(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
15 December 2016 (15.12.2016)

WIPO | PCT

(10) International Publication Number
WO 2016/199103 A1

(51) International Patent Classification:
E21B 19/14 (2006.01) *B25J 15/00* (2006.01)
E21B 19/087 (2006.01) *B25J 15/04* (2006.01)

(21) International Application Number:
PCT/IB2016/053460

(22) International Filing Date:
12 June 2016 (12.06.2016)

(25) Filing Language: Norwegian

(26) Publication Language: English

(30) Priority Data:
20150768 12 June 2015 (12.06.2015) NO

(71) Applicant: **WEST DRILLING PRODUCTS AS** [NO/NO]; Lagerveien 1, N-4033 Stavanger (NO).

(72) Inventors: **SKJÆRSETH, Odd B.**; Ulsbergleitet 19, N-4034 Stavanger (NO). **EILERTSEN, Bjørn**; Notveien 11, N-4085 Hundvåg (NO).

(74) Agent: **ONSAGERS AS**; P.O. Box 1813 Vika, N-0123 Oslo (NO).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

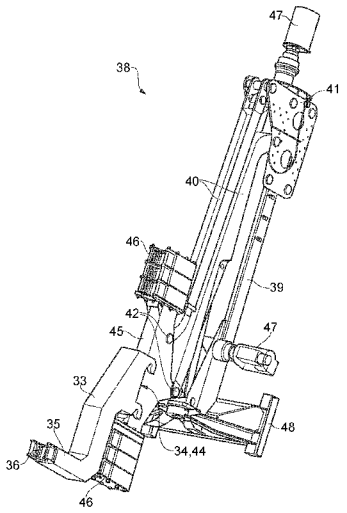
Published:

— *with international search report (Art. 21(3))*

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

(54) Title: PIPE HANDLING ARM, AND A DRILLING FLOOR SYSTEM AND A METHOD FOR PERFORMING FULLY AUTOMATIC WORK OPERATIONS ON A DRILLING FLOOR

FIG. 3



(57) Abstract: A pipe handling arm is described comprising a permanently mounted pipe gripping tool with gripping devices for gripping and holding a tubular element. The pipe handling arm further comprises a first coupling half arranged on the pipe gripping tool for connection of a work tool capable of gripping, holding and moving a downhole device. There is also a drill floor system and a method for performing a plurality of fully automatic work operations on a drill floor, the drill floor system comprising at least one fully automatic pipe handling arm and at least one work tool for performing work operations on the drill floor. The at least one pipe handling arm and the at least one work tool are adapted for fully automatic connection of the at least one work tool to the at least one pipe handling arm and fully automatic disconnection of a connected work tool from the at least one pipe handling arm. The drill floor system further comprises a control system which at least is adapted for controlling the movements of the pipe handling arm, the automatic connection of a work tool to the at least one pipe handling arm and the automatic disconnection of a work tool from the at least one pipe handling arm such that a number of work operations on the drill floor, with the use of respective work tools, can be automated and performed without the assistance of personnel.

WO 2016/199103 A1

Pipe handling arm, and a drilling floor system and a method for performing fully automatic work operations on a drilling floor

The present application relates to a drill floor system for performing a plurality of fully automatic work operations on a drill floor, and to a method for performing a plurality of work operations on a drill floor.

When drilling hydrocarbon wells and during offshore production of hydrocarbons, platforms are used which either have platform legs anchored to the seabed or are floating structures in deeper waters. During drilling, new lengths of the drill pipe are screwed on as the well is drilled deeper. At the bottom of the pipe string is arranged a bottom hole assembly (BHA) comprising different components. The bottom hole assembly components have to be assembled and the bottom hole assembly mounted on the pipe string on the drill floor before it is lowered, and more tubular elements are screwed onto the pipe string as it is run into the borehole and as the drilling advances. If some form of intervention has to be made in the well, different types of tools will be used depending on what well operation is to be carried out. These tools must be handled on the drill floor and are handled with varying degrees of involvement by personnel on the drill floor in order to control the different work operations that are being carried out. The presence of personnel on the drill floor when tools and pipe sections are moved is associated with a risk of accidents and serious injuries.

Today no system exists that is able to handle different types of devices on the drill floor without personnel being involved in the operations. It will therefore be desirable to have a system that reduces the need for personnel on the drill floor, partly in order to reduce the chances of accidents occurring when personnel handle the equipment on the drill floor. There is also a desire to boost the efficiency of and rationalise the work operations that are performed on the drill floor and thereby reduce expenditure of time and costs.

The object of the present invention has therefore been to develop a new system for handling different types of work tools and/or downhole tools on the drill floor.

In particular, it has been an object of the present invention to provide a tool for automatic handling of both tubular elements and the different components of a bottom hole assembly and other parts that are to be lowered into the borehole.

It has further been an object of the present invention to develop a system that reduces the risk of injuries to personnel on the drill floor.

It has also been an object of the present invention to save space on the drill floor and reduce installation costs and to rationalise the work flow, thereby saving time

and reducing costs in connection with different types of work operations on the drill floor.

These objects are achieved by a pipe handling arm as defined in claim 1, a drill floor system as defined in claim 3, and a method for performing a plurality of work operations on a drill floor as defined in claim 15. Additional embodiments of the pipe handling arm, drill floor system and method are disclosed in the dependent claims.

Accordingly, there is provided a pipe handling arm comprising a pipe gripping tool with gripping devices for gripping and holding a tubular element, wherein the pipe handling tool further comprises a first coupling half arranged on the pipe gripping tool for connection of a work tool. The work tool can, for example, be used to handle a downhole device such as small subs (i.e., short pipes that are to be screwed into the drill string, bit, bit breaker, or to handle work platforms and personnel baskets and parts of other machines on the drill floor. By using an already existing pipe handling arm/apparatus on the drill floor and providing it with a coupling half, preferably a rapid coupling, and using a work tool that has a complementarily shaped second coupling half such that the work tool can be connected to and disconnected from the pipe handling arm as required, it is possible to reduce the number of machines on the drill floor that handle pipes and other devices that have to be moved around on the deck. This saves space on the drill floor and gives lower installation costs.

The pipe handling arm is preferably adapted for fully automatic connection to and disconnection from the work tool.

A drill floor system is also provided for performing a plurality of fully automatic work operations on a drill floor. The drill floor system comprises at least one fully automatic pipe handling arm as described above and at least one work tool for performing a number of different work operations on the drill floor, where the at least one pipe handling arm and the at least one work tool are adapted for fully automatic connection of the at least one work tool to the at least one pipe handling arm and fully automatic disconnection of a connected work tool from the at least one pipe handling arm. The drill floor system further comprises a control system which at least is adapted to control the movements of the pipe handling arm, the automatic connection of the at least one work tool to the at least one pipe handling arm, and the automatic disconnection of the at least one work tool from the at least one pipe handling arm such that a number of work operations on the drill floor can be automated and performed without the assistance of personnel.

A work operation here will typically be taking a downhole device, for example, a bottom hole assembly component, and mounting it on another downhole device, which also may be a component of the bottom hole assembly, or mounting a tubular

element on a downhole device, for example, a bottom hole assembly component, or vice versa. A work operation can also involve moving a device, for example, a valve device that is to be used in a downhole operation, from a position in which the device is stored into a position in which the device can be lowered into the well. A work operation can, of course, also consist of dismantling a pipe string and/or downhole devices that are pulled out of the well and placing tubular elements and/or downhole devices in their respective positions on the drill floor.

Different devices that are used down in the well might need different work tools to be moved from a position on the drill floor in which they are stored into a position in which they are ready to be sent down into the well. It may therefore be necessary to have several work tools that can be mounted and removed as required.

That the work operation is fully automatic means that the control system monitors and controls the pipe handling arm and the work tool, if any, connected to the pipe handling arm. The pipe handling arm preferably comprises gripping devices such that when no work tool is mounted on the pipe handling arm, it can preferably be used to handle tubular elements. The control system preferably has control of where the different work tools and/or downhole devices are located, and monitors and controls the operations required to connect a work tool to the pipe handling arm, the operations required to disconnect a work tool from the pipe handling arm, and it monitors and controls the pipe handling arm and the mounted work tool when the pipe handling arm performs a work operation with the work tool on the drill floor, such as gripping and assembling the components of a bottom hole assembly as mentioned above, or moving a downhole device into a position in which it can be run into the well, and moving a downhole device that has been taken up from the well into its storage position on the drill floor. That the work operations required to perform a particular action, such as handling a bottom hole assembly on the drill floor, are fully automatic thus means that no persons are involved in connecting the right work tool, in the movements of the pipe handling arm and the work tool for performing the work operations, such as gripping the right component of the bottom hole assembly and mounting it together with a tubular element or another component of the bottom hole assembly. The only thing the personnel need do is therefore to sit in a control room and start the process. As soon as the control system has received a message as to what is to be done, i.e., what process should be performed, it takes over and controls the pipe handling arm, the connection and disconnection of work tools and the performance of the necessary work operations in order to execute the desired process, as, for example, assembling a bottom hole assembly. Thus, the need to have personnel moving around on the drill floor is obviated, which will reduce significantly the number of personal injuries.

The drill floor system may comprise one or a plurality of work tools for performing a number of different work operations on the drill floor, wherein the at least one

pipe handling arm and the work tool or tools are adapted for fully automatic connection to the at least one pipe handling arm and fully automatic disconnection from the at least one pipe handling arm.

The at least one work tool preferably comprises at least one holding device for gripping and holding a downhole device on the drill floor. It may, for example, be a holding device for a tubular element or a downhole tool such as a component of a bottom hole assembly, a valve device, a pipe plug etc.

In order for the control system to have control of where the different work tools are located, the drill floor system may comprise a separate storage space for each work tool and/or each downhole device, where the work tools and/or downhole devices are placed when they are disconnected from the at least one pipe handling arm and are not in use. The position for each work tool and each downhole device is entered in the control system such that the pipe handling arm can move into the right place for connection of the right work tool or downhole device, or disconnection and placing in the correct storage space for downhole devices and work tools after use.

To save space on the drill floor, the drill floor system comprises at least one tool store comprising at least one storage space for a tool that is adapted for connection to the at least one pipe handling arm, and/or a downhole device that is adapted for connection to the work tool. In the cases where the drill floor system comprises many different work tools and/or downhole devices, it is conceivable that the drill floor system may comprise two or more tool stores.

The at least one tool store preferably comprises a plurality of storage spaces for a number of work tools and/or downhole devices. All the work tools and downhole devices preferably have their own storage space in the tool store, unless they are of a shape and/or size which makes it impossible for them to fit into such a tool store. The work tools and/or downhole devices that perhaps for different reasons do not fit into the tool store will preferably have a specific storage space on the drill floor where they are stored when not in use. The tool store preferably comprises a system of shelves, each shelf having one or more compartments depending on the size and shape of the work tools and/or downhole devices and available space on the drill floor.

To ensure that connection of a work tool to the at least one pipe handling arm, or connection of a downhole device to a work tool, takes place without any problems, the storage spaces may comprise a holding device to hold the at least one work tool and/or downhole device or devices in a fixed position in their respective storage spaces. The control system will then know exactly where the different work tools and/or downhole devices are and how they are oriented in the space. This prevents the work tools and/or downhole devices from changing their position as a result of being inadvertently knocked into or jolted when in storage on the drill floor, which

would have made it more complicated to ensure performance of a fully automatic connection of a work tool to the at least one pipe handling arm and connection of a downhole device to a work tool on a pipe handling arm. Holding devices can, for example, comprise a depression in the surface of the storage space and a complementarily shaped base on the work tool or downhole device, or a form of gripping device that physically holds the work tools and/or downhole devices in place in their respective storage spaces.

For connection of a work tool to the at least one pipe handling arm, the at least one pipe handling arm is preferably provided with a first coupling half and each work tool is provided with a second coupling half, wherein the first coupling half and the second coupling half are matingly configured for fully automatic connection of the work tools to the at least one pipe handling arm and fully automatic disconnection of a connected work tool from the at least one pipe handling arm. A fully automatic connection and disconnection of the work tools means, as in the above, that the connection and disconnection of the work tools is monitored and controlled by the control system, and that the connection and disconnection takes place without personnel being involved in the process. The mating first and second coupling halves are preferably standard coupling elements that can be controlled by a control system.

The at least one pipe handling arm preferably comprises a permanently mounted tool, for example, one or more gripping tools for tubular elements, in addition to the first coupling half. The at least one pipe handling arm thus normally handles tubular elements that are taken from their storage space and screwed onto the drill pipe as the drilling of the well advances, and, where relevant, tubular elements that are unscrewed and placed in the storage space if the drill pipe has to be taken up from the well. In this embodiment, a first coupling half for fully automatic connection of a work tool and fully automatic disconnection of a connected work tool from the at least one pipe handling arm is preferably provided on the permanently mounted work tool. When there is a need to use a work tool other than the permanently mounted tool, the at least one pipe handling arm can be connected to the desired work tool which is preferably stored in the tool store.

The pipe handling arm and/or the at least one work tool is preferably provided with necessary sensors of various types, such as GPS devices and other position-determining devices, speed sensors etc., the various sensors being signally connected to the control system, such that the control system is able to control the connection and disconnection of the work tool to/from the at least one pipe handling arm, the movement of the pipe handling arm and connected work tool, and the handling of downhole devices and tubular elements on the drill floor through use of the at least one pipe handling arm and the connected work tool. For example, the first coupling half on the at least one pipe handling arm may comprise a position-

determining device for determining the position of the first coupling half on the drill floor, which position-determining device is signally connected to the control system, whilst the second coupling half on the work tools may comprise a position-determining device for determining the position of the second coupling half on the drill floor, which position-determining device is signally connected to the control system. The position-determining devices preferably comprise one or more sensors that are signally connected to the control system and which, in a known way, will be able to determine the precise position of the first coupling half and/or the second coupling half.

As mentioned above, the control system is preferably adapted to at least register and remember the respective disconnected positions of the work tools, to monitor and control the movements of the at least one pipe handling arm, and to monitor and control fully automatic connection of a work tool to the at least one pipe handling arm and fully automatic disconnection of a work tool from the at least one pipe handling arm, such that a plurality of work operations on the drill floor, using respective work tools, can be automated and performed without the assistance of personnel.

In the cases where the reach of the at least one pipe handling arm is not sufficient to reach the work tools in their respective storage spaces, the downhole devices to be handled on the drill floor and the storage positions for the downhole tools and the position they are to be moved into, typically above the borehole, the at least one pipe handling arm can be movably arranged on the drill floor for vertical and/or horizontal movement of the at least one pipe handling arm relative to the drill floor. The at least one pipe handling arm can, for example, be arranged on a support element that can be moved up and down along one or more columns for vertical movement of the pipe handling arm. For horizontal movement of the at least one pipe handling arm, it can be arranged on a support element that runs on guides, such as rails, on the drill floor.

In the cases where it is not sufficient to have one pipe handling arm, the drill floor system may comprise a plurality of pipe handling arms that are adapted for fully automatic connection of a work tool to each of the pipe handling arms and fully automatic disconnection of a work tool from each of the pipe handling arms. This means that several different work operations can be performed in quick succession where one work tool is not capable of performing all the work operations. For example, a first pipe handling arm with a work tool can bring a device into a position above the drill pipe where a second pipe handling arm with a second work tool is ready to connect this device to equipment for lowering the device into the well. In some cases, this may be so time-saving that it is worthwhile using two or more pipe handling arms instead of using one pipe handling arm that has to change work tool between the different work operations.

A method is also provided for performing a plurality of work operations on a drill floor, for example, on a floating structure, where the work operations are performed using a pipe handling arm and a drill floor system, as described above, comprising at least one work tool, wherein the method comprises:

- fully automatic connection of the at least one work tool to the at least one pipe handling arm;
- performance of at least one fully automatic work operation using the at least one work tool;
- fully automatic disconnection of the at least one work tool from the at least one pipe handling arm.

If the system comprises several work tools, they are preferably placed, as described above, in separate storage spaces when they are disconnected from the at least one pipe handling arm. As mentioned above, each work tool and/or each downhole device is preferably placed in a tool store comprising a plurality of storage spaces for respective downhole tools and/or work tools that are disconnected from the at least one pipe handling arm.

The at least one fully automatic work operation may comprise connecting at least one downhole device to a pipe string or to another downhole device. The at least one downhole device may comprise at least one component of a bottom hole assembly, and the at least one fully automatic work operation may comprise connecting the at least one component of the bottom hole assembly to a pipe string or to another bottom hole assembly component. The at least one work tool is preferably disconnected from the at least one pipe handling arm before the at least one pipe handling arm is to handle a tubular element.

A non-limiting embodiment of the invention will be described below with reference to the attached figures, wherein:

Figure 1 shows a schematic diagram of a drill floor system with one pipe handling arm.

Figure 2 shows a schematic diagram of a drill floor system with two pipe handling arms.

Figure 3 shows an embodiment of a pipe handling arm with a permanently mounted work tool for handling tubular elements and a removable work tool for handling a downhole device.

Figure 4 shows a pipe handling arm that is vertically movable.

It should first be mentioned that in all the figures the same reference numerals have been used to designate the same technical features.

Figure 1 is a schematic illustration of an embodiment of the present drill floor system 10 with an opening 13 for passage of the drill string 50 and various downhole devices 21, as for instance bottom hole assembly (BHA) components, or valve devices that are run into the well to perform different types of operations downhole. The downhole devices 21 are illustrated shown purely schematically in Figures 1 and 2 and will normally have another form in reality.

On the drill floor 12 there is provided at least one pipe handling arm 38. The pipe handling arm 38 comprises a first arm 39 and a second arm 40 that are connected to one another by a first articulated joint 41, such that the first arm 39 and the second arm 40 are able to rotate relative to each other. At the opposite end, the first arm 39 is connected to a support element 26 by means of an articulated element 27 such that the first arm is rotatable relative to the support element 26, preferably both up and down in a vertical direction and back and forth in a lateral direction.

The support element is preferably arranged movably up and down along a guide element 25, which, for instance, may be a tubular element. To further increase the reach of the pipe handling arm, the support element 26 may also be arranged rotatably about the guide element 25. It will also be possible to configure the support element 26 as a frame that slides up and down on two or more parallel guide elements 25.

The pipe handling arm 38 is shown in the figures with a first arm 39 and a second arm 40, but it may also be equipped with only one arm or with three or more arms if so desired, where the arms are rotatably connected to one another.

At the opposite end of the second arm 40 in relation to the first articulated joint 41, the embodiment of the pipe handling arm 38 shown in Figure 1, has mounted thereto a permanently mounted work tool 45. The permanently mounted work tool 45 preferably comprises a pipe gripping tool with gripping elements 46 that are capable of gripping a tubular element placed in a pipe racking device 20 arranged on or in connection with the drill floor, and moving it into a position above the drill string 50 so as to allow the tubular element to be screwed onto the top of the drill string 50 by suitable pipe handling tools 16, 17 (see Figure 4). Similarly, the pipe handling arm 38 can, of course, also grip a tubular element at the top of the drill string 50 and put it back in the pipe racking device 20. The permanently mounted work tool can be rotatably connected to the second arm 40 by a second articulated joint 42 as indicated in Figures 1 and 2.

The pipe handling arm 38 shown in Figure 1 comprises, in addition to the permanently mounted work tool 45, a first coupling half 44 for connecting a work tool 33. The first coupling half 44 is, in the embodiment of the pipe handling arm shown in Figure 1, preferably provided on the permanently mounted work tool 45,

but can of course be arranged immediately on the pipe handling arm 38 itself, if so desired.

The drill floor system can, if necessary, comprise a plurality of work tools 33, all of which are provided with a second coupling half 34 that is complementarily shaped to the first coupling half 44 on the pipe handling arm 38, such that the work tools 23 can selectively be connected to the pipe handling arm 38. When a work tool 33 is connected to the pipe handling arm 38, the pipe handling arm can be used, for example, to grip a bottom hole assembly component and connect it to another component of the bottom hole assembly that is located above the borehole. As mentioned above, the downhole devices 21, in addition to being borehole assembly components, may be different types of devices that are used in connection with different types of operations in a hydrocarbon well, such as a valve device, a plug etc.

It should also be mentioned that, as indicated above and as shown in Figure 2, the pipe handling arm 38 must not necessarily have a permanently mounted work tool 45 as shown in Figure 1.

The work tool or tools 33 and downhole devices are preferably arranged in a tool store 22 provided on the drill floor 12 as shown in Figures 1 and 2. The tool store 22 is preferably provided with a plurality of storage spaces 23 for work tools 33 and/or downhole devices 21. To save space on the drill floor, the tool store 22 can advantageously be configured with shelf-like storage spaces 23 arranged vertically one above the other. It should be stressed that work tools 33 and/or downhole devices 21 as shown in Figures 1-2, are in a purely schematic form and the work tools and downhole devices will of course have other configurations in reality.

The drill floor system 10 also comprises a control system as indicated in Figures 1 and 2. This control system comprises necessary sensors that are arranged on the pipe handling arm 38 and/or the work tools 33 and/or the downhole devices 21 so as to allow the performance of at least the connection of a work tool 33 that is in its storage space 23 in the tool store 22 to the pipe handling arm 38; the placing of a connected work tool in its storage space 33 in the tool store 22 and subsequent disconnection of the work tool 33 from the pipe handling arm 33; and the control of the pipe handling arm 38 and connected work tool 33 such that the pipe handling arm 38 is able to manipulate the downhole devices 21 between desired positions and in a desired sequence. Such sensors are prior art and are commercially available, and will not be described in more detail here. The sensors are signally connected to a control unit 19 by signal cables (not shown in the figures) or preferably by wireless technology such as Bluetooth. The control unit 19 comprises at least one computer that monitors and controls the drill floor system 10 such that all operations performed by the pipe handling arm 38, and connection and

disconnection of work tools 33 as required, are carried out fully automatically by the drill floor system without the assistance of personnel on the drill floor 12. All the work operations that are to be performed by the pipe handling arm can thus be started by personnel who are in a control room, preferably with a full view of the drill floor, so that control of the drill floor system can be taken over manually should there occur an emergency situation or other situations that require personnel to intervene and stop or control the pipe handling arm. When the control system has received a message to perform one or more actions, all the necessary operations that the pipe handling arm has to perform are entered in the control system so that they are performed in the correct order and without physical assistance of personnel on the drill floor 12. As performance of operations on the drill floor is associated with a relatively high risk of injury to personnel on the drill floor, the fully automatic performance of work operations on the drill floor, which previously have been performed with the assistance of personnel, results in a reduced risk of injury to personnel, which will be almost zero. In addition, there is expected to be an increase in efficiency and associated cost savings when using the fully automatic drill floor system 12.

Figure 2 shows a drill floor system 10 that has all the elements shown in Figure 1. These will not be described again.

In addition, the embodiment of the drill floor system in Figure 2 has a second pipe handling arm 38 that preferably, but not necessarily, is almost identical in form to the first pipe handling arm. The second pipe handling arm 38 is however normally not provided with a permanently mounted work tool 45. The second pipe handling arm 38 comprises a first coupling half 44 for connection of a work tool 33. The first coupling half 44 can be mounted on a support element 43 that is rotatably connected to the second arm 40 on the pipe handling arm by a second articulated joint 42, such that a work tool 33 connected to the pipe handling arm can be pivoted about the second arm 40.

The first arm 39 of the second pipe handling arm 38 is at one end rotatably connected to the second arm 40 by a first articulated joint 41. At the other end, the first arm 39 is rotatably connected to a support element 30 by an articulated element 31, preferably such that the first arm 39 can be pivoted in all directions with a desired angle about the articulated element 31. The support element 30 is preferably, but not necessarily, movably arranged along guide elements 29 that are arranged on the drill floor 12. The reach of the second pipe handling arm 38 is thus significantly increased.

Figure 3 shows a more detailed embodiment of a pipe handling arm 38 that comprises a permanently mounted work tool 45 as explained in more detail in the description of Figure 1 above. The structure of the pipe handling arm is essentially

as described in connection with the pipe handling arm in Figure 1, and it comprises a first arm 39 rotatably connected to a second arm 40 by a first articulated joint 41. At the other end, the first arm 39 is rotatably connected to a mounting support 48 that is adapted for permanent mounting on the drill floor or for mounting to one or more guide elements 25 such that the mounting arm 38 can be moved vertically. The permanently mounted work tool 45 is rotatably connected to the second arm 40 by a second articulated joint 42. As shown in Figure 3, the permanently mounted work tool 45 is preferably, but not necessarily, a pipe gripping device comprising pipe gripping elements 46 for gripping and holding tubular elements that are to be moved between a pipe racking device 20, as indicated in Figures 1 and 2, and a position in which it can be screwed onto the top of the drill string 50, or for moving a tubular element that has been unscrewed from the drill string 50 back to the pipe racking device 20. Drive units 47 for driving the pipe handling arm are also indicated in Figure 3.

Figure 3 further shows a work tool 33 that is connected to the pipe handling arm 38. Preferably, the permanently mounted work tool 45 comprises the first coupling half 44 that is connected the second coupling half 34 on the work tool 33 as indicated in Figure 3. The work tool comprises a gripping element 36 or a similar device for gripping, holding and moving a downhole device 21 between desired positions on the drill floor 12. In the embodiment of the invention in Figure 3, the gripping element 36 is arranged on a projecting support element such that the gripping element more easily reaches and grips the downhole device 21 that preferably is placed in its storage position in the tool store 22.

Figure 4 indicates how a pipe handling arm as shown in Figure 3 can be arranged on one or more guide elements 25 using support elements 26 as described above, such that the pipe handling arm 38 can be moved upwards and downwards along the guide element or elements 25 in a vertical direction. There is further shown a tower 15 with two pipe handling tools 16, 17 that are used to screw tubular elements to and unscrew them from the drill string 50 (not shown in Figure 4). The pipe handling tools 16, 17 can also be configured in such a way that they are also able to handle downhole devices 21 that are to be used for purposes and operations of different types in the well. The pipe handling arm 38 will then be adapted such that it fully automatically connects to a desired work tool 33 that is located in its storage space 23 and then grips and moves the desired downhole device 21, as for example, a bottom hole assembly component, to the pipe handling tools 16, 17 which take over the handling of the downhole devices.

Lastly, it should be noted that to increase and reduce the reach of the pipe handling arm it is conceivable that the first arm 39 or the second arm 40, or possibly both the first and the second arm, may have a telescopic configuration.

CLAIMS

1. A pipe handling arm comprising a pipe gripping tool with gripping devices for gripping and holding a tubular element,
c h a r a c t e r i s e d i n that the pipe handling arm further comprises a first coupling half arranged on the pipe gripping tool for connection of a work tool.

2. A pipe handling arm according to claim 1,
c h a r a c t e r i s e d i n that the pipe handling arm is adapted for fully automatic connection to and disconnection from the work tool.

3. A drill floor system for performing a plurality of fully automatic work operations on a drill floor, which drill floor system comprises:
   - at least one fully automatic pipe handling arm according to claim 1 or 2 and at least one work tool for performing a number of different work operations on the drill floor, where the at least one pipe handling arm and the at least one work tool are adapted for fully automatic connection of the at least one work tool to the at least one pipe handling arm and fully automatic disconnection of a connected work tool from the at least one pipe handling arm;
   - a control system that is at least adapted to control the movements of the pipe handling arm, the automatic connection of a work tool to the at least one pipe handling arm and the automatic disconnection of a work tool from the at least one pipe handling arm, such that a plurality of work operations on the drill floor, with the use of respective work tools, can be automated and performed without the assistance of personnel.

4. A drill floor system according to claim 3,
c h a r a c t e r i s e d i n that the at least one work tool comprises at least one holding device for gripping and holding a downhole device on the drill floor.

5. A drill floor system according to claim 3 or 4,
c h a r a c t e r i s e d i n that the drill floor system comprises a separate storage space for each work tool and/or a downhole device in which the work tools are placed when they are disconnected from the at least one pipe handling arm.

6. A drill floor system according to one of claims 3-5,
c h a r a c t e r i s e d i n that the drill floor system comprises at least one tool store comprising a plurality of storage spaces for at least one work tool and/or at least one downhole device.

7. A drill floor system according to claim 6,
c h a r a c t e r i s e d i n that the at least one downhole device comprises a bottom hole assembly (BHA) component.

8. A drill floor system according to one of claims 5-7,
c h a r a c t e r i s e d i n that the storage spaces comprise a holding device for holding the work tools in a fixed position in their respective storage spaces.

9. A drill floor system according to one of claims 3-8,
c h a r a c t e r i s e d i n that the at least one pipe handling arm is provided with a first coupling half and the at least one work tool is provided with a second coupling half, where the first coupling half and the second coupling half are matingly configured for fully automatic connection of the at least one work tool to the at least one pipe handling arm and fully automatic disconnection of a connected work tool from the at least one pipe handling arm.

10. A drill floor system according to claim 9,
c h a r a c t e r i s e d i n that the first coupling half on the at least one pipe handling arm comprises a position-determining device for determining the position of the first coupling half on the drill floor, which position-determining device is signally connected to the control system.

11. A drill floor system according to one of claims 9-10,
c h a r a c t e r i s e d i n that the second coupling half on the at least one work tool comprises a position-determining device for determining the position of the second coupling half on the drill floor, which position-determining device is signally connected to the control system.

12. A drill floor system according to one of claims 1-11,
c h a r a c t e r i s e d i n that the at least one pipe handling arm is movably arranged on the drill floor for vertical and/or horizontal movement of the at least one pipe handling arm relative to the drill floor.

13. A drill floor system according to one of claims 1-12,
c h a r a c t e r i s e d i n that the control system is adapted to at least register and remember the respective disconnected positions of the at least one work tool and the at least one downhole device, to monitor and control movements of the at least one pipe handling arm and to monitor and control fully automatic connection of a work tool or a downhole device to the at least one pipe handling arm and fully automatic disconnection of a work tool or a downhole device from the at least one pipe handling arm.

14. A drill floor system according to one of claims 1-13, characterised in that the drill floor system comprises a plurality of pipe handling arms that are adapted for fully automatic connection of a work tool to each of the pipe handling arms and fully automatic disconnection of a work tool from the pipe handling arms.

15. A method for performing a plurality of work operations on a drill floor where the work operations are performed by a pipe handling arm according to claim 1 or 2, and a drill floor system according to one of claims 3-14 comprising at least one work tool, the method comprising:
- fully automatic connection of the at least one work tool to the at least one pipe handling arm;
- performance of at least one fully automatic work operation with the at least one work tool;
- fully automatic disconnection of the at least one work tool from the at least one pipe handling arm when the at least one fully automatic work operation has been performed.

16. A method according to claim 15, characterised in that the at least one fully automatic work operation comprises connecting at least one downhole device to a pipe string or to another downhole device.

17. A method according to claim 16, characterised in that the at least one downhole device comprises at least one component of a bottom hole assembly and that the at least one fully automatic work operation comprises connecting the at least one component of the bottom hole assembly to a pipe string or to another component of the bottom hole assembly.

18. A method according to claim 16 or 17, characterised in that each downhole device and/or work tool is placed in a separate storage space, preferably in a tool store, when they are disconnected from the at least one pipe handling arm.

19. A method according to one of claims 15-18, characterised in that each downhole device and/or each work tool is placed in a tool store comprising a plurality of storage spaces for respective downhole devices and/or work tools when they are disconnected from the at least one pipe handling arm.

20. A method according to one of claims 14-18 claims 15-19,
c h a r a c t e r i s e d i n that the at least one work tool is disconnected from the at least one pipe handling arm before the at least one pipe handling arm is to handle a tubular element.

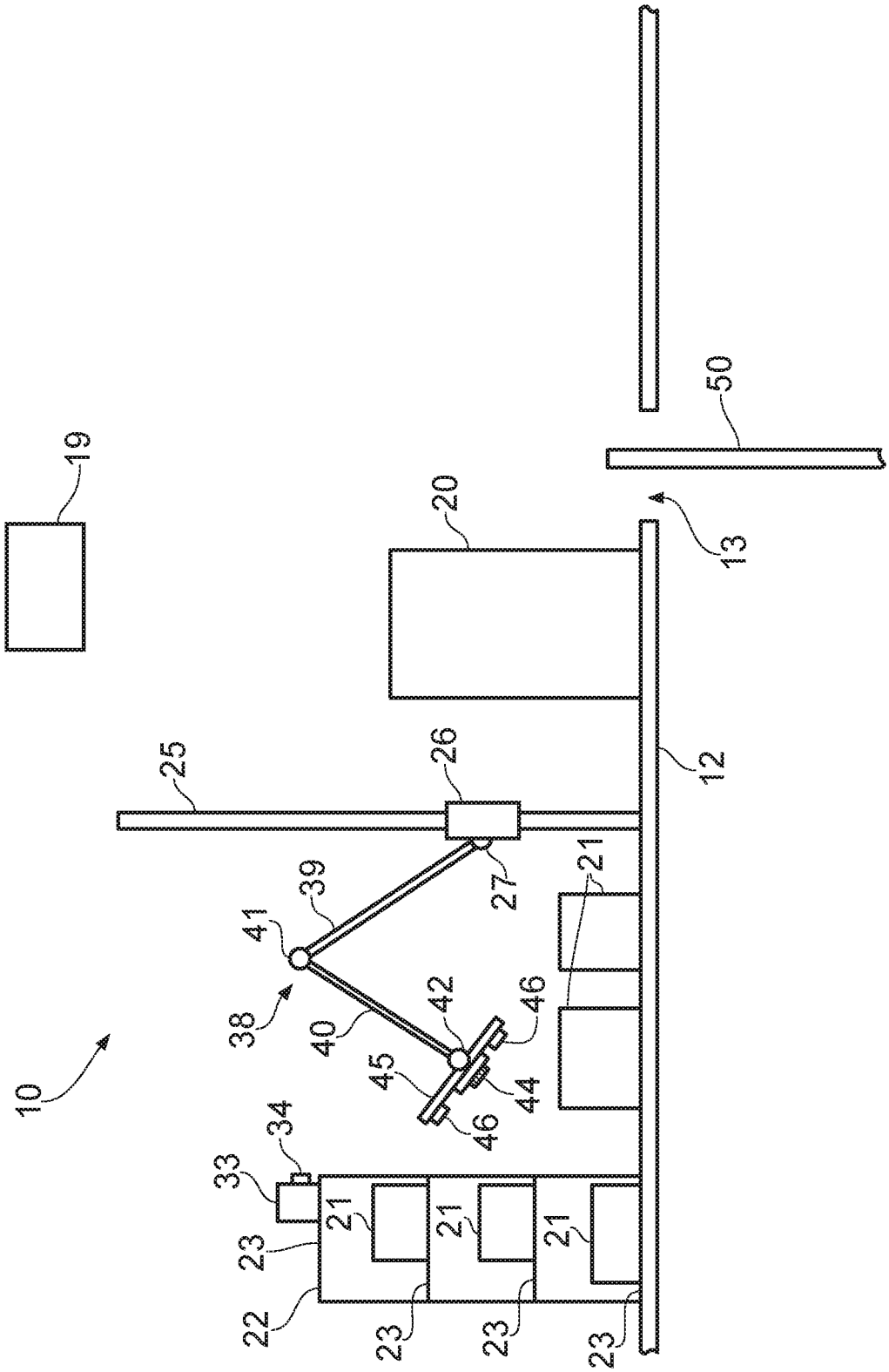

19
20
50
13
25
26
12
39
41
27
21
38
40
42
46
45
44
10
34
33
21
23
22
23
23
23

FIG. 1

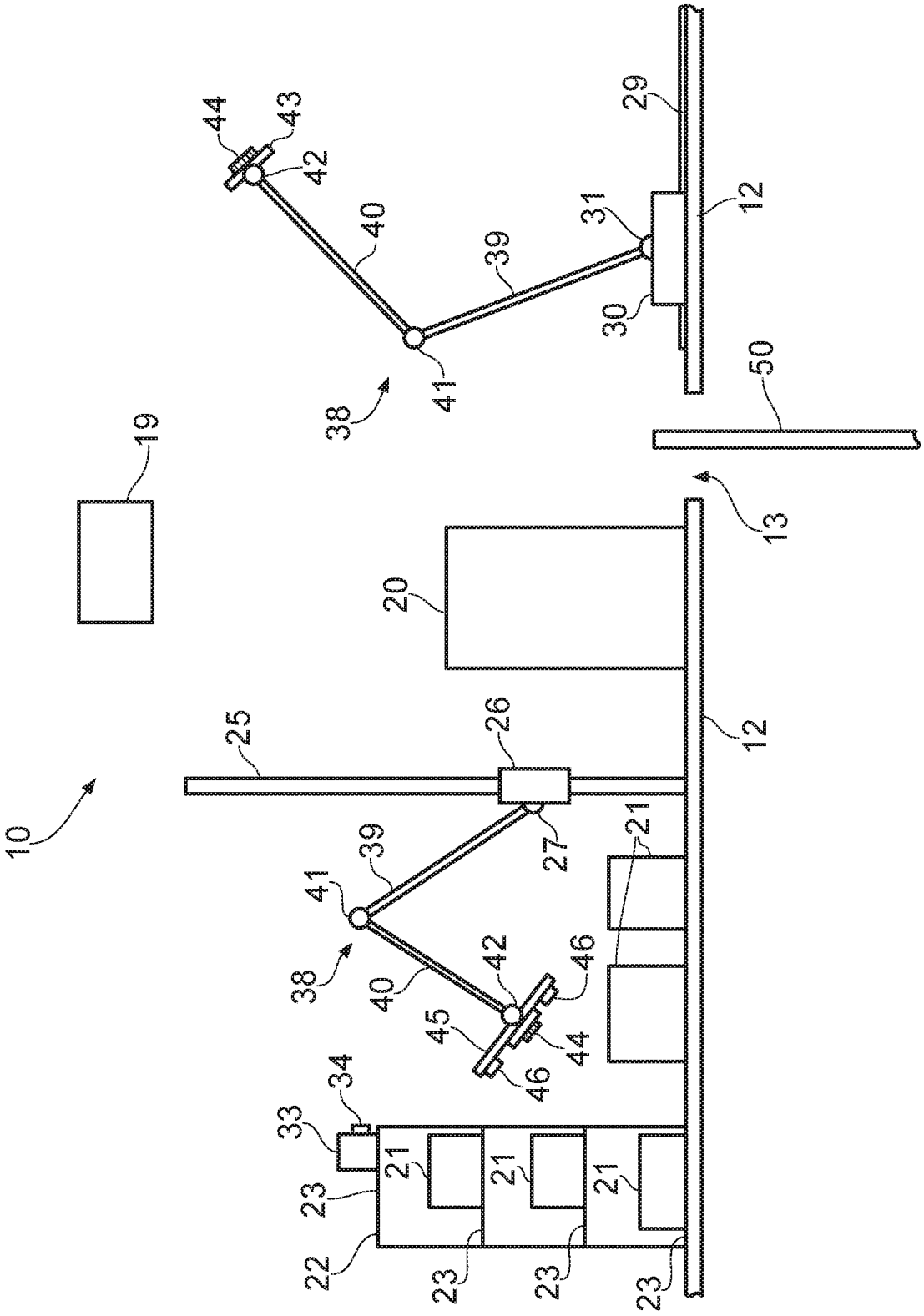

10
12
12
13
19
20
21
21
21
21
22
23
23
23
23
25
26
27
29
30
31
33
34
38
38
39
39
40
40
41
41
42
42
43
44
44
45
46
46
50

FIG. 2

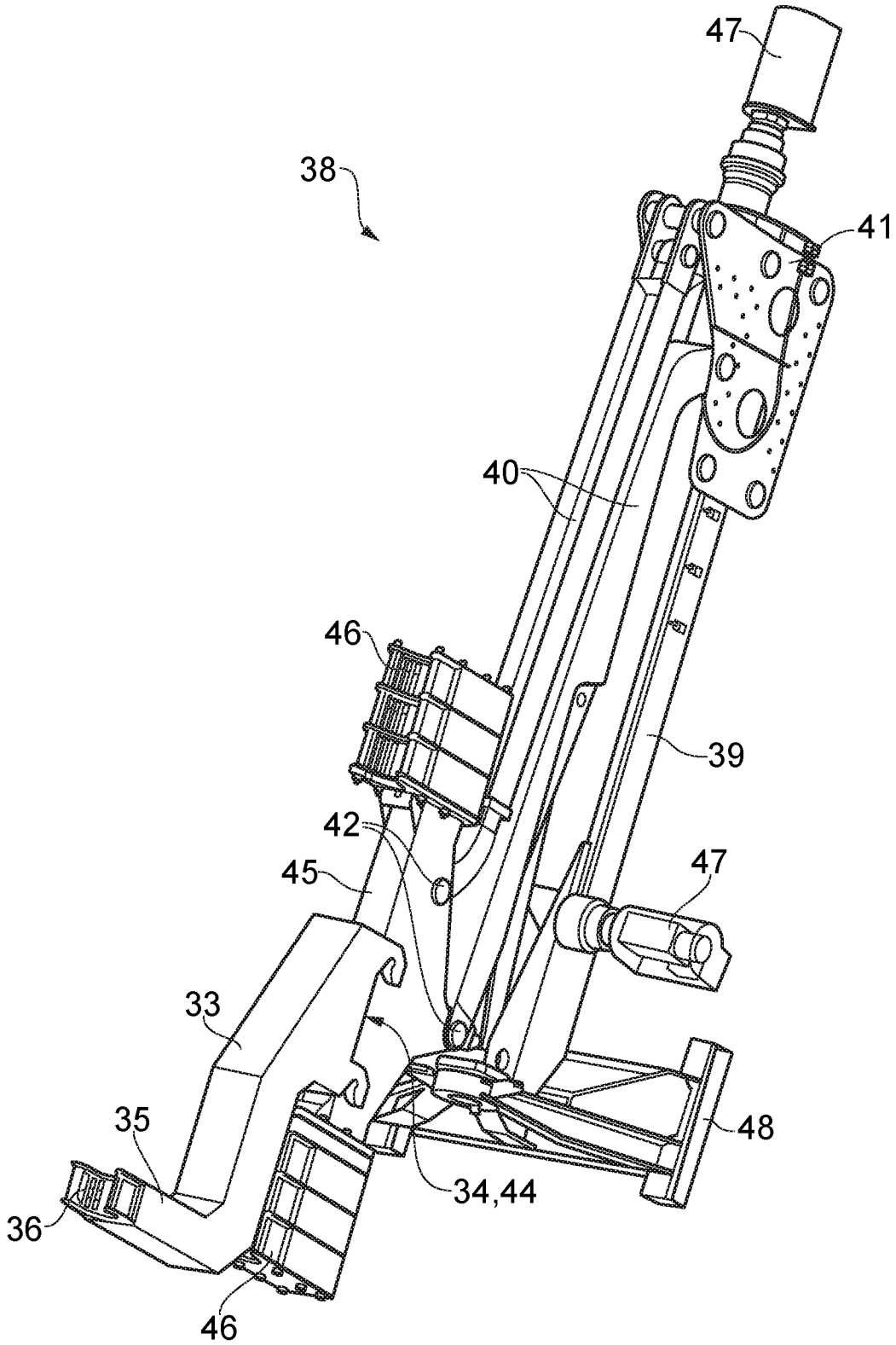


FIG. 3

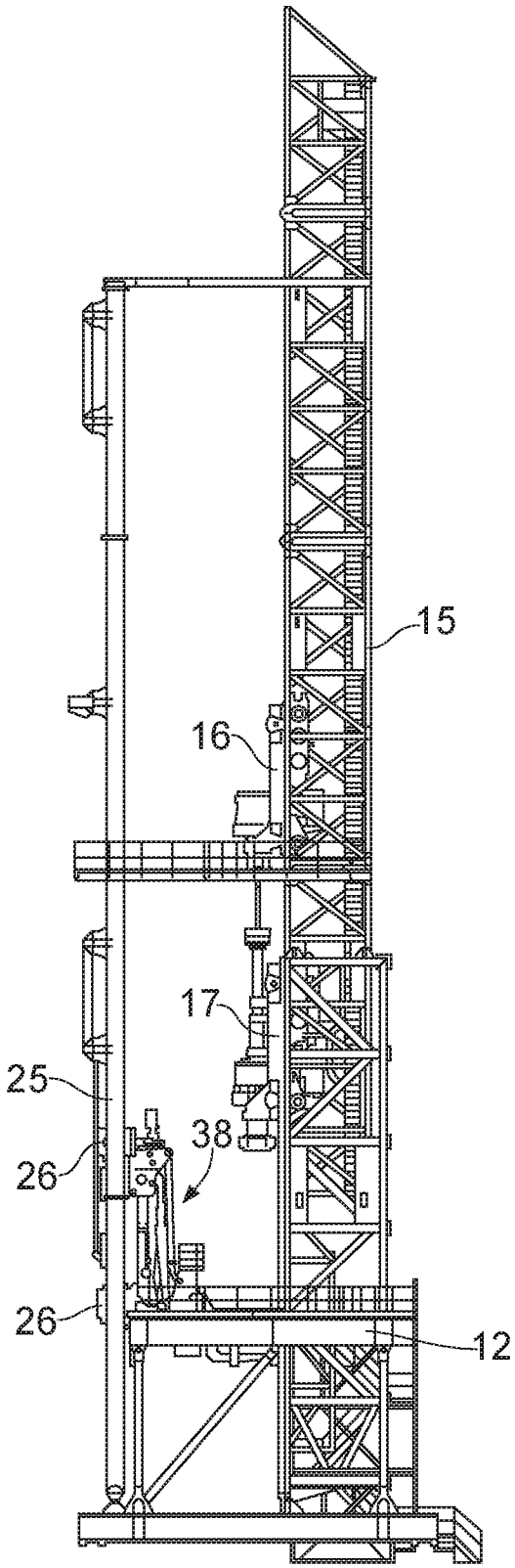


FIG. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2016/053460

A. CLASSIFICATION OF SUBJECT MATTER
INV. E21B19/14 E21B19/087 B25J15/00 B25J15/04
ADD.

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)
E21B B25J B23Q

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 93/22535 A2 (DRECO GROUP CO LTD [CA]) 11 November 1993 (1993-11-11)	1-6, 8-10, 12-16, 18-20
Y	figures 1,2,7,8 page 1, lines 5-10 page 5, line 34 - page 6, line 8 page 7, lines 1-3 page 7, line 13 - page 8, line 2 page 10, lines 14-27 page 11, line 19 - page 12, line 6 page 13, line 13 - page 14, line 30 page 15, line 24 - page 16, line 13 claim 1	11

-/--

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

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

"E" earlier application or patent but published on or after the international filing date

"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	Date of mailing of the international search report
4 October 2016	14/10/2016

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Pasquini, Matteo

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2016/053460

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2010/105159 A2 (T & T ENGINEERING SERVICES INC [US]; SIGMAR AXEL M [US]; ORGERON KEITH) 16 September 2010 (2010-09-16)	1-10,12, 14-20
Y	figures 1,2 paragraph [0002] paragraph [0063] paragraph [0061] paragraph [0069] paragraph [0074]	11

Y	EP 1 798 007 A1 (ABB RESEARCH LTD [CH]) 20 June 2007 (2007-06-20)	11
A	figures 1-3 paragraph [0002] paragraph [0007] paragraph [0016] paragraph [0017] paragraph [0020] - paragraph [0024] paragraph [0029]	20

A	US 4 587 716 A (BYTOW PETER [DE]) 13 May 1986 (1986-05-13) column 1, lines 8-16; figures 1-6 column 3, lines 62-68 column 4, line 24 - column 5, line 18 column 5, lines 28-42	1-20

A	Mads Grinrød: "SPE/IADC 139403 Continuous Motion Rig. A Detailed Study of a 750 Ton Capacity, 3600 m/hr Trip Speed Rig", , 1 March 2011 (2011-03-01), XP055283619, Retrieved from the Internet: URL:https://www.onepetro.org/download/conference-paper/SPE-139403-MS?id=conference-paper/SPE-139403-MS [retrieved on 2016-06-24] the whole document	1-20

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2016/053460

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9322535 A2	11-11-1993	AT 201743 T	15-06-2001
		AU 4258193 A	29-11-1993
		CA 2067697 A1	31-10-1993
		CA 2518604 A1	31-10-1993
		DE 69330262 D1	05-07-2001
		DE 69330262 T2	02-05-2002
		EP 0592653 A1	20-04-1994
		NO 934883 A	28-02-1994
		US 5458454 A	17-10-1995
		US 6220807 B1	24-04-2001
		WO 9322535 A2	11-11-1993
WO 2010105159 A2	16-09-2010	CA 2755227 A1	16-09-2010
		EP 2406457 A2	18-01-2012
		US 2010230166 A1	16-09-2010
		WO 2010105159 A2	16-09-2010
EP 1798007 A1	20-06-2007	AT 398509 T	15-07-2008
		EP 1798007 A1	20-06-2007
US 4587716 A	13-05-1986	DE 3320762 A1	13-12-1984
		EP 0128487 A1	19-12-1984
		JP H0411283 B2	28-02-1992
		JP S6046829 A	13-03-1985
		US 4587716 A	13-05-1986