United States Patent [19]

Wilderman

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[45] **May 22, 1973**

[54] CARRIER MOUNTED DRILLING UNIT

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[73] Assignee: **Kenting Drilling Ltd.**, Calgary, Alberta, Canada

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[52] **U.S. Cl.**.....**175/85**, 175/219

[51] **Int. Cl.**.....**E21b 19/14**

[58] **Field of Search**.....175/85, 52, 219, 175/220

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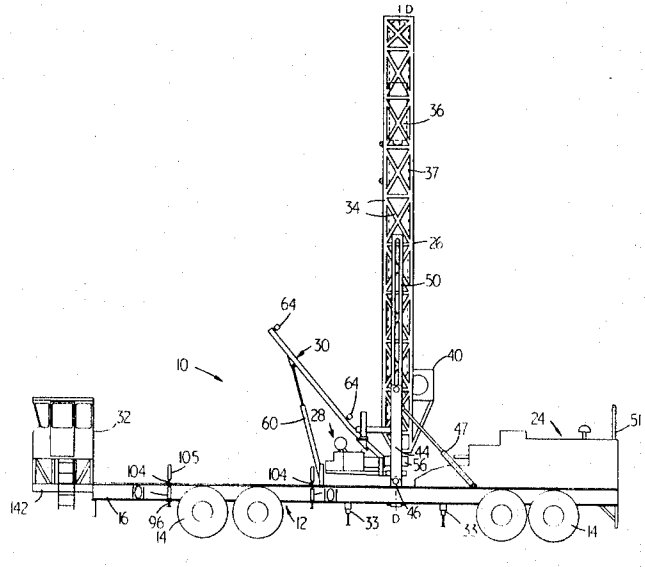
[57] **ABSTRACT**

Improvements in apparatus for drilling wells. The apparatus is particularly suitable for drilling exploration holes or shallow production holes up to about 2,500 or 3,000 feet in depth. The drilling unit is readily transportable from one site to another and is capable of carrying, on racks provided for the purpose, all the drill pipe required for the drilling of relatively shallow production holes or exploration holes. The drilling unit, including the drill pipe racks, is preferably arranged such that a major portion of the weight of the complete drilling unit including a full complement of drill pipe supported on the drill racks is available to produce downward thrust of the drill bit when drawdown forces are being applied to the drill string. The power source, the drive train and the propulsion wheels are located adjacent one end of the chassis thereby leaving the central region of the chassis free of drive train components and the like. It is in this central region that the drill mast and its associated equipment is located. An operators' station is mounted on the chassis and means are provided to support the station for movement from a first position for transportation of the drilling unit wherein the operators' station overlies a portion of the racking area to a second operating position dispolaced outwardly of the racking area whereby a ready access may be had to the latter for addition or withdrawal of drill stem as the case may be. The apparatus also includes means for adding and withdrawing sections of drill pipe to and from the drill string including a pipe handling arm adapted to grasp and wing individual pipe sections between a generally upwardly directed position at or in the mast and a lower generally horizontal position. The apparatus includes storage means for the sections of drill pipe having a bed for supporting a plurality of layers of generally horizontally disposed pipe sections, the layers being in generally vertically stacked relation. Means are provided for raising or lowering the bed of the pipe storage means thereby to raise or lower the layers of pipe sections supported thereon to enable one of of said layers to be positioned adjacent the lower generally horizontal position taken by the pipe handling arm. Means are provided for individually transferring the sections of pipe from the storage means at the level of said pipe layer to the pipe handling arm for engagement thereby and vice versa.

26 Claims, 13 Drawing Figures



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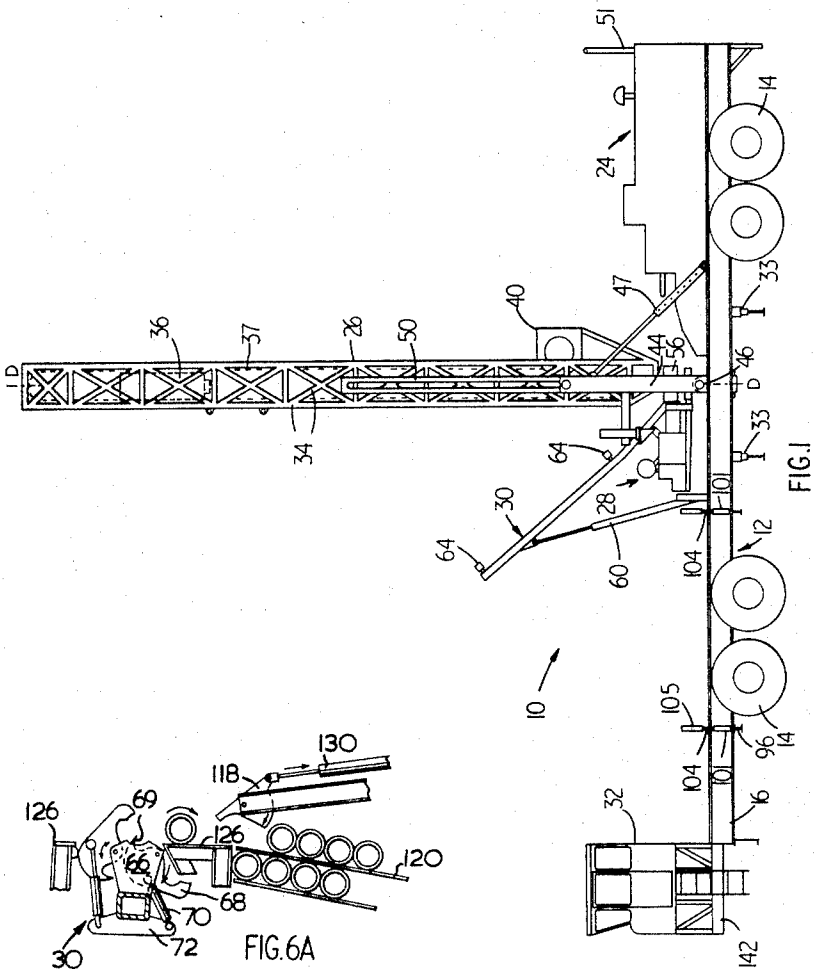

FIG. 1

FIG. 6A

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ATTORNEYS

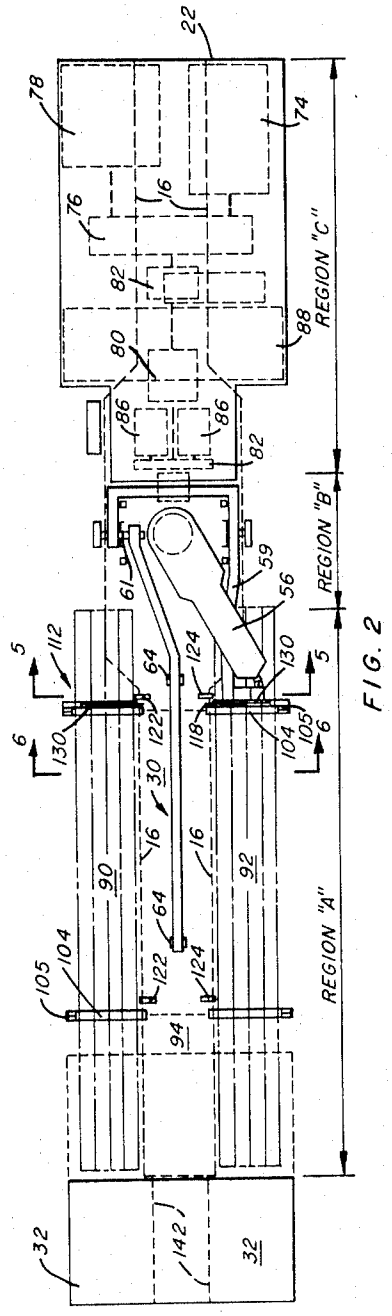
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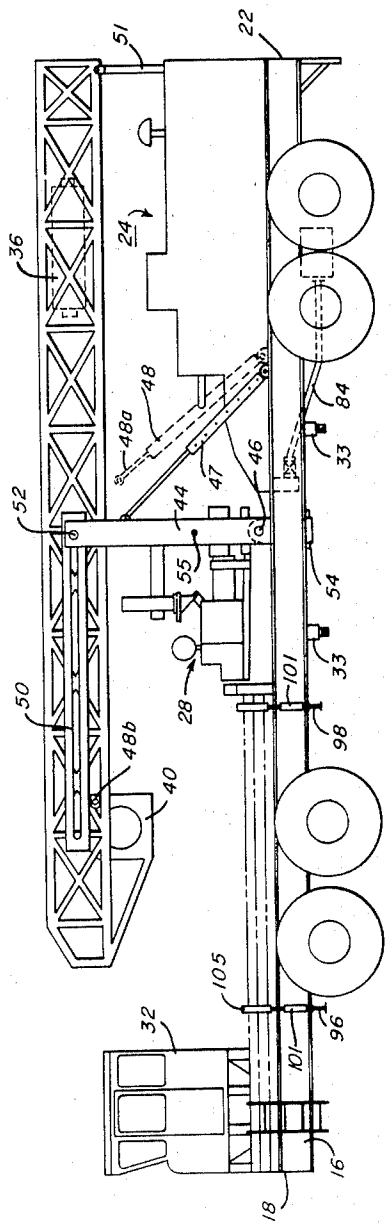
FIG. 2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48a
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FIG. 3

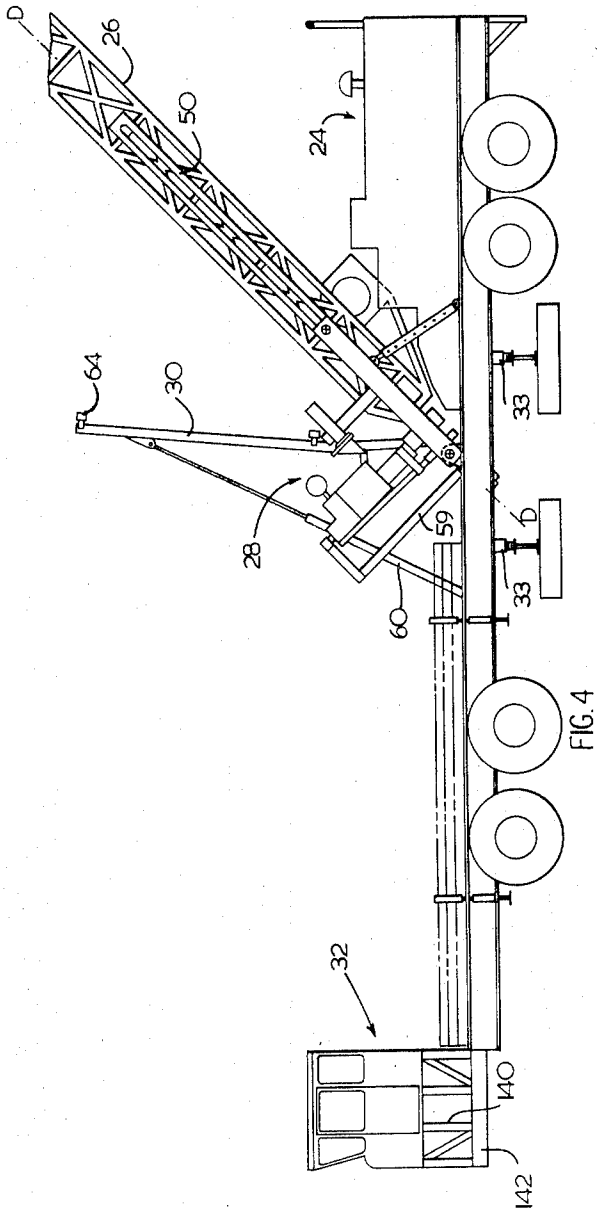

FIG. 4

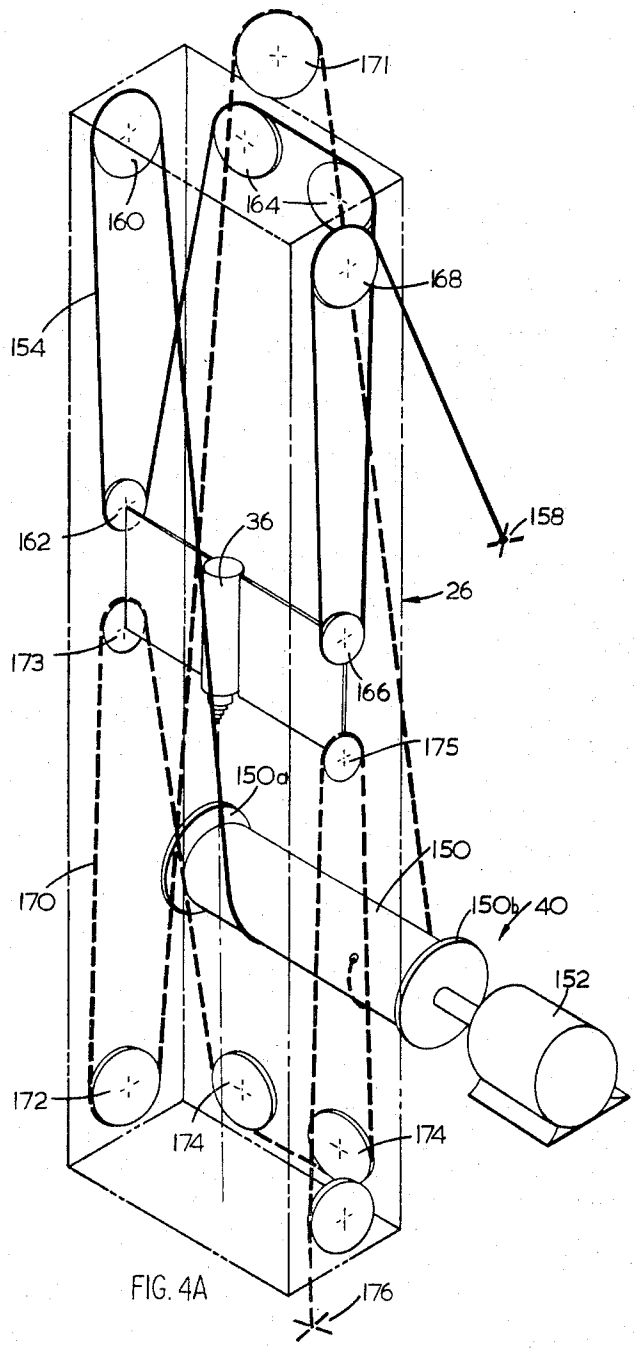
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FIG. 4A

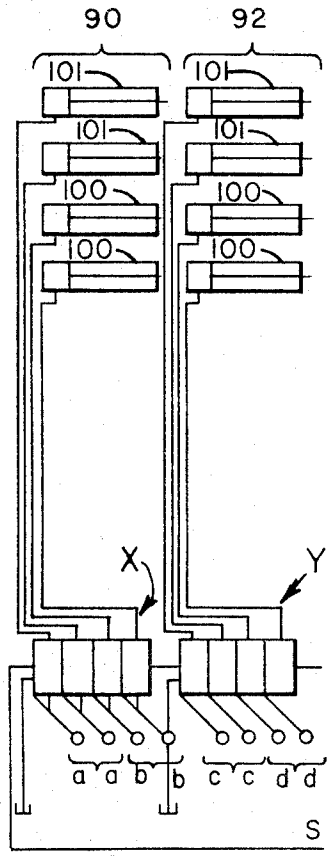
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FIG. 11

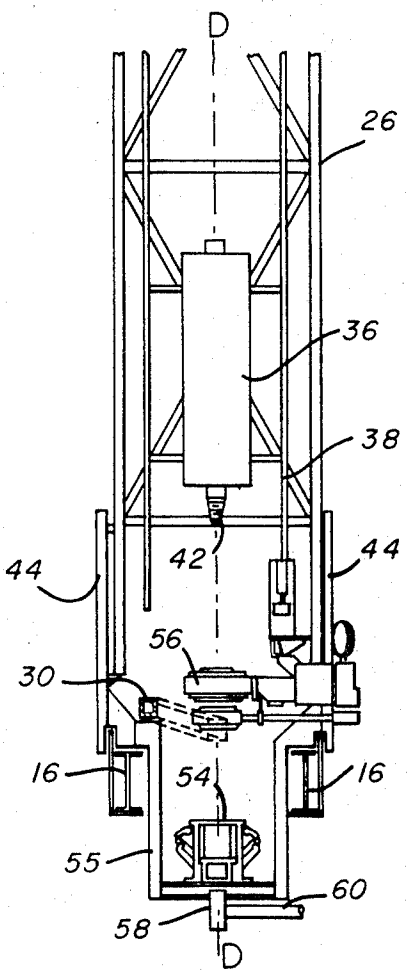
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FIG. 5

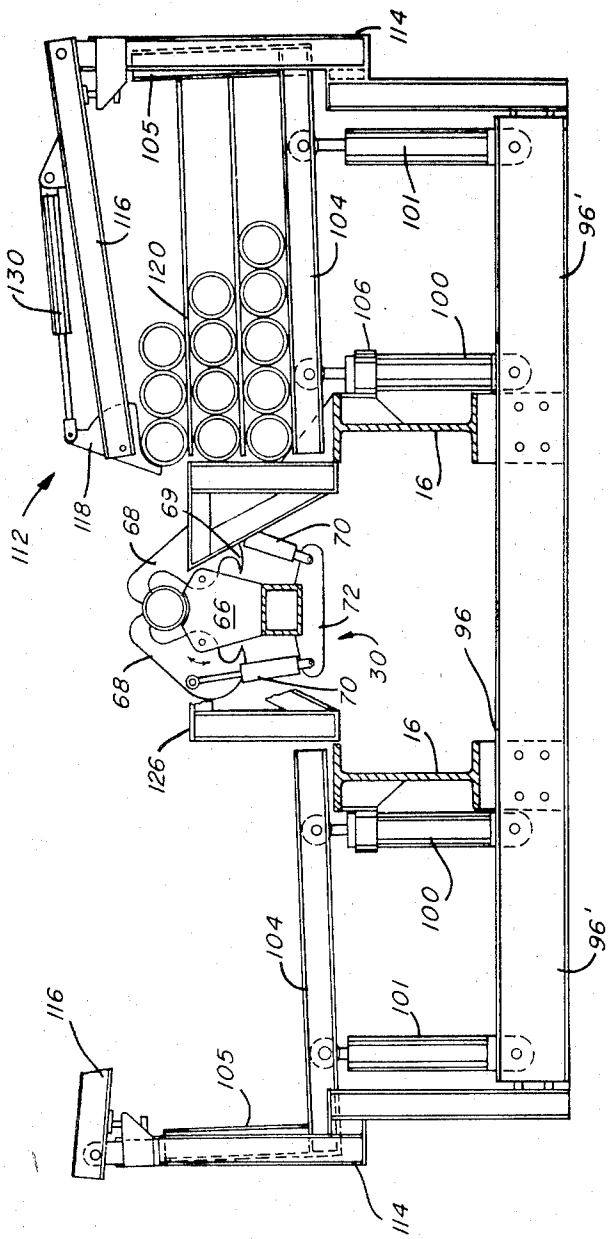
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FIG. 6

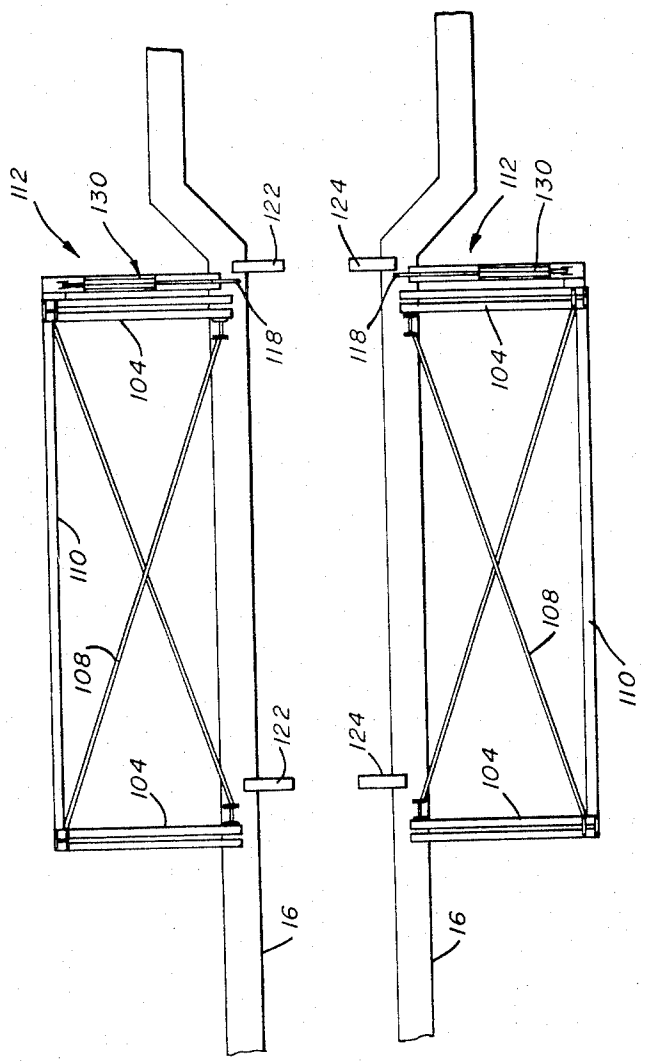
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FIG. 7

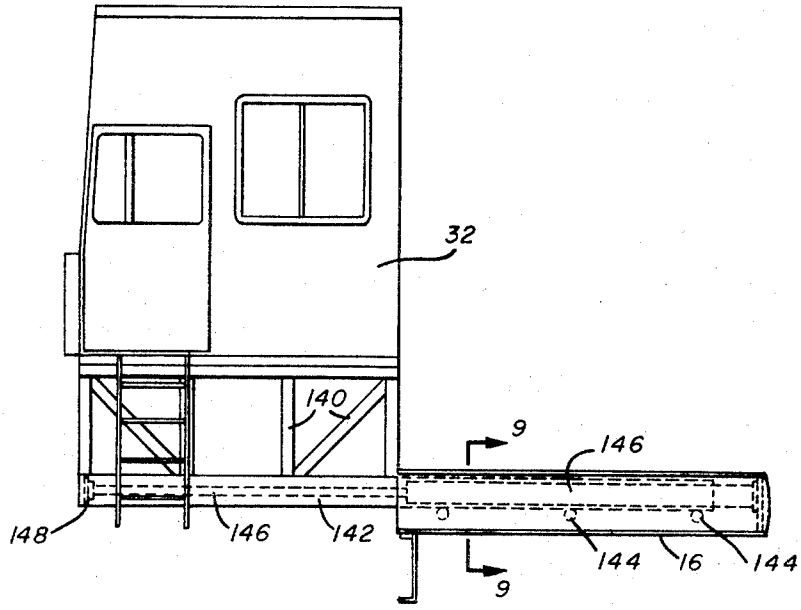

FIG. 8

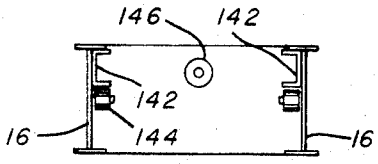

FIG. 9

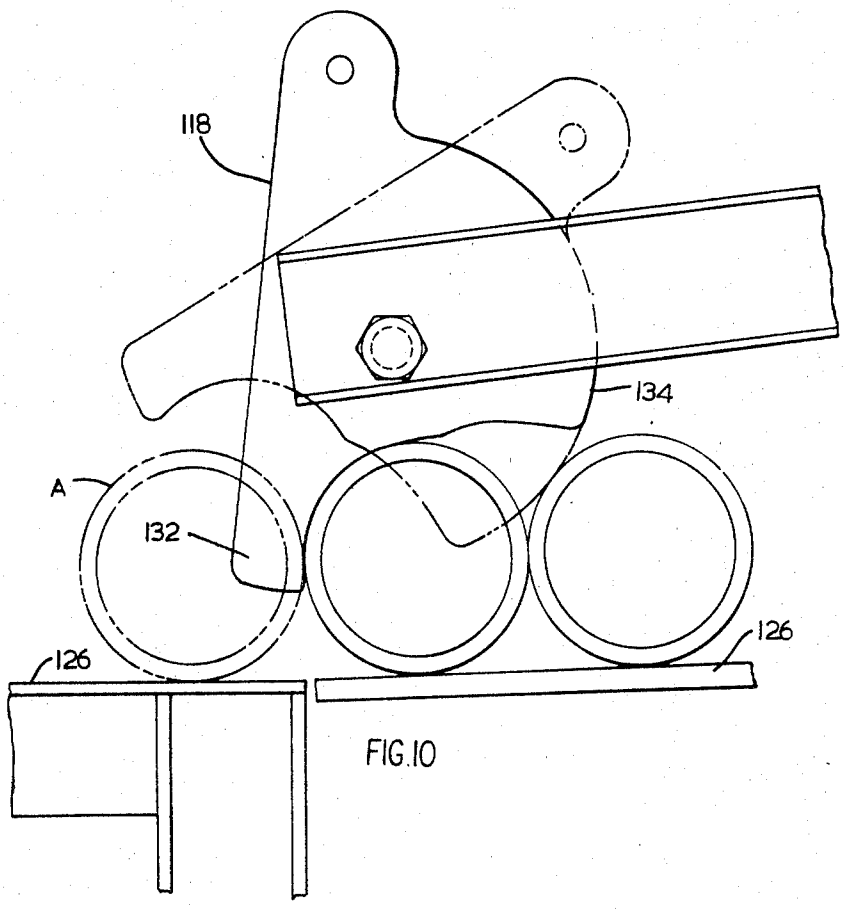

FIG. 10

CARRIER MOUNTED DRILLING UNIT

BACKGROUND OF THE INVENTION

This invention relates generally to improvements in apparatus for drilling wells particularly mobile well drilling apparatus. The apparatus is particularly suitable for drilling exploration holes or shallow production holes up to about 2,500 or 3,000 feet in depth, and for blast hole drilling.

One problem faced by manufacturers of mobile relatively light weight drilling equipment of the type under consideration is that of providing sufficient pressure on the drill bit when drilling shallow holes as to provide a reasonably fast rate of travel of the bit through the earth's crust. In large drilling rigs for drilling in the 3,000–10,000 feet hole depth range this does not constitute a major problem as the necessary pressure on the drill bit may be supplied by the weight of the relatively long drill string itself. However, in drilling machines specially adapted for shallow hole drilling (0–3,000 feet approximately) or in blast hole drilling, it has been found necessary to provide pull-down means for applying at least a portion of the weight of the entire drilling rig to the drill string and thus to the drill bit. Therefore, it is readily apparent that the greater the proportion of the weight of the entire drilling rig made available for applying downward thrust to the drill string, the greater the overall efficiency of the drilling apparatus. Since virtually all prior art mobile drilling equipment has utilized a design wherein the drilling axis is positioned at the rear, or occasionally at the front, of the machine they were capable of applying only a relatively small proportion of their weight to the drill bit. A major advance in the art came with the introduction of mobile drilling rigs having their components arranged such that the drilling axis thereof passes through or near to the center of gravity whereby to enable utilization of virtually all of the weight of the drilling unit to provide downward thrust on the drill string. Reference may be had here to the structure disclosed in Canadian Pat. No. 781,323 issued Mar. 26, 1968 and assigned to the assignee of the present invention. This patent discloses a lightweight drilling rig specially adapted for transportation from one drilling site to another by helicopter with the various components of the rig being arranged such that its drilling axis passes substantially through its center of gravity. In this way the drilling unit was made sufficiently light as to be transportable by helicopter and at the same time was capable of providing sufficient downward thrust on the drill bit as to provide for a reasonably fast drilling rate.

SUMMARY OF THE INVENTION

The present invention provides in a first aspect, a mobile drilling unit including an elongated mobile chassis and a drilling mast attached to the chassis and arranged for movement between a transport position and an operative drilling position. Means are included for rotatably supporting a drill string within the mast together with means for applying drawdown forces to the drill string support means. A drill pipe racking means and drill operating machinery are also mounted on the chassis. The racking means is capable of carrying a sufficient weight of drill pipe and the drilling machinery, drill mast and racking mans are arranged relative to one another such as to permit a major portion of the combined weight of the drilling unit and the weight of

the drill pipe on said racking means to be made available to produce downward thrust on the drill string when drawdown forces are being applied to the means for rotatably supporting the same i.e. the center of gravity of the entire system is at or near to the drilling axis.

It will be appreciated that as the depth of the hole increases during drilling, the drill pipe on the racking device will be gradually used up as additional sections are added to the drill string; as a result the center of gravity of the entire system will gradually be displaced away from the drilling axis. However, this does not create a problem, because as the hole becomes deeper the weight of the lengthening drill string becomes progressively greater with the result being that adequate downward thrust can be applied to the drill bit at all times. The need for the drilling axis to pass through the center of gravity of the drilling unit-racked drill pipe combination is greatest at the start-up of drilling operations when the length of the drill string is quite short. As the length of the drill string increases, the center of gravity of the racked drill pipe-drilling unit combination can shift away from the center of gravity of the system without creating any difficulty. Hence this aspect of the invention provides a self contained drilling unit, capable of carrying its own drill pipe and wherein the weight of the pipe is used to advantage particularly during the early stages of a well drilling operation. A further advantage of the above described arrangement wherein the racked drill pipe is supported on the drilling unit is that the drilling apparatus may be shifted from one drilling site to another while carrying its own drill pipe; there is usually no need for additional vehicles to carry the drill pipe. This reduces moving and set up costs and makes for a more economical operation. Since the weight of the drill pipe supported on the racks of the drilling unit is used to supply downward thrust to the drill bit, the overall weight of the remainder of the drilling unit is dictated solely by structural strength requirements i.e. there is absolutely no need to make the unit heavier than design requirements dictate solely for the purpose of providing additional weight to the unit which can be used to produce additional downward thrust on the drill.

As mentioned previously, prior art machines have been arranged such that the drilling axis is disposed at one end or other of the drilling unit for several reasons. In self-propelled mobile drilling units i.e. units including a power source connected by a drive train to one or more sets of propulsion wheels, the drive shaft and other various components of the drive train are located in the center section of the machine and thus would be in the way of any drilling mast and its associated equipment in this area. As a result there is a tendency to place the drill mast etc. at one end, preferably the rear end, of the unit.

The present invention provides, in a further aspect, for a major change in the positioning and arrangement of the various components of the drilling rig. The invention provides for the power source, the drive train and the propulsion wheels to be located adjacent one end of the chassis thereby leaving the central region of the chassis free of drive train components and the like. It is in this central region that the drill mast and its associated equipment is located.

Accordingly therefore, in a further aspect of the invention, there is provided a self-propelled mobile dril-

ling unit including an elongated chassis, sets of wheels mounted forwardly and rearwardly of said chassis, a drive engine mounted rearwardly on said chassis. Racking means are mounted on the chassis forwardly of said region in spaced relation therewith for storing lengths of drill pipe such that they extend longitudinally of the chassis. The drilling mast is connected to the chassis generally between the rearwardly disposed region and the racking means and is movable from an upright operating position to a downfolded position for transport, the drill mast including means for rotatably supporting a length of drill string therein. Means are included for rotating the drill string and supplying drawdown or lifting forces thereto. A drive train is positioned in the rearwardly disposed region and is adapted to provide an operable connection of the drive engine to either said rearwardly disposed set of wheels to effect propulsion of the drilling unit or to the means for rotating the drill string.

In accordance with a further aspect of the invention there is provided a mobile drilling unit including an elongated wheeled mobile chassis, a mast mounted on the chassis and means for rotatably supporting a drill string therein. The drill pipe racking area extends longitudinally of the chassis for storing lengths of drill pipe thereon and means are provided for pivoting lengths of drill pipe between the racking area and the mast for addition or withdrawal of the lengths of pipe from the drill string. An operator's station is mounted on the chassis and means are provided to support the station for movement from a first position for transportation of the drilling unit wherein the operator's station overlies a portion of the racking area to a second position displaced outwardly of the racking area whereby a ready access may be had to the latter for addition or withdrawal of drill stem as the case may be. In the preferred arrangement the supporting means is arranged such that the operator's station moves in a path parallel to the longitudinal axis of the chassis. The operating position of the operator's station during drilling is located outwardly, of the end of the elongated chassis.

By providing for a movable operator's station the required overall length of the mobile drilling unit is reduced. This is important because if the drilling unit as a whole is overly long it is unwieldy and difficult to handle particularly when travelling along public highways or the like. With the above described arrangement the mobile drilling unit need only be made long enough so as to accommodate the mast and its associated drill operating machinery and the drill pipe racking means. There is no need for the operator's station to take up additional space lengthwise of the drilling unit as it can overlie a portion of the drill pipe racking area during transportation and thereafter be displaced outwardly of the racking area during a drilling operation.

In accordance with a further feature of the invention there is provided a well drilling apparatus including a mast and means for rotatably supporting a drill string therein. This apparatus includes means for adding and withdrawing sections of drill pipe to and from the drill string including a pipe handling arm adapted to grasp and swing individual pipe sections between a generally upwardly directed position at or in the mast and a lower generally horizontal position. The apparatus includes storage means for the sections of drill pipe having a bed for supporting a plurality of layers of generally horizontally disposed pipe sections, the layers being in generally vertically stacked relation. Means are provided for raising or lowering the bed of the pipe storage means thereby to raise or lower the layers of pipe sections supported thereon to enable successive pipe layers to be positioned adjacent the lower, generally horizontal, position taken by the pipe handling arm. Means are provided for individually transferring the sections of pipe from the storage means at the level of said pipe layer to the pipe handling arm for engagement thereby and vice versa.

In the preferred arrangement the pipe storage means are adapted to tilt the bed such that the pipe sections tend to roll towards or away from the pipe handling arm during transferral of the pipe sections into or out of the storage means respectively. In the preferred arrangement the storage means includes a pair of beds located in spaced generally parallel relationship with one another on opposing sides of the lower position taken by the pipe handling arm, the pip handling arm being adapted to receive and grip a drill pipe transferred thereto from either bed.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Further aspects and advantages of the present invention will be apparent to those skilled in the art from a reading of the following description of a preferred embodiment of the invention with reference being made to drawings wherein:

FIG. **1** is an elevation view of the mobile drilling rig during a vertical drilling operation;

FIG. **2** is a plan view of the mobile drilling apparatus;

FIG. **3** is an elevation view of the mobile drilling apparatus showing the drill mast in down folded position and the operator's cab assembly in a retracted position overlying a portion of the drill stem racking area;

FIG. **4** is an elevation view of the mobile drilling apparatus illustrating the mast in an inclined position for inclined drilling operations;

FIG. **4A** illustrates drill stem hoisting and drawdown means;

FIG. **5** is a cross sectional view taken along line **5—5** in FIG. **2** and illustrating the make and break mechanism;

FIG. **6** is a cross sectional view taken along line **6—6** in FIG. **2** illustrating a portion of the pipe gripping means of the pipe handling arm together with the drill pipe racking means;

FIG. **6A** is a view of a portion of the structure shown in FIG. **6**;

FIG. **7** is a plan view of the pipe racking means;

FIG. **8** is an elevation view of the operator's cab and its support assembly;

FIG. **9** is a section view taken along **9—9** in FIG. **8**;

FIG. **10** is a detail view of a device for transferring drill pipe into and out of the racking means;

FIG. **11** is a schematic diagram of a portion of the hydraulic control circuit for the drill pipe rack beams.

GENERAL ARRANGEMENT

Referring now to the drawings it will be seen that the drilling unit **10** includes an elongated mobile chassis **12** supported for travel from one site to another on a plurality of wheels **14** having pneumatic tires mounted thereon. Chassis **12** comprises a spaced pair of elongated steel frame members **16** (which, in plan, have the configuration shown by the heavy dashed lines in FIG.

2) and suitable cross members and bracing members (not shown), all designed to give the chassis the necessary structural strength and rigidity. The chassis may be considered as being made up of three regions A, B and C which extend longitudinally of the chassis as shown in FIG. 2. Region "A" extends longitudinally of the chassis from the front end **18** thereof to a point roughly half way along the length of the chassis and defines a region wherein lengths of drill pipe are stored on suitable racking devices **20** provided for that purpose. Region "C" extends from the rear end **22** of the chassis towards region "A" but is separated therefrom by an intermediate region "B" which is relatively short in comparison with the length of region A or region C. Drill operating machinery **24** including a prime mover, compressor, pumps etc. is supported in region C while an elongated drill mast **26** (which is mounted for movement between a generally horizontal transport position and an upright operating position) and its associated equipment e.g. drill pipe make up and break out equipment **28**, are disposed in region B. A swinging pipe handling arm **30** conveys individual sections of drill pipe between a generally horizontal position in the drill pipe storage area and an upright position in mast **26** during drill pipe make up and break out operations. An operators' cab **32** is disposed adjacent the front end of the chassis and is mounted for limited movement longitudinally of the chassis in a fashion to be more fully described hereinafter. A plurality of hydraulic levelling jacks **33** are provided on the chassis to assist in levelling the drilling rig and providing support to same during a drilling operation.

As mentioned previously, the drilling unit is preferably designed such that at the commencement of a drilling operation, with a full complement of drill pipe disposed on racking devices **20** and the mast **26** in an operative position, the drilling axis D—D (as shown in FIGS. **1, 4** and **5**) passes substantially through the center of gravity of the entire system, the latter comprising the drilling unit together with the drill pipe on the racking means. In any event, it should be designed such that at least 70 percent of the total weight of the system, including the racked drill pipe, is available at start-up to produce downward thrust on the drill. Those skilled in the art will be able to make the necessary calculations to determine the total weight of the drill pipe which the racking devices **20** should be designed to carry at the commencement of a drilling operation as well as the weights of and the relative locations of the various items going to make up the drill operating machinery **24**, the drilling mast **26** and its associated equipment, as well as the chassis, the operators' cab (such cab being in the extended operating position shown in FIGS. 2 or 4) in order to effect placement of the center of gravity of the system properly relative to the drilling axis.

A notable advantage of the arrangement described above, with the racked drill pipe supported entirely on the drilling unit, is that the drilling apparatus may be transported from one drilling site to another while carrying its own drill pipe; there is usually no need for additional vehicles to carry the drill pipe. This reduces moving and set up costs and makes for a more economical operation.

As the depth of the drilled hole increases, with a corresponding increase in the length of the drill string, the center of gravity of the entire system will gradually shift away from the drilling axis. However, as mentioned previously, this does not create a problem because the weight of the lengthening drill string becomes progressively greater with the result being that adequate downward thrust can be applied to the drill bit at all times. It is at the commencement of drilling operations that the need for the center of gravity of the entire system to be positioned close to or at the drilling axis D—D is the greatest.

DRILL MAST

The drill mast **26** is of standard construction, i.e. it is constructed of steel members arranged to define an open lattice work-like structure which is light in weight but at the same time sufficiently strong as to enable it to perform in a satisfactory fashion. Mast **26** includes an open side **34** facing toward the drill pipe racking area whereby lengths of drill pipe may be carried into and out of the mast interior by means of the pipe handling arm **30.** The means provided for rotatably supporting the drill string within the mast comprises a power swivel **36** of any suitable construction mounted for movement longitudinally of the mast on spaced rails **38** (see FIG. **5**). A cable and pulley system including lifting and drawdown cables arranged to provide the required mechanical advantage is provided for applying lifting or drawdown forces to the power swivel **36** in the manner well known in the prior art. When a drawdown force is being applied to the power swivel **36** a corresponding lifting force is, of course, being applied to the drill unit. Since the drilling axis D—D along which the drill string passes is near to or coincident with the center of gravity of the entire system, virtually the entire weight of said system is applied to the drill string before the drill unit is lifted off the ground by the lifting force referred to above. A powered winch arrangement **40** e.g. a "Gearmatic" Series **40** winch, mounted on and adjacent the lower end of mast **26** tensions the lift or drawdown cables as required.

The drill mast **26,** the power swivel **36** and the means for moving same longitudinally of the mast are shown diagrammatically in FIG. **4A**, it being realized that the components shown are not in their usual proportions Prior art details, such as the means for guiding the power swivel longitudinally of the mast etc. are not shown. The powered winch **40** includes a single winch drum **150** which is driven in either direction by winch drive assembly **152.** In order to hoist the power swivel **36** upwardly a hoisting line **154** (shown as a solid line) is provided which has its one end connected adjacent one end **150*a*** of the hoisting drum while its opposing end is firmly anchored at **158** to a fixed point on the drilling unit. Hoisting line **154** passes upwardly from winch drum **150** over fixed sheave **160** then around sheave **162** on power swivel **36,** around sheaves **164,** down around sheave **166** and then over sheave **168** and then down to the anchor point **158.** The hoisting arrangement just described is a "four string" arrangement in that a mechanical advantage of four is provided. The power swivel drawdown arrangement also is a "four string" arrangement. The drawdown cable **170** (shown as a dashed line) is connected at its one end to winch drum **150** adjacent end (**150**a) of the latter, and at is other end to an anchor point **176** fixed to the drilling unit. Between these points the cable passes over and around sheaves **171, 172, 173, 174, 175** (sheaves **173** and **175** being mounted on power swivel **36**) and

then down to anchor point **176.** The drawdown and hoist cables **170** and **154** are arranged such that as winch drum **150** is rotated, one of said cables wraps on the drum in a single layer while the other cable unwraps therefrom thus ensuring equal rates of pay out and take up of the two cables at all times thus causing the power swivel to move upwardly or downwardly within the mast **26** to effect lifting or drawdown of the drill string as required.

The power swivel **36** includes suitable hydraulic motors therein to rotatably drive threaded nipple **42** mounted therein, the latter being adapted to screw into the upper end of a drill string and effect rotation thereof, all as well known in the art. Suitable connections to the power swivel **36** are provided to supply hydraulic fluid thereto and to supply drilling fluid to the interior of the drill string and thence to the drill bit.

The mast **26** is supported at its lower end by means of a spaced pair of arms **44** which flank the lower end of the mast. Arms **44** are each pivotally connected to chassis member **16** by pivotal connections **46** with the angle of inclination thereof being determined by the degree of extension of a pair of telescoping braces **47** each interconnected between a respective one of the arms **44** and its associated frame member **16.** When the braces **47** are partially retracted or telescoped, arms **44** assume an inclined position with the mast **26** also taking a similar inclination thereby to permit inclined drilling to take place as shown in FIG. **4.** The mast **26** is connected to arms **44** by way of groove defining guides **50** which extend along opposed sides of the mast from the lower end thereof to about half way along its length. The grooves of guides **50** engage with pin means **52** mounted in the upper ends of arms **44.** To assist in raising and lowering the mast **26,** it is convenient to provide a pair of hydraulic rams **48** (one being shown in FIG. **3**). When the mast is to be raised, it is slid rearwardly and the end **48***a* of each ram is connected to mast **26** at points **48***b* and the ram actuated to cause the mast to pivot upwardly. Lock bolts **55** extending through arms **44** and into mast **26** are used to effect engagement between the lower portion of both the mast and arms **44** when the mast has been aligned with arms **44.** When the equipment is being readied for highway travel, lock bolts **55** are withdrawn, the mast is pivoted around to the horizontal position shown in FIGS. **3,** hydraulic rams **48** are disconnected and the mast is slid forwardly until pin means **52** reach the ends of the groove defined by guides **50,** at which point the top of mast **26** is in the most compact travelling configuration. The end of mast **26** is attached to mast support leg **51** during travelling to prevent oscillation of the mast.

DRILL STRING MAKE UP AND BREAK OUT MECHANISM

The drill string make up and break out means **28** is located at the base of the mast **26** and is mounted such that it pivots about the axis defined by pivot pins **46** together with mast support arms **44** as illustrated in FIG. **4.** The make up and break out system **28** includes a set of conventional air pressure operated slips **54** (FIG. **5**) which are supported by slips support frame **55.** Slips **54** are aligned with the drilling axis and are adapted to releasably grip the upper end of the drill string to support the latter within the drill hole. A set of power tongs **56** of any suitable commercially available variety (e.g. "Foster" Power Tongs) are disposed above the slips **54,** and are adapted to engage and rotate the drill stem to loosen or tighten the threaded joints between the drill pipes during drill string make up or break out. Tongs **56** are mounted on a torque arm **59** in conventional manner. Below slips **54** is a drilling nipple **58** through which the drill string passes; flow line **60** is connected to nipple **58** for use in the usual fashion. Those skilled in the art will realize that the nipple **42** of the power swivel **36,** the power tongs **56,** the slips **54** and drilling nipple **58** are all in alignment with each other along the drilling axis D-D.

PIPE HANDLING ARM

The drill pipe handling arm **30** is pivotally connected to the chassis **12** at pivot point **61** which is adjacent the foot of the mast and near to or aligned with the axis defined by pivot pins **46.** Handling arm **30** is adapted for movement in a vertical plane between a substantially horizontal position in the drill pipe racking region "A" and a generally upright position in the drill mast **26** to permit the nipple **42** of the power swivel to screw into or out of the upper end of a length of drill pipe engaged by the pipe handling arm. Pivotal movement of arm **30** is effected by the elongated hydraulic cylinder **60** which is pivotally connected at its one end to the chassis and at its other end at **62** to arm **30.** A suitable hydraulic system (not shown) connected to cylinder **60** is used to effect control of the movement of the pipe handling arm. Arm **30** is provided with a spaced apart pair of clamps **64** for grasping individual sections of drill pipe. Each clamp **64** (see FIG. **6**) includes a seat member **66** rigidly connected to the arm proper. Pivotally connected to opposing sides of seat **66** are a pair of jaws **68,** the movement of each of which is controlled by respective one of two hydraulic cylinders **70,** each of the latter being interconnected between rigid member **72** affixed to arm **30** and its associated jaw **68.** When jaws **68** are closed, the pipe is securely clamped against seat **66.** However, when one jaw or the other opens, jaw portion **69** (FIG. **6**) engages the underside of the pipe and lifts it out of seat **66** with the result being that the pipe rolls away from that side of the handling arm on which jaws **68** have opened. This action is clearly illustrated in FIG. **6A,**

PIPE RACKING AND TRANSFER SYSTEM

As mentioned previously, the drill pipe racking area is located in region "A" as seen in FIG. **2.** The racking device actually comprises two parallel racks **90** and **92** which extend longitudinally of the chassis in laterally spaced relation to one another to define therebetween a longitudinally extending well **94** within which the pipe handling arm **30** is received when it is in the lower, generally horizontal, position. The pipe racks are supported on a pair of transversally extending beams **96, 98** (FIG. **3**) spaced longitudinally of and connected beneath the main chassis members **16.** The opposing ends **96' 98'** of each beam **96, 98** project laterally outwardly of the main chassis members, and each of these end portions **96' 98'** carries a spaced pair of upright hydraulic jacks **100, 101** (FIG. **6**). Each pair of jacks is pivotally connected to an associated rack beam **104.** A longitudinally spaced pair of rack beams **104** serve to define the bed of each pipe rack. Actuation of the jacks **100, 101** serves to raise or lower the rack beams **104** in the manner to be hereinafter described. In order to promote stability of the pipe racks **90, 92** the jacks **100**

nearest the main chassis members **16** are connected thereto by suitable clamps **106** and the two rack beams **104** of each rack **90** and **92** are connected together by cross braces **108** and brace **110** as shown in FIG. **7.** As seen in FIG. **6** several layers of the drill pipe are supported on each of the racks **90** and **92**; the layers are separated from one another by suitable spacers **120** so that the pipe sections can roll towards or away from the longitudinal center line of the vehicle depending upon the direction of inclination of the associated pairs of rack beams **104.** In order to prevent the pipe sections from rolling off the rack beams **104,** upright posts **105** are rigidly connected to the outer end of each beam as best seen in FIG. **6** against which the pipes bear. Each rack **90, 92** further includes respective shelves **122, 124** secured to the machine chassis and arranged in flanking relation to the well **94** between racks **90, 92** as best seen in FIGS. **6** and **7.** Shelves **122, 124** serve to rollingly support lengths of pipe as the latter are transferred between the handling arm **30** and the respective racks **90** and **92** and for this purpose they are provided with short, horizontal support zones **126**(FIGS. **6, 6A,10**) located just below the elevation taken by a pipe section when the latter is engaged in handling arm **30** with the latter in its lower loading or unloading position.

Associated with each rack **90, 92** is a pipe transfer assembly **112** each of which includes an upright support post **114** mounted on the outermost end of beam portion **96'** (FIG. **6**) to which is connected a support arm **116** extending across the width of the rack and having a pipe flipper **118** pivotally connected to the free end thereof closely adjacent the well within which the pipe handling arm is received. Each pipe flipper **118** is adapted to individually engage each pipe section during the process of transferring the sections into or out of the racks. Referring to FIGS. **6** and **10** it will be seen that pivotal movement of each flipper **118** is effected by an air cylinder **130** mounted on support arm **116** to effect pivotal motion of the flipper between the dotted and full line positions thereof seen in FIG. **10.** The flipper element includes a finger portion **132** which (a) serves to engage a section of the drill pipe delivered thereto from the handling arm and push same into its associated rack and (b) serves to release a pipe section from the rack so that the section may roll towards the handling arm **30** for engagement thereby. Flipper **118** also includes arcuate portion **134** angularly spaced from finger **132** which engages the pipe section next to the one being transferred into the handling arm **30** and prevents it from rolling towards the pipe handling arm i.e. more than one pipe rolling toward the handling arm at any one time is prevented.

In order to effect raising or lowering of the rack support beams **104** so as to bring each layer of drill pipe up to the level of the shelf means **126,** and further to effect tilting of the rack beams **104** so that the individual sections roll towards or away from the pipe handling arm **30,** a suitable hydraulic control system is provided. The hydraulic control system is devised such that, when considering one racking area, rack **90** for example, all four hydraulic jacks **100, 101,** can be actuated simultaneously so as to lift both racking beams **104** and the drill pipe layers supported thereon by an equal distance. In addition, the hydraulic system should permit the two outer hydraulic jacks **101** to be actuated independently of the two inner hydraulic jacks **100** thereby to permit the racking beams **104** to be tilted in the same direction. For example, beams **104** may be tilted so that the sections roll towards the pipe handling arm **30** i.e. towards the elongated well **94** between the two pipe racks **90** and **92.** This action is necessary when "going into the hole" i.e. when the pipe sections are being removed from the racks and connected together into a drill string. Alternatively it is necessary to tilt the rack beams **104** so that the individual pipe sections roll away from the pipe handling arm **30**(see FIG. **6A**) when coming "out of the hole" i.e. when the drill string is being broken up into pipe sections and stored in the racking areas. A typical hydraulic system capable of performing as mentioned above is shown in the schematic diagram of FIG. **11** wherein there is illustrated a source of hydraulic pressure "S" connected to two banks of hydraulic control valves X and Y the latter being connected individually to the hydraulic jacks **100, 101** as shown. Bank X controls rack beams **104** of racking area **90** (on the right hand of the machine) while bank Y controls the rack beams on the opposite side of the machine in racking area **92.** Each bank of control valves has four valve actuating levers, one for each hydraulic jack **100, 101.** However, since one usually desires to operate the hydraulic jacks in pairs to effect bed tilting or all four in unison to raise or lower the beds, suitable means (not shown) may be provided to link pairs of the valve actuating levers together to permit actuation of two hydraulic jacks **101** or **100** together to effect tilting motion of the rack beams **104** in unison; suitable means may also be provided to facilitate actuation of all four jacks together to effect raising and lowering in unison of both rack beams **104** as described above.

OPERATORS' STATION

As mentioned previously the operators' station **32** is mounted on the front end of the chassis **12** in such a way that the station is supported for movement from a first position for transportation of the drilling unit with the station overlying the end portion of the racking area **20** to a second operating position displaced outwardly of the end of the racking area whereby ready access may be had to the racking area for addition or withdrawal of drill pipe as the case may be. The operating position of the operators' station **32** is illustrated in FIGS. **1, 2, 4** and **8.** FIG. **3** illustrates the operators' station **32** in the retracted position overlying an end portion of the racking area **20.** With this arrangement the overall length of the drilling unit can be reduced when the drilling unit is travelling along public highways or the like. The chassis need thus be made only long enough so as to accommodate the mast, its associated drill operating machinery and the drill pipe racking means **20.** Referring particularly to FIGS. **8** and **9** it will be seen that the operators' station **32** includes a suitable housing or cab which contains, a steering wheel and other controls so that the operator may control the movement of the drilling unit over public highways. The operators' cab is not usually used to house the operators' console used to effect control of the various components of the drilling unit during a drilling operation. This control console (not shown) may conveniently be mounted on the side of the drilling unit just forwardly of the mast so that the operator can easily see the components of the machine in operation. The cab, per se, may be of any well known construction and fur-

ther details of same need not be given here. The cab is mounted on a suitable framework **140** which includes a pair of spaced generally parallel support beams **142** which extend beneath and project rearwardly of the cab unit for a substantial distance. Support beams **142** are spaced apart a distance just slightly less than the spacing between the main chassis members **16** with each of the support beams **142** being located immediately inwardly of a corresponding one of the chassis members **16** in slidable relation therewith as shown in FIGS. **8** and **9.** In order to provide for ease of movement of the operators' station **32** from the advanced position to the retracted position shown in FIG. **3** and vice versa, a plurality of rollers **144** are mounted on spaced stub shafts secured to the main chassis members **16** and project inwardly from the inner face of the web of each chassis member as shown in FIG. **9.** These spaced rollers **144** serve to rollingly support the support beams **142.** In order to positively shift the operators' station from the retracted position for travelling to the advanced operating position, an elongated hydraulic jack **146** is provided which extends parallel to the longitudinal axis of the chassis and is connected at one end to a transversely extending frame member which interconnects support beams **142** together and at its other end to a transverse frame member interconnecting main chassis members **16.**

DRILL OPERATING MACHINERY

The previously mentioned drill operating machinery **24** includes a prime mover (e.g. a G.M. 12V–71) diesel engine **74** connected to chain case **76.** Chain case **76** has an output connected to air compressor **78** (e.g. an Atlas Copco DR 418 or equivalent) and another output connected to transmission **80** (e.g. an Allison TG–64T transmission) via drop box **82.** The transmission output may be connected, upon selection, to drive either the rear tandem wheels of the machine via drive shaft **84**(FIG. **3**) or the hydraulic pumps **86** which, among other things, supply power to the power swivel **36** to effect drill string rotation, or for the winch system for effecting lifting or drawdown of the power swivel **36.** A mud pump **88** is also driven from chain case **76.** Suitable clutch means (not shown) are provided in the above described power train to permit individual ones or groups of the above mentioned units to be driven at any one time by the prime mover as desired.

It will be seen from the above that since the power source and drive train, including drive shaft **84** and the rearwardly disposed propulsion wheels, are located adjacent the rear of the drilling unit in region C, the central region of the drilling unit, particularly region B wherein the drilling mast and its associated equipment are located, is completely free of drive train components for propelling the mobile drilling unit. This is in contrast to prior art machines which generally have the drive shaft and other various components of the drive train located in the center section of the machine thus placing them in the way of any drilling mast and its associated equipment in this area and necessitating placement of the latter at one end or the other of the drilling unit.

OPERATION OF DRILLING UNIT

The operation of the drilling unit will probably be self-evident from a reading of the above. However, to assist those skilled in the art, a brief description of the operation of the device will now be given. After the drilling unit has been located at the desired drilling site and properly levelled, the mast **26** is swung to the vertical operating position shown in FIG. **1**; or alternatively if drilling on an incline is to take place the mast is swung to the inclined position shown in FIG. **4.** The operators' station is advanced, by actuation of hydraulic cylinder **146,** to the operating position shown in FIGS. **1** and **4.**

At the commencement of the drilling operation it will be recalled that since the racking means **20** contains a full complement of drill pipe, the drilling axis passes substantially through the center of gravity of the entire system so that a major portion of the weight of the entire system is made available to produce downward thrust on the drill bit when drawdown forces are being applied to the power swivel **36.** The hydraulic jacks **100** and **101** are actuated relative to one another so that the rack support beams **104** are tilted inwardly toward the center line of the machine so that the individual pipe sections tend to roll toward the pipe handling arm **30.** The hydraulic jacks **100, 101** are actuated in unison thereby to bring the uppermost layer of drill pipe to a level just slightly above the upper level of the shelf means **126** as illustrated in FIGS. **6** and **10.** The pipe handling arm **30** is then swung by virtue of the action of hydraulic cylinder **60** to its lower horizontal loading position as shown in FIG. **6** and the appropriate set of hydraulic cylinders **70** are actuated so as to cause one jaw **68** of each of the two clamping devices **64** to swing open thereby to enable the pipe handling arm **30** to receive a section of drill pipe. The air cylinder **130** is then actuated so as to cause the flipper **118** to rotate clockwise as shown in FIG. **10** with the result being that a single section of pipe rolls over the spaced pair of shelf defining means and onto the pipe handling arm **30.** The jaws **68** are then closed to securely clamp the pipe section and the pipe handling arm **30** is pivoted upwardly through a vertical plane into the open side of drilling mast **26.**

The power swivel **36** is then actuated to cause the threaded nipple **42** thereof to screw into the upper internally threaded end of the pipe section. The power tongs **56** and the power slips **54** are held in a retracted or open position so that a drill bit which is attached to the lowermost end of this first section of drill may be passed downwardly therethrough. The jaws **68** of the handling arm **30** are released and rotation of the drill pipe is effected while drawdown forces are applied to the power swivel **36** thus causing the drill to penetrate the earth. Drilling then continues until the upper end of the first section of drill pipe is located between the level of the power tongs **56** and the slips **54.** Rotation of the drill pipe is stopped at this position and the power slips **54** may then be closed to support the drilling pipe extending downwardly into the bore hole. The nipple **42** of the power swivel **36** is then screwed out of the upper end of the drill pipe by reversing its direction of rotation and the power swivel **36** is raised by the drawworks to a level above that of the top of the next section of drill pipe to be added. When the power swivel **36** has been raised to its upper position, the pipe handling arm **30** pivots upwardly while grasping a new section of drill pipe and positions it in alignment with both the section of drill pipe in the bore hole and the threaded nipple **42** of power swivel **36.** The power swivel then engages the upper end of the new section

of drill pipe and the stem handling arm **30** again pivots downwardly as before after disengaging from the new section. The new section of the drill pipe is then lowered into position by the power swivel for its threads to engage matching threads on the section in the bore hole and rotation of the new pipe section is effected to start the joint between the pipe sections with the power tongs **56** then being advanced to close around the drill string to securely tighten the threaded joint between the two pipe sections to the required degree. Power slips **54** are then disengaged and rotation of the drill string by means of the power swivel **36** is effected with drawdown forces again being applied thereto until the upper end of the second section is between the levels of the power tongs **56** and slips **54.** The above described operation is repeated over and over again until the desired hole depth is achieved.

In removing the drill string from the bore hole essentially the reverse procedure is utilized. The drill string is raised by elevating the power swivel **36** until the joint between the uppermost and the next section of drill pipe is below the power tongs **56** and above slips **54.** Slips **54** are then engaged to support the drill string in the bore hole and the pipe handling arm **30** is raised to the upright position and the uppermost section of drill pipe securely clamped by clamp means **64** thereon. The power tongs **56** are advanced and closed around the section of pipe just above the joint and the pipe is rotated thereby just sufficiently to disengage the uppermost section from the drill string then in the hole. The power swivel **36** is operated in a reverse direction to disengage its threaded nipple **42** from the upper end of the pipe section. The pipe handling arm which has engaged the pipe then swings downwardly to the horizontal position; the appropriate set of jaws **68** are swung open and the disengaged section rolls downwardly onto the shelf means and thence into the appropriate racking means. Just before the pipe reaches the racking means, the flipper **118** is actuated so that it occupies the dotted line position shown in FIG. **10.** When the pipe section reaches the dotted line position A shown in FIG. **10** the air cylinder **130** is actuated to pivot the flipper **118** counterclockwise with the result being that it is positively pushed into the appropriate racking area. Little force is required here since at this time the appropriate set of hydraulic jacks has been actuated to tilt the rack support beams **104** so that the sections tend to roll away from the center line of the machine towards the upright posts **105** as seen in FIGS. **6** and **6A.** When a complete layer of drill pipe has been placed on one of the drill racks, the hydraulic jacks **100, 101** supporting the rack beams **104** of same are lowered in unison and thin spacer members **120** are positioned on top of the newly added layer after which a new layer of pipe is added. The above described process is repeated until all of the drill string has been removed from the bore hole.

It is to be understood that the above disclosure of the preferred embodiment of the invention has been made only by way of example and that numerous changes in the details of construction and the combination and arrangements of parts may be resorted without departing from the spirit and the scope of the invention as hereinafter claimed.

I claim:

1. A self-propelled drilling unit comprising an elongated chassis, sets of wheels mounted forwardly and rearwardly of said chassis, a drive engine mounted in a region disposed rearwardly of said chassis, on said chassis forwardly of said rearwardly disposed region in spaced relation therewith for storing lengths of drill pipe such that they extend longitudinally of said chassis, a drilling mast connected to said chassis generally between said rearwardly disposed region and the racking means and movable from an upright operating position to a downfolded position for transport, said drill mast including means for rotatably supporting a length of drill string therein, means for rotating a drill string supported in said mast and supplying drawdown or lifting forces thereto, means for adding and removing lengths of drill pipe from a drill string supported in said mast including means for shifting individually said lengths of drill pipe between said racking means and said mast, and a drive train positioned in said rearwardly disposed region and adapted to provide an operable connection of said drive engine either to said rearwardly disposed set of wheels to effect propulsion of the drilling unit or to the means for rotating the drill string.

2. The self-propelled portable drilling unit according to claim **1** wherein the forwardly disposed set of wheels is steerable to effect directional control of the vehicle.

3. A mobile drilling unit comprising: an elongated mobile chassis, a drilling mast attached to said chassis and arranged for movement between a downfolded transport position and an operative drilling position, means in said mast for supporting a string of drill pipe parallel to the mast and within a drill hole during a drilling operation, means acting between the drilling unit and the means for supporting the string of drill pipe for applying drawdown forces to the drill string to enable at least a portion of the weight of the drilling unit to be applied to produce downward thrust on the drill string during the drilling operation, a drill pipe racking means supported on said chassis, drilling machinery also mounted on said chassis, said racking means being capable of carrying a sufficient weight of drill pipe and the spacing and the locations of the drilling machinery, drill mast and racking means relative to one another on said chassis being such as to permit a major portion of the combined weight of said drilling unit and the weight of the drill pipe on said racking means to be available during the initial stages of a drilling operation to produce downward thrust on the drill string when said drawdown forces are being applied to the means for supporting the drill string, said drill pipe racking means being supported on a first longitudinally extending region of said chassis, said drilling machinery being mounted on a second region of said chassis longitudinally spaced from said first region, and said drill mast being located generally intermediate said first and second regions.

4. The drilling unit according to claim **3** wherein the drill pipe racking means is arranged to support lengths of said drill pipe such that they extend longitudinally of said chassis.

5. The drilling unit according to claim **3** wherein said drill pipe racking means is constructed and positioned on said chassis such that when the racking means has a full complement of drill pipe thereon the center of gravity of the drilling unit together with the drill pipe on the racking means is sufficiently close to said drilling axis defined by the string of drill pipe as to make at least 70 percent of the total weight of the drilling unit-

racked drill pipe combination available to produce downward thrust on the drill string.

6. The drilling unit according to claim **3** further comprising means for transferring sections of drill pipe between said drilling mast and said racking means.

7. A mobile drilling unit including an elongated wheeled mobile chassis, a mast mounted on the chassis and means in said mast for supporting a drill string within a drill hole during a drilling operation and effecting drilling movement thereof, a drill pipe racking area extending longitudinally of said chassis for storing lengths of drill pipe thereon, means for pivoting individual lengths of drill pipe between said racking area and said mast during addition or withdrawal of the pipe lengths to or from the drill string, an operator's station mounted on said chassis, and means supporting said station for movement from a first position for transportation of the drilling unit overlying a portion of said racking area to a second operating position displaced outwardly of the racking area whereby ready access may be had to lengths of drill pipe lying in the racking area.

8. The drilling unit according to claim **7** wherein the station supporting means is arranged such that the station moves in a path parallel to the longitudinal axis of said chassis.

9. The drilling unit according to claim **8** wherein said supporting means is arranged such that said second position is disposed outwardly of the end of said elongated chassis.

10. The drilling unit according to claim **9** further including means for positively shifting said station from said first position to said second position.

11. The drilling unit according to claim **10** wherein the operator's station is defined by an at least partially enclosed cab.

12. The drilling unit according to claim **10** wherein said shifting means includes hydraulic cylinder and ram means.

13. The drilling unit according to claim **10** wherein the supporting means includes means rollingly supporting the operator's station for easy movement in its path of travel.

14. Apparatus for drilling wells comprising a mast and means in the mast for supporting a drill string and effecting drilling movement thereof during a drilling operation, means for adding and withdrawing sections of drill pipe to and from the drill string including a pipe handling arm adapted to grasp and swing individual pipe sections between a generally upwardly directed position at or in said mast and a lower generally horizontal position, and storage means for said sections of drill pipe including a bed for supporting a plurality of layers of generally horizontal pipe sections in stacked relation, means for raising or lowering said bed to raise or lower the layers of pipe sections supported thereon to enable a selected one of said layers to be positioned adjacent said lower generally horizontal position taken by the pipe handling arm, and means for individually transferring the pipe sections between said bed and said pipe handling arm when the latter is in said lower generally horizontal position.

15. Apparatus according to claim **14** wherein said storage means includes a pair of said beds for supporting said drill pipe, said beds being in spaced generally parallel relation to one another on opposing sides of said lower position taken by said pipe handling arm, the latter being adapted to receive and grip drill pipe transferred thereto from each one of said beds.

16. Apparatus according to claim **14** wherein the drilling apparatus is mobile, and includes an elongated mobile chassis, the bed of the pipe storage means being mounted on said chassis and arranged to support said drill pipe in parallelism with the longitudinal axis thereof, said mast and said pipe handling arm also being mounted on said chassis with said pipe handling arm adapted to pivot each said drill pipe through a vertical plane extending between said upwardly directed position and said generally horizontal position.

17. Apparatus according to claim **14** wherein said storage means are further adapted to tilt said bed such that the sections tend to roll toward or away from said pipe handling arm during transferral of said sections into or out of said storage means respectively.

18. Apparatus according to claim **17** wherein the means for transferring the drill pipe sections are adapted to transfer individual pipe sections into or out of the uppermost layer of pipe in said stack.

19. A mobile drilling apparatus comprising: an elongated mobile chassis, a drill mast connected to said chassis and adapted to be folded downwardly during transportation, means for rotatably supporting a string of drill pipe within the mast, said last mentioned means being movable longitudinally of said mast, means for adding and withdrawing sections of drill pipe to and from the drill string including a pipe handling arm for engaging and swinging individual sections of drill pipe between a loading and unloading position and a position in said mast for addition or withdrawal of the sections to or from the drill string, a rack for supporting said drill pipe such that said pipe extends longitudinally of the chassis, said rack being mounted on said chassis and supported thereby such that said chassis bears the full weight of said rack and the drill stem thereon, means for transferring individual pipe sections between said arm and said rack at the loading and unloading position, and wherein the drilling apparatus further includes drilling machinery including drill string drive means mounted in a first region extending longitudinally of said chassis adjacent one end thereof, said rack for supporting drill pipe being disposed in another region spaced longitudinally of the chassis from said first region with said drill mast being connected to said chassis intermediate said rack and said drilling machinery.

20. Apparatus according to claim **19** wherein said rack comprises a pair of sections spaced transversely of said chassis to define a region therebetween wherein said arm is received at said lower loading position, said arm being adapted to grip pipe transferred thereto from each one of said rack sections.

21. Apparatus according to claim **20** wherein said rack is adapted to rollingly support a layer of the drill pipe thereon and wherein the rack includes a tilting bed arranged to cause the pipe sections to roll under the influence of gravity towards or away from the transferring means during addition or withdrawal respectively of drill pipe from the drill string.

22. Drilling apparatus comprising a mast having means for supporting a drill string therein and effecting drilling motion thereof during a drilling operation and a pipe rack for supporting lengths of drill string generally horizontally, said rack comprising a pair of pipe support beds parallel to and spaced apart from one an-

other and a pipe handling arm adapted to pivot from a first position between said beds to a second position at or in said mast for transferring individual lengths of the pipe between said first and second positions, said pipe handling arm having pipe clamps thereon each comprising a seat and a pair of pivoting jaws on opposing sides of the clamp for holding pipe on said seat and means for removing a pipe from said seat constructed and arranged such that upon opening of said jaw the pipe is caused to roll away from that side of said arm on which the jaws have opened, means for supporting a rolling pipe between said arm and each one of said beds and means for individually engaging each rolling pipe section to move some positively into said bed.

23. Apparatus according to claim **22** wherein the means for removing the pipe from the seat comprises a portion on each jaw arranged to contact and lift said pipe from said seat upon opening of said jaw to cause the lifted pipe to roll away from that side of the arm on which said jaws have opened, the means for supporting the pipe between said arm and each of the beds comprising shelves located adjacent the first position taken by said pipe to rollingly support the pipe.

24. Apparatus according to claim **23** wherein the means for individually engaging each rolling pipe section comprises pipe flipper elements disposed adjacent said shelves for engaging and shifting rolling sections of pipe into said bed.

25. Apparatus according to claim **24** wherein said pipe support beds are adapted to support a plurality of layers of pipe in stacked relation and include means for raising or lowering said beds to permit the layers of pipe to be brought to the level of said shelves.

26. Mobile drilling equipment comprising an elongated mobile chassis in combination with and supporting the apparatus of claim **25**, said pipe support beds being parallel to the longitudinal dimension of the chassis.

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