(54) Title: ROTATING DRILLING TOWERS

(57) Abstract: Two or more rotating towers on a drilling rig may be configured to rotate between one or more wells. The rotating towers may have a common well center, such that the two or more towers can operate over the same well to provide redundant or cooperative operations. Some example cooperative operations include heavy lifting and/or isochronous tripping operations. Redundancy can be provided by the two or more rotating towers to prevent equipment failures from halting operations.

FIG. 1a
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ROTATING DRILLING TOWERS

BACKGROUND


   [0001] This application claims the benefit of U.S. Provisional Patent Application No. 62/426,415 to Daniel Haslam entitled “Rotating Drilling Towers” and filed on November 25, 2016, and claims the benefit of U.S. Provisional Patent Application No. 62/331,653 to Daniel Haslam entitled “Rotating Drilling Towers” and filed on May 4, 2016, both of which are incorporated by reference.

2. Field of Invention

   [0002] The present invention relates generally to well construction, and more specifically, but not by way of limitation, to use one or more rotatable drilling towers to perform various drilling operations, such as may be performed on a drilling vessel.

3. Description of Related Art

   [0003] Drilling an oil or gas well conventionally involves operating a single, fixed drilling tower (or mast or derrick) to hoist (e.g., load/unload) tubulars and other equipment along a fixed path below or to the side of the drilling tower. The fixed nature of the drilling tower limits drilling operations to a single well located below or next to the drilling tower. Because only a single, fixed tower is used, drilling operations cease if the drilling tower requires maintenance or if any drilling tower equipment (e.g., hoisting, circulating, rotating, auxiliary equipment) fails. To mitigate these costly delays, operators and innovators schedule maintenance when not drilling and design drilling towers such that maintenance can be performed outside the critical drilling
path. While helpful, these solutions still incur delays and do not account for unplanned events such as equipment and/or procedural failures.

[0004] Delays also occur when changing equipment, because such equipment must be configured along the drilling path. Further delays occur when using a fixed drilling tower during tripping operations. Tripping operations feed or pull individual segments of pipe into or out of a well. Each pipe or tubular is fed into or out of the well one at a time and connected or disconnected from the prior pipe or tubular by threading. Tripping requires heavy equipment like hoisting and rotating equipment and is conventionally a very time consuming process. One time-consuming aspect of conventional tripping is the requirement of the hoisting system to reposition in an unloaded state after raising or lowering the entire weight of the tubing string. This repositioning takes time that could otherwise be used to continue tripping operations.

[0005] Another drawback of traditional fixed drilling towers is that they generally must be designed to hoist the largest potential load, even if hoisting such a large load is infrequent. This requires the tower to be heavier and more expensive than usually needed, increases maintenance costs, and can reduce operating efficiency (due to the slow traveling speeds of the load path under all load conditions). Adjustable hoisting capacity technology, such as variable cylinder rig designs where cylinders can be taken offline, can compromise tripping efficiency because they still require the traveling block to large enough to handle the largest load, and variable cylinder rig designs do not allow the block to retract off the drilling path.

SUMMARY

[0006] One or more rotating towers may be located on a drilling rig to improve upon the drawbacks of conventional technology described above, while additionally offering other benefits. For example, rotating towers may reduce delays, such as the delays described above
that occur in conventional drilling rigs. Furthermore, greater operational flexibility is achieved because the one or more towers can perform operations off the critical path.

[0007] The one or more rotating towers may be configured to rotate about their vertical centerlines to lift, lower, move, or hold a load along their respective rotation paths. In some embodiments, the one or more towers can be capable of supporting operations or activities outside the critical path of a well, such as transverse movement of loads or maintenance. In some embodiments, the one or more drilling towers can include counterbalances. In some embodiments, the one or more towers can include active or passive compensation mechanisms to compensate for forces generated by ocean waves or other factors. In some embodiments, the one or more towers can include adjustable crown sheaves capable of transversely positioning the path of a load carried by the one or more towers. In some embodiments, the one or more towers can include one or more traveling assemblies, drill lines, retraction mechanisms, hooks, top drives, swivels, blocks, and/or block-and-tackles.

[0008] In some configurations, the two towers can be used with at least one of the towers configured to rotate between more than one well. For example, the two towers can be disposed close enough to each other so that their respective rotational paths at least partially overlap. In some embodiments, both towers can rotate over the same well. In some embodiments, more than one well can be located at asymmetrical positions along at least one of the paths of the two towers. In some embodiments, a well can be located off boat longitudinal axis, off the circular rotational path of at least one tower, or both. In some embodiments, the rotational path of at least one of the towers can be off-center. In some embodiments, at least one of the towers can include adjustable crown sheaves capable of transversely positioning the path of a load carried by the tower(s) in order to reach a well located outside the circular rotational path of the
tower(s). In some embodiments, the two towers are separate, independent units. In some embodiments, operations carried out by one tower do not affect or depend on operations carried out by the other tower. Some of these configurations may provide (i) increased operational flexibility because more than one well can be operated by a single tower; (ii) higher operation uptime due to increased maintainability, redundancy, and the ability to recover from unplanned events without delaying operations; and (iii) lower maintenance costs due to the ability to perform maintenance and equipment dressing off the critical path.

[0009] Two towers can be used with both towers configured to rotate over the same well center and perform operations over that well center at the same time. In some embodiments, the drill lines of the two towers can be configured to facilitate cooperation. For example, the drill lines of each tower can be offset or employ different drill line termination points than each other so that they do not interfere; or the towers can be positioned at different fixed or variable heights. In some embodiments, telescoping means may be provided in one of the drilling towers to provide variable height. In some embodiments, the two towers can cooperate to raise, lower, or hold a load. In some embodiments, the two towers can cooperate to isochronously, continuously, or conventionally perform tripping operations. In some embodiments, tubulars used in tripping operations can be stored and/or retrieved from various locations, including within the hull of a rig (e.g., a moonpool), on a rig floor, or horizontally on a pipe deck or in a dedicated hold. In some embodiments, the two towers can cooperatively operate a single top drive to perform an operation. In some embodiments, the two towers can operate two top drives cooperatively to perform a single operation. In some embodiments, each tower can be optimized to hoist the most frequently encountered load, rather than the heaviest anticipated load, of an operation. In some embodiments, the two towers can be configured to together hoist the maximum anticipated load
for a given operation. In some embodiments, the two towers can include a brace to resist the force or moment created when lifting, lowering, or holding a load. In some embodiments, the brace can be located between and coupled to the two towers. In some embodiments, the brace can be located above the highest possible vertical location of one or more traveling assemblies and/or other equipment of the towers. In some embodiments, the brace can include one or more brace supports that can circumscribe and/or couple to at least one of the two towers. In some embodiments, the one or more brace supports can be configured to permit the at least one of the two towers to rotate and/or telescope substantially freely while not substantially limiting the movement of one or more traveling assemblies and/or other equipment of the towers. Some of these configurations may provide (i) lower initial capital expenditures because less equipment and/or less robust equipment is needed; (ii) lower maintenance costs because the towers operate a less amount of and/or less heavy hoisting equipment; and (iii) increased efficiency in tripping operations because tripping operations can continue during unloaded travel.

[0010] The term “coupled” is defined as connected, although not necessarily directly, and not necessarily mechanically; two items that are “coupled” may be unitary with each other. The terms “a” and “an” are defined as one or more unless this disclosure explicitly requires otherwise. The term “substantially” is defined as largely but not necessarily wholly what is specified (and includes what is specified; e.g., substantially 90 degrees includes 90 degrees and substantially parallel includes parallel), as understood by a person of ordinary skill in the art. In any disclosed embodiment, the terms “substantially” and “approximately” may be substituted with “within [a percentage] of” what is specified, where the percentage includes .1, 1, 5, and 10 percent.
[0011] The phrase “and/or” means and or or. To illustrate, A, B, and/or C includes: A alone, B alone, C alone, a combination of A and B, a combination of A and C, a combination of B and C, or a combination of A, B, and C. In other words, “and/or” operates as an inclusive or.

[0012] Further, a device or system that is configured in a certain way is configured in at least that way, but it can also be configured in other ways than those specifically described.

[0013] The terms “comprise” (and any form of comprise, such as “comprises” and “comprising”), “have” (and any form of have, such as “has” and “having”), and “include” (and any form of include, such as “includes” and “including”) are open-ended linking verbs. As a result, an apparatus that “comprises,” “has,” or “includes” one or more elements possesses those one or more elements, but is not limited to possessing only those elements. Likewise, a method that “comprises,” “has,” or “includes,” one or more steps possesses those one or more steps, but is not limited to possessing only those one or more steps.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] The following drawings illustrate by way of example and not limitation. For the sake of brevity and clarity, every feature of a given structure is not always labeled in every figure in which that structure appears. Identical reference numbers do not necessarily indicate an identical structure. Rather, the same reference number may be used to indicate a similar feature or a feature with similar functionality, as may non-identical reference numbers.

[0015] FIG. 1a depicts rotating drilling towers operating over different wells according to some embodiments of the disclosure.

[0016] FIG. 1b depicts rotating drilling towers operating over the same well according to some embodiments of the disclosure.
FIGs. 1c and 1d depict an adjustable crown sheave system according to some embodiments of the disclosure.

FIG. 2a depicts two rotating drilling towers performing “heavy lift” operations, according to some embodiments of the disclosure.

FIG. 2b depicts a top view of an embodiment of a brace, according some embodiments of the disclosure.

FIG. 2c is a flow chart illustrating a method of performing a “heavy lift” operation, according to the embodiments disclosed in FIG. 2a.

FIG. 2d is a flow chart illustrating a method of performing a “heavy lift” operation, according to some embodiments of the disclosure.

FIG. 3a depicts a first step of running tubing out of a well by an isochronous tripping operation, according to some embodiments of the disclosure.

FIG. 3b depicts a second step of running tubing out of a well by an isochronous tripping operation, according to some embodiments of the disclosure.

FIG. 3c depicts a third step of running tubing out of a well by an isochronous tripping operation, according to some embodiments of the disclosure.

FIG. 3d depicts a fourth step of running tubing out of a well by an isochronous tripping operation, according to some embodiments of the disclosure.

FIG. 3e depicts a fifth step of running tubing out of a well by an isochronous tripping operation, according to some embodiments of the disclosure.

FIG. 3f depicts a sixth step of running tubing out of a well by an isochronous tripping operation, according to some embodiments of the disclosure.
[0028] FIG. 3g depicts a seventh step of running tubing out of a well by an isochronous tripping operation, according to some embodiments of the disclosure.

[0029] FIG. 3h depicts an eighth step of running tubing out of a well by an isochronous tripping operation, according to some embodiments of the disclosure.

[0030] FIG. 3i is a flow chart illustrating a method of performing an isochronous tripping operation, according to some of the embodiments disclosed in FIGs. 3a-3h.

[0031] FIG. 3j is a flow chart illustrating a method of performing an isochronous tripping operation, according to some embodiments of the disclosure.

[0032] FIG. 4a depicts a first step of running tubing into a well by an isochronous tripping operation, according to some embodiments of the disclosure.

[0033] FIG. 4b depicts a second step of running tubing into a well by an isochronous tripping operation, according to some embodiments of the disclosure.

[0034] FIG. 4c depicts a third step of running tubing into a well by an isochronous tripping operation, according to some embodiments of the disclosure.

[0035] FIG. 4d depicts a fourth step of running tubing into a well by an isochronous tripping operation, according to some embodiments of the disclosure.

[0036] FIG. 4e depicts a fifth step of running tubing into a well by an isochronous tripping operation, according to some embodiments of the disclosure.

[0037] FIG. 4f depicts a sixth step of running tubing into a well by an isochronous tripping operation, according to some embodiments of the disclosure.

[0038] FIG. 4g depicts a seventh step of running tubing into a well by an isochronous tripping operation, according to some embodiments of the disclosure.
FIG. 4h depicts an eighth step of running tubing into a well by an isochronous tripping operation, according to some embodiments of the disclosure.

FIG. 4i is a flow chart illustrating a method of performing an isochronous tripping operation, according to some of the embodiments disclosed in FIGs. 4a-4h.

FIG. 4j is a flow chart illustrating a method of performing an isochronous tripping operation, according to some embodiments of the disclosure.

DETAILED DESCRIPTION

Referring to the drawings, FIGs. 1a and 1b depict different configurations of drilling operation 100, which includes two rotating drilling towers (or masts or derricks) 101a, 101b. Drilling towers 101a, 101b can perform various well operations, including those that employ hoisting, circulating, rotating, and/or auxiliary equipment. Drilling towers 101a, 101b may each include a set of sheaves 102, 104 (e.g., a crown sheave cluster) and a traveling assembly (not shown) located under sheave 104. Though not shown, drilling towers 101a, 101b can also include other components of drilling towers, including a motion compensating device, which can be any mechanism capable of compensating for the relative movement of the drilling towers versus the seabed. The traveling assemblies of towers 101a, 101b can retract transversely toward and away from towers 101a, 101b when performing the various well construction operations. Drilling towers 101a, 101b may be included in an offshore vessel such as an oil rig or drilling vessel. When used in such an application, compensation mechanisms may be integrated with drilling towers 101a, 101b to compensate for the motion induced by ocean waves and/or other forces generated on the offshore vessel or drilling towers. The compensation mechanisms can be active or passive compensation systems. Drilling towers 101a, 101b can rotate about their vertical centerlines (i.e., out of the page) to lift, lower, move, or hold a load anywhere along their
respective rotational paths 105, 106 (shown in dashed lines). Additionally, the traveling assemblies of towers 101a, 101b can be retracted toward or away from towers 101a, 101b to increase or decrease the diameter of rotational paths 105, 106. The diameter of rotational paths 105, 106 can also be adjusted by employing an adjustable crown sheave system on towers 101a, 101b, such as system 123.

[0043] FIGs. 1c and 1d show side views of adjustable crown sheave system 123 disposed on a tower 101 (e.g., tower 101a or tower 101b). Adjustable crown sheave system 123 includes two crown sheaves 102, 104 mounted to the top of tower 101 via mounting assemblies 124. Mounting assemblies 124 can be configured to permit crown sheaves 102, 104 to move transversely (i.e., left or right, as depicted) via, e.g., rotation of bars 125 about pins 126. Mounting assemblies 124 can further include stops 127 on either side of bars 125 that restrict the transverse motion of crown sheaves 102, 104. Crown sheaves 102, 104 can move transversely via operation of tie-bar 128. As seen by comparing FIG. 1c to FIG. 1d, tie-bar 128 can decrease or increase its transverse length via, e.g., a sliding mechanism. Tie-bar 128 can be operated manually or remotely and can be operated by mechanical, electrical, hydraulic, or other means. When tie-bar 128 is actuated to reduce its transverse length from the length shown in FIG. 1c to the length shown in FIG. 1d, the operational path 129 of drill line 132 moves from a distance 130 away from tower 101 to a shorter distance 131 away from tower 101, thus decreasing the diameter of the rotational path of tower 101.

[0044] Towers 101a, 101b may be located close enough to one another such that their respective rotational paths can at least partially overlap. Well 103a lies along path 105 such that drilling tower 101a can perform operations on well 103a, while well 103b lies along path 106 such that drilling tower 101b can perform operations on well 103b. Well 103c lies along both
paths 105 and 106 such that both drilling towers 101a, 101b can perform operations on well 103c. While shown symmetrically, wells 103a-c (or other wells) can also be located at asymmetrical positions. For example, wells can be located off boat longitudinal axis, off the circular rotational paths of towers 101a, 101b, or both. To facilitate operation of these wells by towers 101a, 101b, the rotational path of either or both towers 101a, 101b can be off-center (e.g., oval). An off-center rotational path can be accomplished in at least one of two ways. First, an off-center rotational path can be accomplished by retraction of the traveling assemblies toward or away from towers 101a, 101b during rotation. Second, an off-center rotational path can be accomplished by employing an adjustable crown sheave system, such as system 123 shown in FIGs. 1c and 1d, on towers 101a, 101b.

Each tower 101a, 101b may be configured and operated as a separate, independent unit. Operations carried out on one tower (e.g. tower 101a) do not affect nor depend on operations of another tower (e.g., tower 101b). Towers 101a, 101b are capable of supporting activities outside the critical path of a well, such as transverse movement of heavy loads or maintenance. While towers 101a, 101b can perform different operations simultaneously, they also provide redundancy that prevents delays. For example, if tower 101b requires maintenance or its equipment fails, it can rotate away from operation over well 103c (e.g., to being over well 103b) and tower 101a can rotate from operation over well 103a to continue the operation over well 103c. This can reduce downtime exposure and provide additional operational flexibility when performing maintenance as the maintenance can be performed off the critical path over well 103c. Additionally, towers 101a, 101b can be dressed for the next operation off the critical path over well 103c (e.g., converted from a configuration to run riser segments to a configuration
to run drill pipe) and then rotated over the critical path over well 103c without delaying operations.

[0046] Towers 101a, 101b can also operate simultaneously or in combination over the same well, as shown in FIG. 1b. To facilitate cooperation, towers 101a and 101b can be configured in a variety of ways. For example, the drill lines of towers 101a, 101b can be offset or employ different drill line termination points in order to ensure that they do not interfere. Drilling towers 101a, 101b can also be at different fixed heights or use telescoping means to adjust the height of either or both towers.

[0047] When operating simultaneously or in combination over the same well, towers 101a, 101b can perform a variety of useful operations. For example, towers 101a, 101b can together raise, lower, or hold a load, referred to herein as a “heavy lift operation” (see FIGs. 2a-2b and accompanying description), or can cooperate to isochronously trip tubulars in and out of a well (see FIGs. 3a-4h and accompanying description). During isochronous tripping, the tripping speed may be maintained constant over a given range of block speeds. Towers 101a, 101b can also be used in conjunction to trip tubulars in other ways. For example, towers 101a and 101b could be used in a continuous tripping operation. Tubulars used for tripping may be stored in and fed to towers 101a, 101b from various locations, including within the hull (e.g., a moonpool), on the rig floor, or horizontally on a pipe deck or in dedicated holds.

[0048] FIG. 2a depicts a heavy lift operation 200, wherein two rotating drilling towers 201a, 201b work together to lift a tubing string 207, 214 into or out of well 203 located below floor 210. Heavy lift operation 200 employs a vertical traveling mechanism 219 comprising a top drive 208 coupled to retraction mechanisms 209a, 209b, as well as other components such as a hook (not shown). Retraction mechanisms 209a, 209b are coupled to tower 201a, 201b,
respectfully, and may be configured to move top drive 208 transversely (left and right, as depicted). In some embodiments, as shown in FIG. 2a, one topdrive has been removed and both retraction mechanisms are shown connected to a single topdrive. In some embodiments, the retraction mechanisms can no longer move 208 transversely and can only align it over well center 103c. In some embodiments, a topdrive is moved transversely when one retraction mechanism is connected to its own topdrive.

[0049] The top drive 208 can be a conventional top drive or other mechanism such as a swivel. While each tower 101a, 101b normally employs its own top drive (or swivel), when used in combination, one of the tower’s top drives can be removed from its retraction mechanism (209a or 209b) and the unloaded retraction mechanism coupled to the other tower’s top drive. Alternatively, both tower top drives may be coupled together so that both work in concert. Top drive 208 shown in FIG. 2a represents at least either of these embodiments.

[0050] In operation, traveling assembly 219 lifts or lowers a heavy tubing string or other load into or out of a wellbore using the combined power of towers 201a, 201b. The lifting or lowering force is supplied through drill lines 232a, 232b coupled to block and tackle assemblies 202a, 211, 219 and 202b, 211, 219 respectively although other hoisting means are also contemplated. Each tower 201a, 201b can be capable of individually lifting a load of approximately half the load 207, 214. Thus, the towers used in heavy lift operation 200 can each be designed to hoist the most frequently occurring, rather than heaviest anticipated load, because when heavy loads are encountered the two towers may operate in combination. During heavy lift operations, components on both towers may be operated together to obtain the additional power to lift the heavy loads.
Heavy lift operation 200 can also employ a brace 220 that can be coupled to each of towers 201a, 201b and located above the highest possible vertical location of traveling assembly 219 (though not necessarily in the same transverse location as traveling assembly 219). Brace 220 can be any configuration capable of resisting, at least in part, the force (moment) generated on towers 201a, 201b when lifting, lowering, or holding load 207, 214, including the configuration shown in FIG. 2b, which shows a top view. Brace 220 includes brace supports 222 that circumscribe and couple to towers 201a, 201b. Brace supports 222 permit towers 201a, 201b to rotate and/or telescope substantially freely while not substantially limiting the movement of traveling assembly 219.

A heavy lift operation using the towers shown in FIG. 2a can be performed according to the method shown in FIG. 2c. For example, towers 201a, 201b can first be rotated over well 203 such that their respective traveling assemblies do not interfere (e.g., they can be in a retracted position). To allow towers 201a, 201b to perform a single operation (e.g., hoisting, lowering, or transversely moving an object), the traveling assemblies of towers 201a, 201b can be configured to operate in concert according to either of the systems described above. For example, tower 201a’s top drive can be removed from its retraction mechanism 209a. Retraction mechanism 209a can then be coupled to tower 201b’s top drive in an operative manner. As an alternative, the bottom of tower 201a’s top drive can be coupled to the top of tower 201b’s top drive (or vice versa) and the top drives configured to operate as a single top drive (e.g., by electronic or mechanical means). In some embodiments, the drive mechanism of one of the top drives can be disabled so that its rotation is a passive part of the top drive 208. Once configured, top drive 208 can be coupled (e.g., hooked) to tubular 207 disposed in well 203. Power
transmitted through block and tackle assemblies 202a, 202b, 211, 219 of towers 201a and 201b can then be used hoist, lower, hold, or otherwise move tubular 207, for example out of well 203.

[0053] More generally, a method for heavy lift operations is described with reference to FIG. 2d. Such a method comprises first rotating first and second towers over the same well; second, configuring the first and second towers to cooperatively hoist an object; third, coupling the object to the first and second towers; and fourth, hoisting the object using the combined power of the first and second towers.

[0054] FIGs. 3a-3i depict isochronous tripping-out method 300 using multiple rotating drilling towers 301a, 301b, which may be located on a rig floor 310 when installed on a drilling vessel. Each tower 301a, 301b has a vertical traveling assembly 319a, 319b, respectively, comprising a top drive (or swivel) 308a, 308b, respectively, and a retracting mechanism 309a, 309b, respectively. As shown in FIG. 3a, traveling assembly 319a may be initially centered over well 303 and coupled (e.g., hooked) to tubular 307, which is the top tubular of a tubular string disposed in well 303. At the same time, traveling assembly 319b is initially disposed vertically above but transversely adjacent to traveling assembly 319a and is in a retracted position (e.g., retracted toward tower 301b) such that it is not centered over well 303. As shown in FIG. 3b, traveling assembly 319a lifts tubular 307 (and the tubing string to which it is attached) out of the well in direction 312 while traveling assembly 319b moves in direction 313. Travel assembly 319b remains in the retracted position while traveling in direction 313 such that traveling assembly 319a and tubular 307 pass by traveling assembly 319b moving in direction 312.

[0055] As shown in FIG. 3c, traveling assembly 319a continues upward until tubular 307 is entirely out of well 303 and tubular 314 (the next tubular in the tubing string) is partially out of well 303 (i.e., at break-out height for tubular 307). Traveling assembly 319b continues
downward until its lower end (the lower end of top drive 308b) is just vertically above but transversely adjacent to the top of tubular 314. Top drive 308a then disconnects tubular 307 from tubular 314 (e.g., by rotation or other means). Retraction mechanism 309a retracts top drive 308a and tubular 307 transversely toward tower 301a, as shown in FIG. 3d. Tubular 307 can then be removed from top drive 308a by other tubular handling equipment (not shown) or lowered by traveling assembly 319a and removed later, as described below with reference to FIGs. 3e and 3f. At the time tubular 307 is moved off the well center (or shortly after), retraction mechanism 309b moves top drive 308b transversely away from tower 301b until it is centered over tubular 314. Traveling assembly 319b then couples (e.g., hooks) to tubular 314.

[0056] As shown in FIG. 3e, traveling assembly 319b then lifts tubular 314 (and the tubing string to which it is attached) in direction 312 while remaining centered over well 303. At the same time, traveling assembly 319a and tubular 307, if not already removed, move in direction 313 while traveling assembly 319a remains in a retracted position such that traveling assembly 319a and tubular 307 can pass by traveling assembly 319b and tubular 314. As shown in FIG. 3f, traveling assembly 319b continues to lift tubular 314 until tubular 314 is entirely out of well 303 and tubular 315 (the next tubular in the tubing string) is partially out of well 303 (e.g., at break-out height for tubular 314). Traveling assembly 319a and tubular 307, if not already removed, continue to move in direction 313 until lower end of traveling assembly 319a (the lower end of top drive 308a) is just vertically above but transversely adjacent to tubular 315. Unless already removed, traveling assembly 319a then uncouples from tubular 307. Tubular 307 can be stored in various locations including below rig floor 310 (e.g., in a moon pool), on rig floor 310, or horizontally on a pipe deck or in dedicated holds. Top drive 308b then disconnects tubular 314 from tubular 315 (e.g., through rotation or other means).
Retraction mechanism 309b then retracts top drive 308b and tubular 314 transversely toward tower 301b, as shown in FIG. 3g. Tubular 314 can then be removed from top drive 308b by other tubular handling equipment (not shown) or lowered by traveling assembly 319b and removed later. At the time tubular 314 is moved off the well center (or shortly after), retraction mechanism 309a moves top drive 308a transversely away from tower 301a until it is centered over tubular 315. Traveling assembly 319a then couples (e.g., hooks) to tubular 315. As shown in FIG. 3h, traveling assembly 319a then lifts tubular 315 (and the tubing string to which it is attached) in direction 312 while remaining centered over well 303. At the same time, traveling assembly 319b and tubular 314, if not already removed, move in direction 313 while traveling assembly 319b remains in a retracted position such that traveling assembly 319b and tubular 314 can pass by traveling assembly 319a and tubular 315. The process of tripping tubulars out of well 303 can then continue according the process just described.

A summary of isochronous tripping-out method 300 is depicted in FIG. 3i. In particular, FIG. 3i broadly describes the steps shown in at least FIGs. 3a-g, including: (1) rotating towers 301a, 301b over the same well 303, while the traveling assemblies 319a, 319b are in the respective retracted positions (i.e., close to towers 301a, 301b, respectively); (2) lowering traveling assembly 319a to a position just above but transversely adjacent to the top of tubular 307 (i.e., break-out height) while traveling assembly 319b is positioned near the top of tower 301b still in its retracted position; (3) moving top drive 319a away from its retracted position against tower 301a and coupling top drive 308a to tubular 307 via, e.g., a hook; (4) hoisting tubular 307 and the tubing string to which it is coupled out of well 303 via traveling assembly 319a to the break-out height for tubular 307 while, at about the same time, lowering traveling assembly 319b to break out height for tubular 307 in anticipation of tubular 307 being removed.
from tubular 314; (5) removing tubular 307 from tubular 314 (e.g., via threading) and retracting top drive 308a and tubular 307 away from the center of well 303 toward tower 301a; (6) moving top drive 308b away from tower 301b via, e.g., retraction mechanism 309b and coupling top drive 308b to tubular 314 via, e.g., a hook; optionally, removing tubular 307 from traveling assembly 319a while tubular 307 is still at break out height and storing tubular 307, e.g., on or under rig floor 310; (7) hoisting tubular 314 and the tubing string to which it is coupled out of well 303 via traveling assembly 319b to the break-out height of tubular 314 while, at about the same time, lowering traveling assembly 319a (and tubular 307, if not already removed) to break out height for tubular 314 in anticipation of tubular 314 being removed from tubular 315; (8) if not already removed, removing tubular 307 from traveling assembly 319a and storing tubular 307, e.g., on or under rig floor 310, while also removing tubular 314 from tubular 315 (e.g., via threading); and (9) retracting top drive 308b and tubular 314 away from the center of well 303 toward tower 301b. Steps 3-9 can then be repeated for subsequent tubulars (modifying step 4 to remove any coupled tubular from traveling assembly 319b, if not previously removed) until tubular desired to be removed from well 303 have been removed from well 303.

[0059] More generally, a method for isochronously tripping tubulars out of a well is described with reference to FIG. 3j. Such a method may include: rotating first and second towers over the same well with both towers positioned off the center of the well; positioning the first tower over the center of the well, coupling the first tower to a first tubular disposed in the well, hoisting the first tubular out of the well by operation of the first tower, and decoupling the first tubular from the tubing string; and storing the first tubular (e.g. on or under a deck of a rig) while positioning the second tower over the center of the well, coupling the second tower to a second tubular disposed in the well (i.e., the next tubular in the tubing string), hoisting the second tubular out of
the well by operation of the second tower, and decoupling the second tubular from the tubing string. The second and third steps can then be repeated with subsequent tubulars (modifying the second step to further store any tubular coupled the second tower) until all tubular desired to be removed from the well are removed from the well.

[0060] FIGs. 4a-4h depict isochronous tripping-in method 400, which employs multiple rotating drilling towers 401a, 401b disposed on rig floor 410. Each tower 401a, 401b has a vertical traveling assembly 419a, 419b, respectively, comprising a top drive (or swivel) 408a, 408b, respectively, and a retracting mechanism 409a, 409b, respectively. As shown in FIG. 4a, traveling assembly 419b is initially centered over well 403 and coupled (e.g., hooked) to tubular 416, which is entirely outside well 403. Tubular 416 is connected to tubular 417 that is partially disposed within well 403 (i.e., at make-up height). Traveling assembly 419a is initially disposed vertically below but transversely adjacent to traveling assembly 419b and is in a retracted position (e.g., retracted toward tower 401a) such that it is not centered over well 403. Tubular 415 can be introduced by other tubular handling equipment (not shown) or coupled (e.g., hooked) to traveling assembly 419a, as shown. Tubular 415 and other tubulars can be retrieved from various locations including below rig floor 410 (e.g., in a moon pool), on rig floor 410, or horizontally on a pipe deck or in dedicated holds.

[0061] As shown in FIG. 4b, traveling assembly 419a lifts tubular 415 in direction 412 while traveling assembly 419b lowers tubulars 416, 417 in direction 413 into well 403. Travel assembly 419a remains in the retracted position (i.e., toward tower 401a) while moving in direction 412 such that traveling assembly 419a and tubular 415 pass by traveling assembly 419b and tubulars 416, 417.
[0062] As shown in FIG. 4c, traveling assembly 419a continues to lift tubular 415 until the bottom of tubular 415 is just vertically above but transversely adjacent to the top of tubular 416 (i.e., at make-up height). Traveling assembly 419b continues in direction 413 until tubular 417 is entirely within well 403 and the top of tubular 416 is just below but transversely adjacent to the bottom of tubular 415 (i.e., at make-up height). Top drive 408b then disconnects (e.g., unhooks) from tubular 416 (e.g., by rotation or other means). Retraction mechanism 409b then retracts top drive 408b transversely toward tower 401b, as shown in FIG. 4d. Tubular 414 can be introduced by other tubular handling equipment (not shown) or coupled (e.g., hooked) to traveling assembly 419b, as shown. Tubular 414 and other tubulars can be retrieved from various locations including below rig floor 410 (e.g., in a moon pool), on rig floor 410, or horizontally on a pipe deck or in dedicated holds. At the time top drive 408b moves off the well center (or shortly after), retraction mechanism 409a moves top drive 408a and tubular 415 transversely away from tower 401a until centered over tubular 416. Top drive 408a then connects tubular 415 to tubular 416 (e.g., by rotation or other means).

[0063] As shown in FIG. 4e, traveling assembly 419b then lifts tubular 414 in direction 412 while traveling assembly 419a lowers tubulars 415, 416 in direction 413 into well 403. Traveling assembly 419b remains in the retracted position (i.e., toward tower 401b) while moving in direction 412 such that traveling assembly 419b and tubular 414 pass by traveling assembly 419a and tubulars 415, 416 moving in direction 413.

[0064] As shown in FIG. 4f, traveling assembly 419b continues to lift tubular 414 until the bottom of tubular 414 is just vertically above but transversely adjacent to the top of tubular 415 (i.e., at make-up height). Traveling assembly 419a continues in direction 413 until tubular 416 is entirely within well 403 and the top of the tubular 415 is just below but transversely adjacent to
the bottom of tubular 414 (i.e., at make-up height). Top drive 408a then disconnects (e.g., unhooks) from tubular 415 (e.g., by rotation or other means). Retraction mechanism 409a then retracts top drive 408a transversely toward tower 401a, as shown in FIG. 4g. Tubular 407 can be introduced by other tubular handling equipment (not shown) or coupled (e.g., hooked) to traveling assembly 419a, as shown. Tubular 407 and other tubulars can be retrieved from various locations including below rig floor 410 (e.g., in a moon pool), on rig floor 410, or horizontally on a pipe deck or in dedicated holds. At the time top drive 408a moves off the well center (or shortly after), retraction mechanism 409b moves top drive 408b and tubular 414 transversely away from tower 401b until centered over tubular 415. Top drive 408b then connects tubular 414 to tubular 415 (e.g., by rotation or other means).

[0065] As shown in FIG. 4h, traveling assembly 419a then lifts tubular 407 in direction 413 while traveling assembly 419a lowers tubulars 414, 415 in direction 413 into well 403. Traveling assembly 419a remains in the retracted position (i.e., toward tower 401a) while moving in direction 412 such that traveling assembly 419a and tubular 407 pass by traveling assembly 419b and tubular 414, 415 moving in direction 413. The process of tripping tubulars into well 403 can then continue according the process just described.

[0066] A summary of isochronous tripping-in method 400 is shown in FIG. 4i. In particular, FIG. 4i broadly describes the steps shown in at least FIGs. 4a-g, including: (1) rotating towers 401a and 401b over well 403, while traveling assemblies 419a and 419b are in their respective retracted positions (i.e., close to towers 401a, 401b, respectively) near the top of towers 401a, 401b, and top drive 408b is coupled to tubular 416 via, e.g., a hook, at make-up height for tubular 416 (i.e., where tubular 416 can be connected to tubular 417); (2) unless otherwise received by traveling assembly 419a, lowering traveling assembly 419a to receive tubular 415
from a stored position (e.g., on or under rig floor 410) and coupling tubular 415 to top drive 408a while moving top drive 408b and tubular 416 away from tower 401b via, e.g., retraction mechanism 409b, and over the center of well 403; (3) coupling tubular 416 to tubular 417 via, e.g., threading, and lowering tubular 416 (and tubular 417) into well 403 while hoisting tubular 415 to make-up height for tubular 415; (4) decoupling top drive 408b from tubular 416 when tubular 416 is at make-up height for tubular 415 and moving top drive 408b toward tower 401b via, e.g., retraction mechanism 409b; (5) moving top drive 408a and tubular 415 away from tower 401a via, e.g., retraction mechanism 409a, and over well 403, and coupling tubular 415 to tubular 416 via, e.g., threading; (6) unless otherwise received by traveling assembly 419b, receiving by traveling assembly 419b tubular 414 from a stored position (e.g., on or under rig floor 410) and coupling tubular 414 to top drive 408b via, e.g., a hook, and hoisting tubular 414 to make-up height for tubular 414 while lowering tubular 415 (and tubular 416) into well 403; (7) decoupling top drive 408a from tubular 415 via, e.g., threading, when at make-up height for tubular 414, and moving top drive 408a toward tower 401a via, e.g., retraction mechanism 409a; and (8) unless otherwise received by traveling assembly 419a, receiving by traveling assembly 419a tubular 407 from a stored position (e.g., on or under rig floor 410) and coupling tubular 407 to top drive 408a via, e.g., a hook, while moving top drive 408b and tubular 414 away from tower 401b via, e.g., retraction mechanism 409b, and over the center of well 403. Steps 3-8 can be repeated for subsequent tubulars until all tubulars desired to be tripped into well 403 have been tripped into well 403.

More generally, a method for isochronously tripping tubulars into a well is described with reference to FIG. 4j. Such a method may include: rotating first and second towers over the same well and receiving a first tubular by the first tower while the second tower is positioned off
the center of the well; positioning the first tubular over the center of the well by operation of the first tower and lowering the first tubular into the well by operation of the first tower, while receiving a second tubular by the second tower; and receiving a third tubular by the first tower while positioning the second tubular over the well center by operation of the second tower, coupling the second tubular to the first tubular via, e.g., threading, and lowering the second tubular into the well by operation of the second tower. The second and third steps can then be repeated with subsequent tubulars (modifying the second step to further couple any tubular received by the first tower to the previous tubular before lowering it into the well) until all tubulars desired to be run into the well are run into the well.

[0068] The above specification and examples provide a complete description of the structure and use of illustrative embodiments. Although certain embodiments have been described above with a certain degree of particularity, or with reference to one or more individual embodiments, those skilled in the art could make numerous alterations to the disclosed embodiments without departing from the scope of this invention. As such, the various illustrative embodiments of the methods and systems are not intended to be limited to the particular forms disclosed. Rather, they include all modifications and alternatives falling within the scope of the claims, and embodiments other than the one shown may include some or all of the features of the depicted embodiment. For example, elements may be omitted or combined as a unitary structure, and/or connections may be substituted. Further, where appropriate, aspects of any of the examples described above may be combined with aspects of any of the other examples described to form further examples having comparable or different properties and/or functions, and addressing the same or different problems. Similarly, it will be understood that the benefits and advantages described above may relate to one embodiment or may relate to several embodiments.
[0069] The schematic flow chart diagrams presented herein are generally set forth as a logical flow chart diagram. The depicted order, labeled steps, and described operations are indicative of aspects of methods of the invention. Other steps and methods may be conceived that are equivalent in function, logic, or effect to one or more steps, or portions thereof, of the illustrated method. Additionally, the format and symbols employed are provided to explain the logical steps of the method and are understood not to limit the scope of the method. Although various arrow types and line types may be employed in the flow chart diagram, they are understood not to limit the scope of the corresponding method. Indeed, some arrows or other connectors may be used to indicate only the logical flow of the method. For instance, an arrow may indicate a waiting or monitoring period of unspecified duration between enumerated steps of the depicted method. Additionally, the order in which a particular method occurs may or may not strictly adhere to the order of the corresponding steps shown.

[0070] The claims are not intended to include, and should not be interpreted to include, means-plus- or step-plus-function limitations, unless such a limitation is explicitly recited in a given claim using the phrase(s) “means for” or “step for,” respectively.
CLAIMS

What is claimed is:

1. A drilling apparatus comprising:
   two or more drilling towers configured to access a common well center,
   wherein at least one of the two or more drilling towers is configured to rotate between the
   common well center and at least one other well center.

2. The apparatus of claim 1, wherein at least one of the two or more drilling towers are
   configured to rotate between a plurality of well centers.

3. The apparatus of claim 2, wherein the two or more drilling towers are located on a rig,
   and wherein at least one of the plurality of well centers is located transversely off the rig.

4. The apparatus of claim 2, wherein the at least one of the plurality of well centers is not
   located along the longitudinal axis of the rig and/or not located along the circular path of
   at least one of the two or more towers.

5. The apparatus of claim 1, wherein at least one of the two or more towers includes an
   adjustable crown sheave configured to reposition a load path.

6. The apparatus of claim 1, wherein the two or more drilling towers are configured to be
   simultaneously rotated over the common well center.

7. The apparatus of claim 6, further comprising a retractable traveling assembly configured
   to move vertically along at least one of the two or more drilling towers.

8. The apparatus of claim 7, wherein the traveling assembly further comprises at least one
   of a top drive, a swivel, and a hook.
9. The apparatus of claim 6, wherein the two or more towers comprise drill lines configured as offset from one another to prevent interference between a drill line of a first tower and a drill line of a second tower when the first tower and the second tower are positioned over the common well center.

10. The apparatus of claim 6, wherein the two or more towers comprise drill lines configured to terminate at different vertical or horizontal locations to prevent interference between a drill line of a first tower and a drill line of a second tower when the first tower and the second tower are positioned over the common well center.

11. The apparatus of claim 1, further comprising a motion compensating device disposed on at least one of the two or more drilling towers and configured to compensate for relative motion versus the seabed on the at least one of the two of more drilling towers.

12. The apparatus of claim 1, wherein the two or more towers have different fixed heights.

13. The apparatus of claim 1, wherein at least one of the two or more towers is configured with variable heights, wherein the at least one of the two or more towers comprises a telescoping device configured to provide a variable height.

14. The apparatus of claim 1, further comprising a brace between the two or more towers, wherein the brace is configured to maintain clearance between the two or more towers.

15. The apparatus of claim 14, wherein the brace comprises brace supports, and wherein the brace is configured to permit the two or more towers to rotate through the brace supports.

16. The apparatus of claim 1, wherein the two or more towers are configured to trip tubulars into or out of a well.

17. The apparatus of claim 16, wherein the two or more towers are configured to move tubulars along different spatial paths during tripping.
18. The apparatus of claim 1, wherein the two or more towers are configured to lift together a single load disposed over the common well center.

19. The apparatus of claim 1, wherein each of the two or more towers is configured to simultaneously perform different functions.

20. A method for performing an operation, the method comprising:
   rotating a first tower over a well;
   performing a first operation over the well by the first tower;
   rotating a second tower over the well; and
   performing a second operation over the well by the second tower.

21. The method of claim 20, wherein the first and second operation are performed at the same time.

22. The method of claim 21, wherein the first operation and the second operation are operations for tripping tubulars into a well.

23. The method of claim 21, wherein the first operation and the second operation are operations of an isochronous tripping operation.

24. The method of claim 21, wherein the first operation and the second operation are operations in a heavy lift operation to lift a load, wherein the load is larger than a capacity of either the first tower or the second tower alone.
ROTATE TOWERS 201a, 201b, OVER THE SAME WELL 203, WHILE THE TRAVELING ASSEMBLIES OF TOWERS 201a, 201b ARE IN THEIR RESPECTIVE RETRACTED POSITIONS

CONFIGURE THE TRAVELING ASSEMBLIES OF TOWERS 201a, 201b TO WORK IN CONCERT BY EITHER (i) REMOVING TOWER 201a's TOP DRIVE AND COUPLING RETRACTION ASSEMBLY 209a TO TOWER 201b's TOP DRIVE; OR (ii) COUPLING TOWER 201a's TOP DRIVE TO TOWER 201b's TOP DRIVE (E.G., BY VERTICALLY STACKING THEM)

COUPLE TUBULAR 207 TO TOP DRIVE 208 (E.G., VIA A HOOK) WHEN TUBULAR 207

OPERATE BLOCK AND TACKLE ASSEMBLIES 202, 211, 219 OF BOTH TOWERS 201a AND 201b TO HOIST TUBULAR STRING 207, 214 OUT OF WELL 203

FIG. 2c
ROTATE FIRST AND SECOND TOWERS OVER THE SAME WELL

CONFIGURE FIRST AND SECOND TOWERS TO COOPERATIVELY HOIST AN OBJECT

COUPLE THE OBJECT TO THE FIRST AND SECOND TOWERS

HOIST THE OBJECT USING THE COMBINED POWER OF THE FIRST AND SECOND TOWERS

FIG. 2d
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ROTATE TOWERS 301a, 301b OVER THE SAME WELL 303, WHILE THE TRAVELING ASSEMBLIES 319a, 319b ARE IN THEIR RESPECTIVE RETRACTED POSITIONS

LOWER TRAVELING ASSEMBLY 319a TO BREAK-OUT HEIGHT WHILE TRAVELING ASSEMBLY 319b IS NEAR THE TOP OF THE TOWER 301b

MOVE TOP DRIVE 308a AWAY FROM TOWER 301a AND COUPLE IT TO TUBULAR 307 (E.G., VIA A HOOK)

HOIST TUBULAR 307 (AND THE TUBING STRING) OUT OF WELL 303 VIA TRAVELING ASSEMBLY 319a TO BREAK-OUT HEIGHT FOR TUBULAR 307 WHILE LOWERING TRAVELING ASSEMBLY 319b TO BREAK-OUT HEIGHT FOR TUBULAR 307

REMOVE TUBULAR 307 FROM TUBULAR 314 AND RETRACT TOP DRIVE 308a AND TUBULAR 307 TOWARD TOWER 301a

MOVE TOP DRIVE 308b AWAY FROM TOWER 301b AND COUPLE IT TO TUBULAR 314 (E.G., VIA A HOOK)

[OPTIONAL] REMOVE TUBULAR 307 FROM TRAVELING ASSEMBLY 319a AND STORE TUBULAR 307

HOIST TUBULAR 314 (AND THE TUBING STRING) OUT OF WELL 303 VIA TRAVELING ASSEMBLY 319b TO BREAK-OUT HEIGHT FOR TUBULAR 315 WHILE LOWERING TRAVELING ASSEMBLY 319a (AND TUBULAR 307, IF NOT ALREADY REMOVED) TO BREAK-OUT HEIGHT FOR TUBULAR 314

IF NOT ALREADY REMOVED, REMOVE TUBULAR 307 FROM TRAVELING ASSEMBLY 319a AND STORE TUBULAR 307 WHILE ALSO REMOVING TUBULAR 314 FROM THE TUBULAR 315

RETRACT TOP DRIVE 308b AND TUBULAR 314 TOWARD TOWER 301b

REPEAT STEPS 3-9 FOR SUBSEQUENT TUBULARS, MODIFYING STEP 4 TO REMOVE AND STORE ANY TUBULAR COUPLED TO TRAVELING ASSEMBLY 319b, IF NOT PREVIOUSLY REMOVED, UNTIL ALL TUBULARS DESIRED TO BE REMOVED FROM WELL 303 HAVE BEEN REMOVED FROM WELL 303

FIG. 3i
ROTATE FIRST AND SECOND TOWERS OVER THE SAME WELL WITH BOTH TOWERS POSITIONED OFF THE CENTER OF THE WELL


REPEAT STEPS 2 AND 3 WITH SUBSEQUENT TUBULARS, MODIFYING STEP 2 TO STORE ANY TUBULAR COUPLED TO THE SECOND TOWER, UNTIL ALL TUBULARS DESIRED TO BE REMOVED ARE REMOVED FROM THE WELL

FIG. 3j
ROTATE TOWERS 401a, 401b, OVER THE SAME WELL 403, WHILE THE TRAVELING ASSEMBLIES 419a, 419b ARE IN THEIR RESPECTIVE RETRACTED POSITIONS AND TOP DRIVE 408b IS COUPLED TO TUBULAR 416 (E.G., VIA A HOOK) AT MAKE-UP HEIGHT FOR TUBULAR 416

UNLESS OTHERWISE RECEIVED BY TRAVELING ASSEMBLY 419a, LOWER TRAVELING ASSEMBLY 419a AND COUPLE TUBULAR 415 TO TOP DRIVE 408a WHILE MOVING TOP DRIVE 408b AND TUBULAR 416 AWAY FROM TOWER 401b ABOVE WELL 403

COUPLE TUBULAR 416 TO TUBULAR 417 AND LOWER TUBULAR 416 INTO WELL 403 WHILE HOISTING TUBULAR 415 TO MAKE-UP HEIGHT FOR TUBULAR 415

DECOUPLE TOP DRIVE 408b FROM TUBULAR 416 WHEN AT MAKE-UP HEIGHT FOR TUBULAR 415 AND MOVE TOP DRIVE 408b TOWARD TOWER 401b

MOVE TOP DRIVE 408a AND TUBULAR 415 AWAY FROM TOWER 401a OVER WELL 403 AND COUPLE TUBULAR 415 TO TUBULAR 416

UNLESS OTHERWISE RECEIVED BY TRAVELING ASSEMBLY 419b, COUPLE TUBULAR 414 TO TOP DRIVE 408b AND HOIST TUBULAR 414 TO MAKE-UP HEIGHT FOR TUBULAR 414 WHILE LOWERING TUBULAR 415 INTO WELL 403

DECOUPLE TOP DRIVE 408a FROM TUBULAR 415 WHEN AT MAKE-UP HEIGHT FOR TUBULAR 414 AND MOVING TOP DRIVE 408a TOWARD TOWER 401a

UNLESS OTHERWISE RECEIVED BY TRAVELING ASSEMBLY 419a, COUPLE TUBULAR 407 TO TOP DRIVE 408a AND MOVE TOP DRIVE 408b AND TUBULAR 414 AWAY FROM TOWER 401b OVER WELL 403

REPEAT STEPS 3-8 FOR SUBSEQUENT TUBULARS UNTIL ALL TUBULARS DESIRED TO BE TRIPPED INTO WELL 403 HAVE BEEN TRIPPED INTO WELL 403

FIG. 4i
ROTATE FIRST AND SECOND TOWERS OVER THE SAME WELL AND RECEIVE A FIRST TUBULAR BY THE FIRST TOWER WHILE THE SECOND TOWER IS POSITIONED OFF THE CENTER OF THE WELL


RECEIVE A THIRD TUBULAR BY THE FIRST TOWER WHILE POSITIONING THE SECOND TUBULAR OVER THE WELL CENTER BY THE SECOND TOWER, COUPLING THE SECOND TUBULAR TO THE FIRST TUBULAR, AND LOWERING THE SECOND TUBULAR INTO THE WELL BY THE SECOND TOWER

REPEAT STEPS 2 AND 3 WITH SUBSEQUENT TUBULARS, MODIFYING STEP 2 TO FURTHER COUPLE ANY TUBULAR RECEIVED BY THE FIRST TOWER TO THE PREVIOUS TUBULAR BEFORE LOWERING IT INTO THE WELL, UNTIL ALL TUBULAR DESIRED TO BE RUN INTO THE WELL ARE RUN INTO THE WELL

FIG. 4j
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

   IPC - E21B 19/06, 19/02, 15/00 (2017.01)
   CPC - E21B 19/02, 19/06, 15/003

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)

See Search History document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

See Search History document

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

See Search History document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category*</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>US 6,587,483 B1 (THORSTEN D ET AL.) February 22, 2005; Column 3, Line 5; Claim 7; Column 5, Line 23; Claim 7; Claim 9; Figure 9; Column 10, Line 25, 29, 53; Figure 10</td>
<td>1-2; 6-10; 16-17; 19-20; 3-5; 11-14; 18; 21-24</td>
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<td>WO 2004/035985 A1 (ITREC B.V.) April 29, 2004; Figure 14; Page 14, 1st full paragraph.</td>
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</tbody>
</table>

☐ Further documents are listed in the continuation of Box C.  ☐ See patent family annex.

| * Special categories of cited documents: |
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Date of the actual completion of the international search

18 July 2017 (18.07.2017)

Date of mailing of the international search report

04 AUG 2017

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