AUTOMATED SYSTEM AND DRILLING RIG FOR CONTINUOUSLY AND AUTOMATICALLY PULLING AND RUNNING A DRILL-PIPE STRING

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AUTOMATED SYSTEM AND DRILLING RIG FOR CONTINUOUSLY AND AUTOMATICALLY PULLING AND RUNNING A DRILL-PIPE STRING

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The present invention relates to an automated system and a drilling rig for continuously performing round trips in oil or gas wells while drilling or producing. Running and pulling the drill-pipe string, casing, tubing or sucker rod strings in oil and gas wells in the conventional way is known to be time consuming. Trip operations require much time particularly in deep drilling, where round trips for changing the bit are more frequent. The total drilling time in the case of deep wells is thereby considerably increased, resulting in a higher cost. In these conditions crew fatigue may become excessive and accidents are likely to occur.

To reduce the trip time and labor, conventional drilling rigs are known to be equipped with fully mechanical devices which perform all the steps involved in the trip operations. In addition there are rigs provided with automatic means for automatically performing some of the steps involved in running or pulling the drill-string. These rigs are operated discontinuously and they are generally designed to handle stands of pipes, which are added or removed while the drill string is supported by slips or an elevator. These known rigs are provided with a single hoisting device for the drill string and the derrick is relatively high. Separate mechanisms are used for the delivery, transfer and positioning of the pipe stands in the central area of the derrick, and the displacement of the pipe stand from the storage rack to the derrick center includes several kinds of correlated movements: vertical and horizontal translating motions and swinging or rotating motions. In these known rigs, the cycle for running or pulling a pipe stand requires that a complete operating cycle be effectuated by the rig.

The main disadvantages of these fully mechanical or partially automated rigs consist in the following: their elaborate design; the requirement of a high derrick; and their discontinuous operation, which does not permit the trip time to be reduced by more than 30% as compared with the conventional rigs using no mechanical or automatic means.

Fully automated rigs are also known, which allow all the steps of the trip operation to be automatically performed. The operation of these rigs is continuous and they are pipe singles for assembling the drill-string instead of pipe stands. The pipes are being added or removed while the drill-string is in continuous motion, at constant speed, which makes possible for the trip operations to be performed at a faster rate, 8—10 times that of the conventional rigs. The tripping operations can be performed at a constant speed owing to the use of two lifts whose movements are synchronized, which support successively the weight of the drill-pipe string, and the single pipe to be added or removed is handled on the upper lift.

The automated rigs now in use, differ essentially in the design of the means used for transferring the pipes from the pipe storage rack for positioning the pipe for stabbing. With these rigs, a complete trip-in or trip-out cycle to run or pull the pipe requires three operating cycles of the rig. Thus, the predetermined sequence of operative steps requires the simultaneous handling of three individual pipes in the rig area: one pipe is being transferred from or to the storage rack, the second pipe is being made up or broken out (joined or dismantled), and the third pipe which was made up or broken out before, is being run in or pulled out, as part of the string which is being tripped in or out in a continuous motion, at constant speed, throughout the operation.

The disadvantage of these automated rigs lies in that they require the delivery of the pipes to take place above the upper lift, using for this purpose separate means to raise the pipe received from the storage rack to the upper half of the derrick, and separate means to bring it in the stabbing position, and separate means to transfer, while in motion, the delivered pipe to the upper lift.

Due to the required special configuration of the pipe delivery means, these rigs have the disadvantage of using derricks of a height exceeding the length of two pipes, as two end-to-end pipes must be permanently available in the derrick: one pipe is being made up in the drill string and the other one is being transferred to the upper lift, in addition a third pipe already made up in the drill-string, is going into the hole.

These automated rigs have further the disadvantage that owing to the fact that the pipes are being delivered in this way, both lifts must be fitted with slips for supporting the drill-string which causes the slip wedges to impress twice their marks upon the pipes each time they are tripped in or out.

A further disadvantage of these known automated rigs lies in that the pipe transfer from the storage rack to the central area of the derrick or back to the storage, which occurs above the upper lift, must involve a number of synchronized translating vertical and horizontal movements, as well as rotating movements.

It is a general object of the present invention to provide a drilling rig in which the aforesaid disadvantages are substantially eliminated.

The system according to the present invention eliminates the above mentioned disadvantages in that, for achieving trip-time reductions similar to those by the automated rigs now in use, the drill-string is automatically run and pulled in a continuous motion by means of two lifts. On the trip-in operation the pipes are delivered successively in horizontal position, to the lower part of the upper lift approximately mid-way up the derrick, where the upper lift moving upwards grips one end of the pipe while the other end is horizontally displaced, whereby the pipe is rotated and positioned in the central area of the derrick and is then being made up in the drill-string in motion at the level of the lower lift which is moving downwards while supporting the drill-string. When the drill-string is tripped out, the steps involved in the operation mentioned above are reversed.

The drilling rig according to this invention uses on the trip-in operation a tray conveyor for picking up the pipe horizontally from the storage rack, which is located near the derrick, thereafter said pipe is transferred to guiding track means mounted midway up the derrick. An upper lift, which transfers the pipe from said guiding track means to the central area of the derrick, carries out the transfer by means of a trolley device which is provided with a hydraulically pivotable arm. This trolley device moves along the guiding track means and the upper lift carries a lower swivel means equipped with an elevator, said power swivel means and elevator rotating 90°, so that the ends of the pipe raised from the storage rack are supported throughout its rotation until positioned in the central area of the derrick by said elevator in conjunction with said trolley device, which after centering the pipe in the derrick changes its function by releasing its clamp jaws, the pipe now being positioned for stabbing. The make-up
operation is performed while the drill-string is in motion, by means of a make-and-break device mounted upon the lower lift, which is running into the drill-string in a continuous motion at constant speed while the drill-string is being supported by a supporting device.

To remove the pipe in the trip-out operation, the same devices are used to transfer the pipe to the storage rack, but the sequence of steps of the operation is reversed. In addition thereto the rig uses a lateral transfer unit for laterally transferring the pipe from the guiding track means mounted mid-way up the derrick, to the tray conveyor which deposits the pipe in the storage rack.

In the accompanying drawings there is shown for purposes of illustration one example of a rig according to this invention in which:

FIG. 1 is a front elevation view of the rig;
FIG. 2 is a side elevation view of the rig; and
FIG. 3 illustrates diagrammatically the operating cycle of the rig.

FIGURES 1 and 2 illustrate the rig action while the rig is performing the steps of the operation indicated in the operating cycle diagram of FIG. 3.

According to the invention, the rig uses a U-shaped derrick 1, the height of which is equal to about two lengths of drill pipe. In order to achieve the guided raising and lowering of the drill-string and of the pipe which is being loaded, an upper hydraulic lift 2 is used in the upper half of derrick 1. The upper lift 2 is actuated by hydraulic telescoping cylinders 3 of known design; a hydraulically or otherwise actuated power swivel 4 is mounted on the upper lift 2. This arrangement enables the power swivel 4 to travel vertically in the upper half of the derrick 1. The power swivel 4 can be made to swing 90° to a horizontal position by means of a well-known mechanism consisting of a hydraulic cylinder slidably connected at one end to the upper lift 2, and at the other end to the power swivel 4. The maximum hydraulic cylinder stroke causes the power swivel 4 to be in a vertical position, and the shortest hydraulic cylinder stroke causes the power swivel 4 to rotate 90° to the horizontal position. The power swivel 4 carries a hydraulically or otherwise actuated elevator member 5, which is axially mounted on the power swivel 4 in order to ensure rotation of its two halves. The elevator member 5 is suspended on both sides thereof so as to centrally support the drill-string weight. The elevator member 5 can be made to swing 90° together with the power swivel 4 so that it can be latched or unlatched around one end of the horizontal pipe positioned mid-way up the derrick 1. In order to remove the drill-string while drilling, a hydraulically or otherwise actuated make-up unit 6 is used, which can be mounted on the power swivel 4 in place of the elevator member 5, and the pipe is then made up directly by means of power swivel 4. The make-up unit 6 is a well known powered jaw tool, the jaws of which are hydraulically actuated for engaging the pipe. Rotation of the make-up unit 6 for making up an additional pipe is performed by the power swivel 4 upon which the unit 6 rests instead of the elevator member 5.

A lower lift 7, actuated by the lower hydraulically actuated cylinder 8 of known design, guides the lowering and elevating of the drill-string in the lower half of derrick 1. There is mounted a make-and-break unit 9 on the lower lift 7. The unit 9 is hydraulically or otherwise actuated and is of known design. It is positioned at all times axially in derrick 1 and serves to "make up" or "break out" the pipe to be added or removed, while lifts 2 and 7 travel up and down in synchronized movements. There is secured on the lower lift 7 a supporting device 10 using slips or other means, of known design. The device 10 is disposed under the make and break unit 9 and serves to support the drill-string while said drill-string is lowered or raised in the lower half of derrick 1 by means of the lower lift 7.

The drill pipes which are to be delivered into the der-

rick 1, are horizontally stored at the ground level on the storage rack 11, wherefrom each pipe can be delivered or received by means of tilting loading forks 12 which are arranged so that the pipe can roll by gravity either from or towards the tray conveyor 13. The latter is provided with double strands of chain 14 and trays 15, or other types of known design, for raising the pipe from the storage rack 11 mid-way up the derrick 1, or for removing the pipe from mid-way up the derrick and lowering it to the storage rack 11.

The pipe raised in horizontal position by the tray conveyor 13 mid-way up the derrick 1, is rotated 90° in order to be positioned in the central area of derrick 1, one end of said pipe being latched in the elevator member 5 and raised in the upper half of derrick 1, while the other end of the pipe is displaced horizontally by a trolley device 16, which is arranged to move horizontally at a level about mid-way up the derrick 1. The horizontal displacement of trolley 16 is effected by a transfer unit 17 which uses cable, chains, or a similar known mechanism for guiding the pipe from the storage rack 11 to the center of the derrick 1. Partial release of the chains 21 of the trolley arm 20 permits the pipe to be positioned for stabbing, while the pipe is supported, by its other end by the upper lift 2. In the trip-out operation a lateral transfer unit 22 is used to transfer the pulled pipe, which has been placed on the guiding track 19, to the tray conveyor 13, which lowers the pipe to the storage rack 11.

A safety device 23, comprising slips or other means of known design, is mounted on the lower level of derrick 1. The safety device 23 is used in the case of a malfunction of the rig should occur.

The rig operation cycle for tripping in the drill-string, in the rig illustrated in FIGS. 1 and 2, is carried out according to the cycle diagram illustrated in FIG. 3, where the main steps of a complete operating cycle of the rig in the order from a . . . i are illustrated; in the trip-out operation the sequence of steps of the operation is reversed, becoming j . . . a.

The main steps illustrated in FIG. 3 relate to the three pipes which are being simultaneously handled in the derrick: pipe A1 which is being transferred from the storage rack 11 to the guiding track 19; pipe A2 which is being transferred from the guiding track 19 to the central area of derrick 1 to be made up in the make-up unit 6; pipe A3 which is already made up in the drill-string which moves into the hole in a continuous motion. The main components described and denoted according to FIG. 1 and 2 perform the following steps forming the operation cycle of the rig:

Step (a).—The upper lift 2 with the power swivel 4 and the elevator member 5 continue their descending motion, supporting the drill-string, whereby pipe A3 is run in; the lower lift 7 with the make-and-break device 9 and the supporting device 10 descend, their movements being synchronized to correspond to the upper lift 2, and the weight of the drill-string is transferred, while in motion, to the supporting device 10; the trolley device 16 with its arm 20 remain for the time being stationary; the tray conveyor 15 moves the pipe A1 to the guiding track 19 located mid-way up the derrick 1.

Step (b).—The upper lift 2 with the power swivel 4 and the elevator member 5 descend, their movements being synchronized to correspond to that of the lower lift 7, at the same time the elevator member 5 is being unlatched; the lower lift 7 descends together with the make-and-break unit 9 and the supporting device 10 which supports and lowers the drill-string together with pipe A3; the trolley arm 20 grips pipe A2 which has been raised mid-way up the derrick 1; the tray conveyor 13 starts lifting the next pipe A1 picked up from the storage rack 11.
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5 Step (c).—The upper lift 2 with power swivel 4 and elevator member 5 are stationary and the power swivel 4 together with elevator member 5 rotate 90° and thereafter latch elevator member 5 around pipe A2 which has been delivered to the guiding track 19; the lower lift 7 descends further together with the make-and-break device 9 and the supporting device 10 which still supports the drill-string, lowering said drill-string together with pipe A2; the transfer unit 17 is stationary together with the track 20 whose arm 20 grasps pipe A2 which has been raised mid-way up the derrick 1; the tray conveyor 13 goes on lifting the next pipe A2.

Step (d).—The upper lift 2 with power swivel 4 and elevator member 5 rise rapidly, the elevator member 5 gripping one end of pipe A2 which is being elevated in the upper half of the derrick 1; the lower lift 7 continues descending together with the make-and-break device 9 and the supporting device 10 which still supports the drill-string, lowering it together with pipe A2; the transfer unit 17 displaces the trolley 16, the arm 20 of which is gripping one end of pipe A2; the tray conveyor 13 continues raising the next pipe A2.

Step (e).—The upper lift 2 continues to rise rapidly with power swivel 4 and elevator member 5 which supports one end of pipe A2; on arriving at the top of its stroke, the upper lift 2 reverses motion and begins to descend. At the movement of said upper lift 2 being synchronized to correspond to that of the lower lift 7, which continues its descent, together with the supporting device 10 which still supports the drill-string thereby lowering said drill string together with pipe A2, the transfer unit 17 stops the trolley 16, and the trolley arm 20 which has been rotating 90°, before releasing its clamp jaws 21 positions pipe A2 in the central area of derrick 1 while said pipe A2 is being lowered to be stabbed in pipe A2; the tray conveyor 13 is raising now the next pipe A2.

Step (f).—The upper lift 2 with power swivel 4 and elevator member 5 descend simultaneously with the lower lift 7, to run pipe A2 of the drill-string being supported by the supporting device 10; meanwhile the make-and-break device 9 after wiping and greasing the tool-joint thread makes up pipe A2 (as indicated by the curved arrows) the clamp jaws 21 of the trolley arm 20 are now completely raised and the trolley 16 with its arm 20 is moved back to its original position; the tray conveyor 13 is raising the next pipe A2.

Step (g).—The upper lift 2 with power swivel 4 and elevator member 5 descend simultaneously with the lower lift 7, but the weight of the drill string is transferred to elevator member 5 by disengaging the supporting device 10; the lower lift 7 continues to descend simultaneously with the upper lift 2 while the supporting device 10 releases the drill-string; the trolley 16 with its arm 20 are moved to their original position by means of the transfer unit 17; the tray conveyor 13 continues raising the next pipe A2.

Step (h).—The upper lift 2 with power swivel 4 and elevator member 5 continue to descend supporting now the drill-string; the lower lift 7 together with the make up and break out unit 9 and the supporting device 10 reverse their motion and rise rapidly the trolley 16 with its arm 20 remain stationary in their original position; the tray conveyor 13 continues raising the next pipe A2.

Step (i).—The upper lift 2 with power swivel 4 and elevator member 5 descend and support the drill-string; the lower lift 7 with the make-and-break device 9 and the supporting device 10 reverse their motion and descend rapidly to move jointly with the upper lift 2. The trolley 16 with its arm 20 and the transfer unit 17 are stationary; the tray conveyor 13 raises pipe A2 and deposits it on the guiding track 19.

On the trip-out operation the steps sequence described above is reversed, being performed in the order i . . . a. At the same time, Step a involves a lateral transfer unit 22, serving to remove pipe A2 from the guiding track 19 to the tray conveyor 13. The lateral transfer unit remains stationary throughout the trip in operation. The storage rack 11 which was delivering pipes to the derrick for the tripping-in operation, changes now to receive the pulled pipes, by setting the lifting loading forks 12 so that the pipe A2 which is being removed, can roll by gravity through the storage rack 11.

For drilling, the drill-string is made up in the power swivel 4 which moves together with the upper lift 2 in the upper half of the derrick, while the lower lift 7 is stationary. In the case of bottom power drilling the power swivel is used as a conventional swivel.

Adding of a new pipe while drilling, is accomplished by means of the power swivel 4 eliminating thus the need for the "kelly," which is generally required for the conventional rotary tables. The power swivel 4 serves to make up directly the pipes to be added in its tool-joint, thus no separate make up device is necessary. However, the elevator member 5 must be replaced by the make up device 6 before adding a new pipe. The bit is made up either separately on the storage rack 11 or in the derrick 1, at the level of the lower lift 7.

Casing running operations are similar to those performed to run in the drill string.

In order to perform "fishing" jobs, the automated operation of the rig is switched off and the upper lift 2 can be independently controlled, so that the "fishing" job can be conducted in the conventional way.

To perform the steps sequence of the rig operation according to the cycle diagram of Fig. 3, the operation of each device of the rig is automatically programmed. In special cases, for example: the malfunction of the automated devices of the rig or when "fishing" jobs or remedial works are necessary, the component devices of the rig can be controlled independently. As the component parts of the automatic drilling rig are hydraulically actuated, their being placed in operation or being stopped requires handling, in a well-known manner, of inlet and outlet valves controlling the pressure fluid that actuates them. The inlet and outlet valves are controlled either hydraulically or electrically, according to the automatic programmer type in use. Switching on and off of each component part necessary for the drilling rig automatic control, occurs according to the operation cyclegram of the automatic drilling rig. All the inlet and outlet valves are thus opened or closed from the automatic programmer. In the case of electrically actuated valves, the automatic programmer will be a well-known multiswitch mechanism, and in case of hydraulically actuated valves the automatic programmer will also be a well-known multidistributor mechanism. For individually handling the drilling rig devices, each inlet and outlet valve can be controlled independently, as required without using the automatic programmer.

The advantages of the method and rig, according to the present invention, are as follows:

The rig described in the present invention allows the trip time to be reduced by an amount similar to that achieved by the known automated rigs, however it is simpler than the latter because it has no separate transfer devices to displace the pipe in the upper half of the derrick, no separate devices to center the pipe in the derrick, no separate devices for transferring the delivered pipe, while in motion, to the upper lift; The rig uses a derrick of reduced height; In tripping in or out the drill string, the slip wedges of the supporting device impress their marks at most only once on each pipe; The number of movements involved in delivering the pipe from the storage rack to the center area of the derrick is reduced; Rig operation is shockless and vibrationless, each pipe being supported at both ends throughout its delivery.

Many modifications and adaptations will become readily apparent to persons skilled in the art and for that reason it is intended that this invention be limited only by the
What is claimed is:

1. System for continuously and automatically performing round trip operations on oil and gas wells while drilling or in production, said system involving for the transfer of each pipe to be added to the drill-string successively, raising of the pipe in a horizontal position from the storage rack to a mid-way station up the derrick, 90° swinging of the pipe to vertical position in the central area of the derrick, whereby one end of the said pipe is directly gripped by the upper lift during its upward movement so as to raise said pipe end to the upper section of the derrick, while the other end of said pipe is being horizontally translated, whereafter said pipe is lowered along the derrick axis at a speed such as to catch up with the drill-string which is continuously descending and thereafter synchronization of said pipe speed with the constant descending speed of the drill-string, rotation of said pipe for its making up at the level of the lower lift, while both said pipe and drill-string are continuously descending, when coming out of the hole the movements are reversed.

2. Rig for continuously and automatically performing the round trip operations on oil and gas wells while drilling or in production, serving to apply the system set forth in claim 1, said rig comprising for the trip-in operation, a tray conveyor which successively picks up the pipes from a storage rack located approximately mid-way up the derrick to a tray conveyor which takes the pipe away to the storage rack, where the tilting loading forks are now set to permit the pipe to roll by gravity to the storage rack.

4. A method of continuously and automatically running in or pulling out a drill pipe string consisting of a plurality of connected drill pipe sections in oil and gas wells, by means of a rig having two separate lifts the movements of which are synchronized with respect to each other, comprising the steps of adding a drill pipe section by raising said section in a horizontal position from a storage rack located at the foot of said rig to a level substantially midway up said rig, pivoting said pipe section 90° to a vertical position in the central area of said rig, said pivoting movement being effected by gripping one end of said pipe section with means connected to the upper lift of said two separate lifts during the upward movement thereof while gripping the other end of said pipe section and horizontally transferring it towards the center of said rig, thereafter lowering said pipe section by means of said upper lift at a speed adapted to catch up with said pipe string which is continuously descending at constant speed and which is being lowered by the lower lift of said two separate lifts, thereafter synchronizing the speeds of said descending drill pipe string and said descending drill pipe section, and rotating said pipe section thereby joining it to the upper end of said drill pipe string while both said drill pipe string and said pipe section are descending at equal speeds.

5. A drilling rig for continuously and automatically running in or pulling out a drill pipe string in oil and gas wells, consisting of a plurality of drill pipe sections, comprising in combination, a rig having upper and lower hydraulic lift means adapted to selectively support said drill pipe string and move in synchronized movements with respect to each other, conveyor means mounted adjacent to said rig and adapted to transport successively individual drill pipe sections in a horizontal position to a level within the operative range of said upper hydraulic lift means, a hydraulic pipe section handling mechanism operatively mounted in said upper hydraulic lift means for transferring said transported pipe section from a horizontal position to a vertical position in axial alignment with said rig, and pipe section make-and-break means operatively mounted in said lower hydraulic lift means for selectively joining or disjointing a pipe section to said drill pipe string.

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