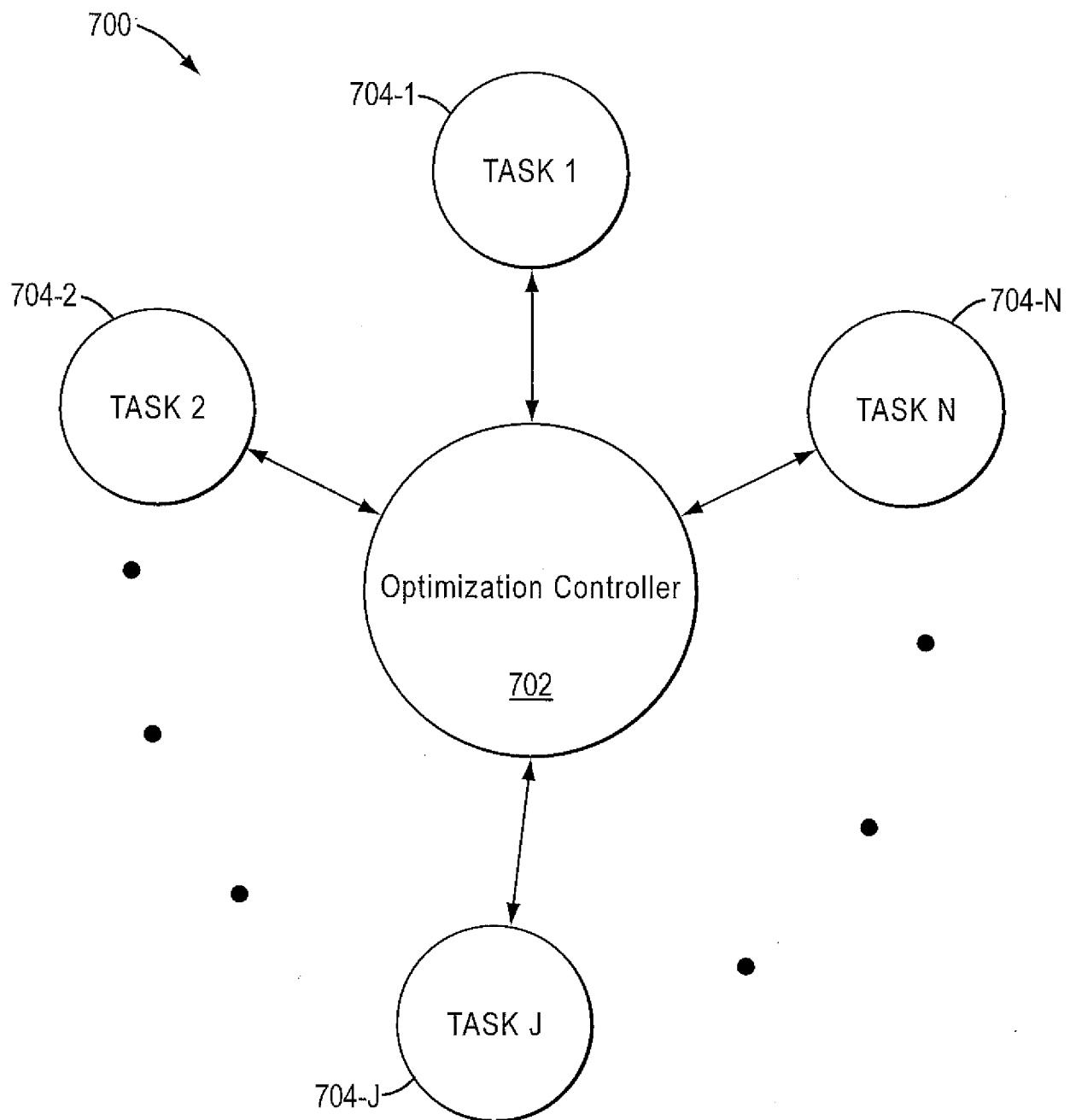


Figure 7

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 12/23343

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - G06Q 10/00 (2012.01)

USPC - 705/7.12

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

USPC: 705/7.12

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC: 705/7.12; 706/19, 929 (keyword limited - see terms below)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

PubWEST (PGPB, USPT, USOC, EPAB, JPAB); GOOGLE; GoogleScholar

Search Terms: drilling, well, borehole, hole, task, workflow, optimization, well design, controller, peripheral, parameter, integrity, fluid, management

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 2005/0209836 A1 (Klumpen et al.) 22 September 2005 (22.09.2005), entire document, especially; abstract, para. [0038], [0063], [0064], [1100]-[1102], [1113]-[1117], Fig. 8	1 - 3 ----- 4
Y	US 2004/0216110 A1 (Noll et al.) 28 October 2004 (28.10.2004), entire document, especially; abstract, para. [0002]-[0005], [0068]-[0070]	4
A	US 2005/0211468 A1 (Veeningen et al.) 29 September 2005 (29.09.2005), entire document	1 - 4
A	US 2007/0199721 A1 (Givens et al.) 30 August 2007 (30.08.2007), entire document	1 - 4

☐ Further documents are listed in the continuation of Box C.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

24 April 2012 (24.04.2012)

Date of mailing of the international search report

15 MAY 2012

Name and mailing address of the ISA/US

Mail Stop PCT, Attn: ISA/US, Commissioner for Patents
P.O. Box 1450, Alexandria, Virginia 22313-1450

Facsimile No. 571-273-3201

Authorized officer:

Lee W. Young

PCT Helpdesk: 571-272-4300

PCT OSP: 571-272-7774