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173/46, 173/57, 173/147, 175/171, 175/332

[51] Int. Cl.E21b 3/02

[58] **Field of Search**173/28, 43, 46, 57; 175/171

[56] **References Cited**

UNITED STATES PATENTS

2,255,241	9/1941	Brown.....	173/43 X
3,463,245	8/1969	Wataha.....	173/43
3,390,730	7/1968	Techy et al.	175/171
2,001,502	5/1935	Satre.....	173/46 X

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[57] **ABSTRACT**

A rotary drilling machine has first and second frames connected by rotary bearing means to rotate on a first axis perpendicular to the frames. A mast assembly is carried by the second frame and rotates on the first axis. In the mast assembly is a moveable platform carrying a drill pipe and casing fixture. The casing fixture releasably supports a casing. Supports in the mast assembly permit the drill pipe and casing to move up and down together, or to permit the casing to move independently of the pipe and core or vice versa. A hollow core in the drill pipe rotates with the pipe and feeds fluid to a drilling area. The fluid is drawn up between the casing and drill pipe. A rotary joint structure connects the first frame to rotatable carrier of a gantry and draw works to rotate on a horizontal second axis. Moveable supports in the first and second frames permit the mast assembly and second frame to move longitudinally with respect to the first frame.

20 Claims, 12 Drawing Figures

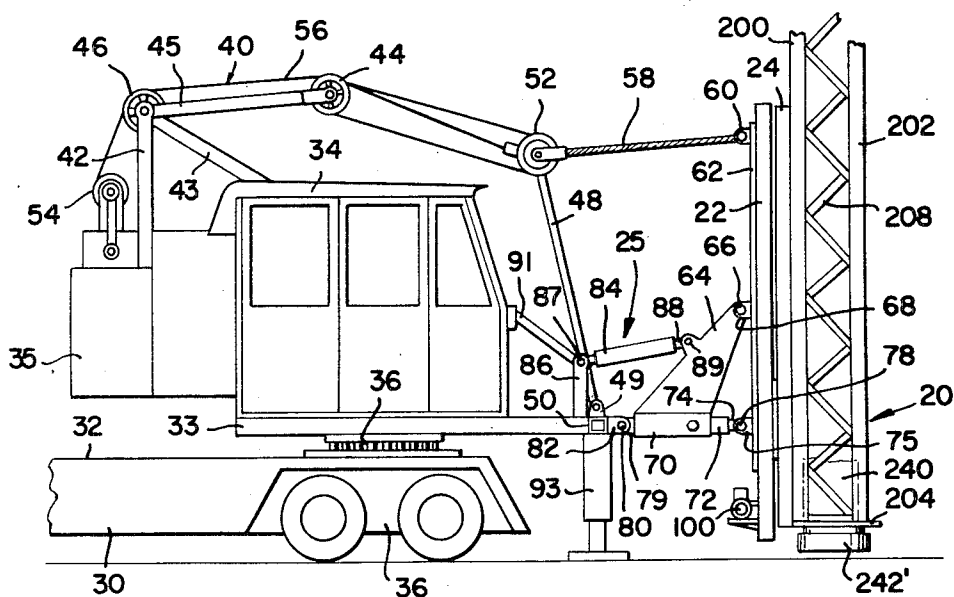


FIG. 1

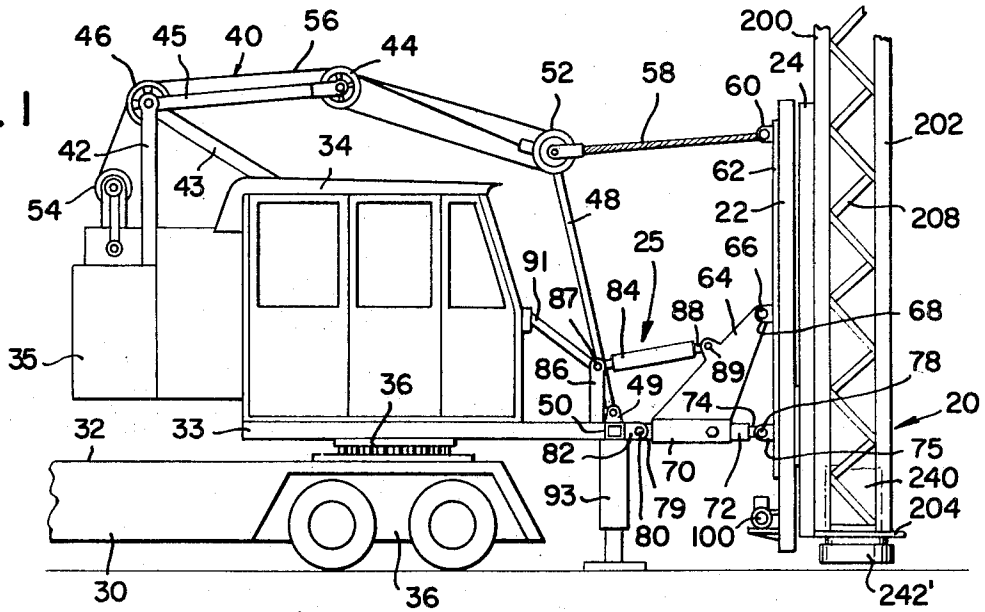


FIG. 2

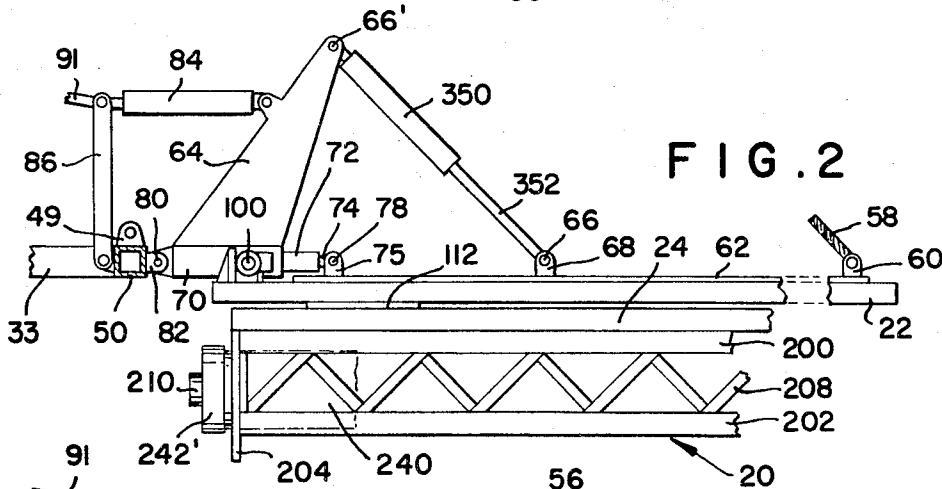
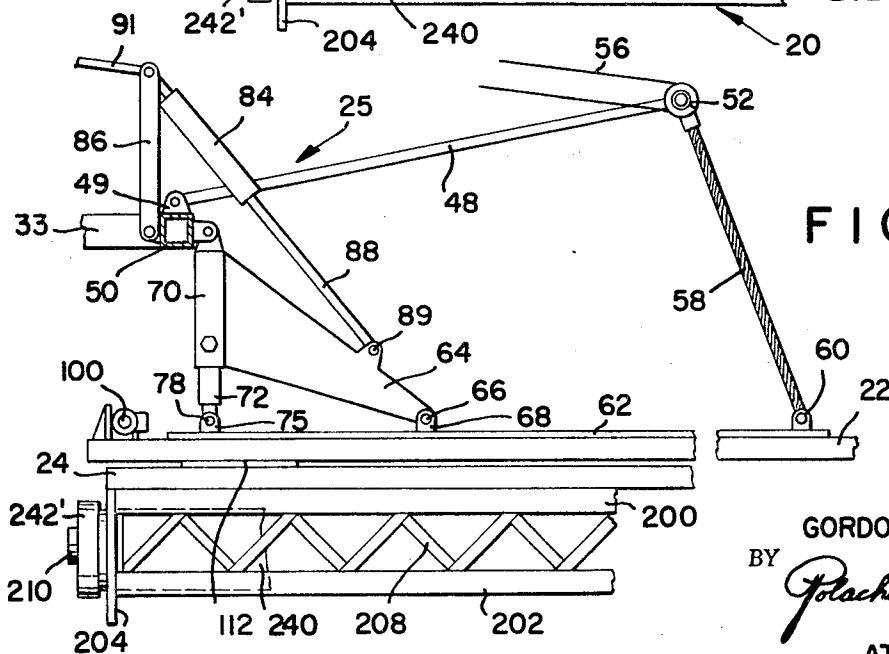


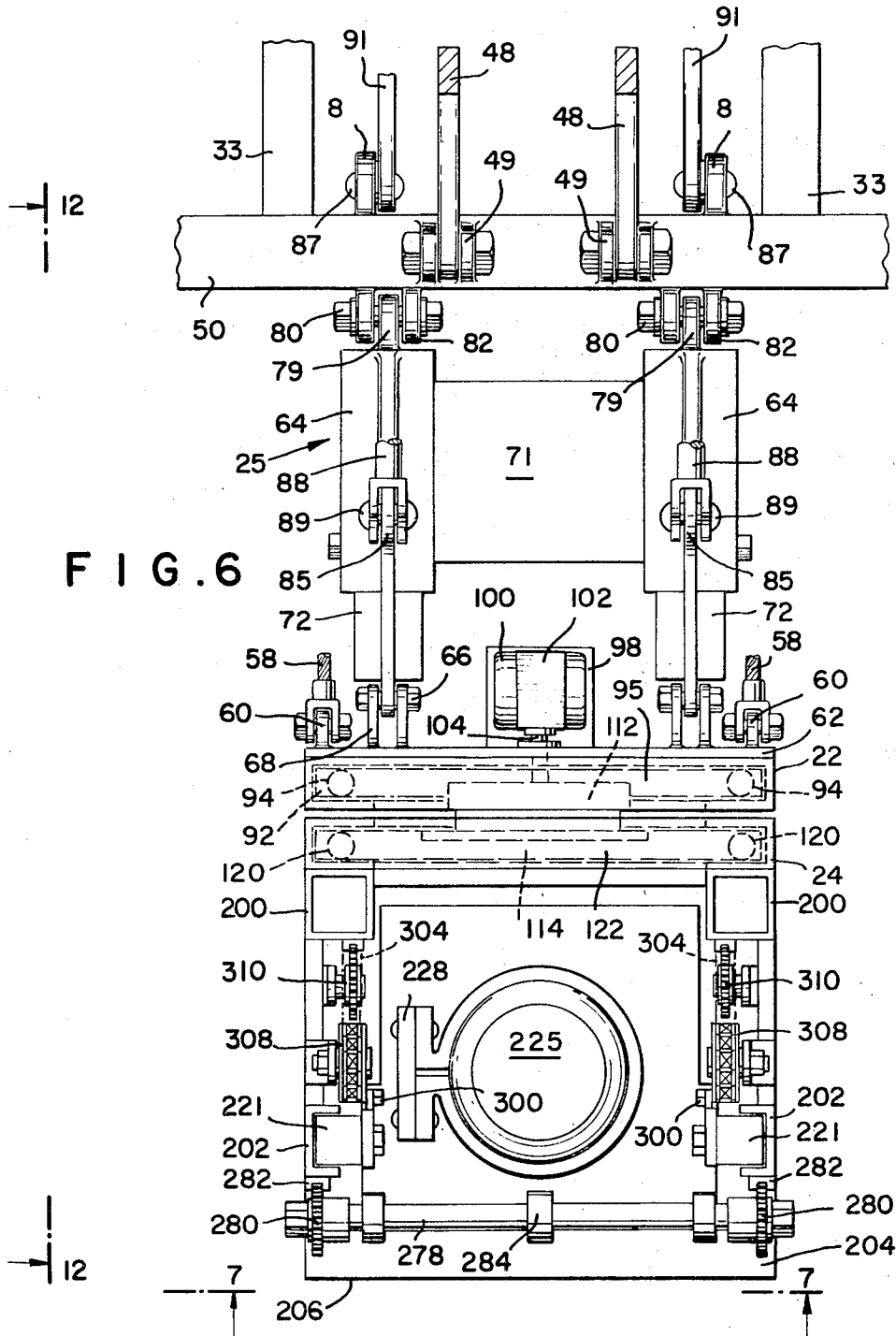
FIG. 3



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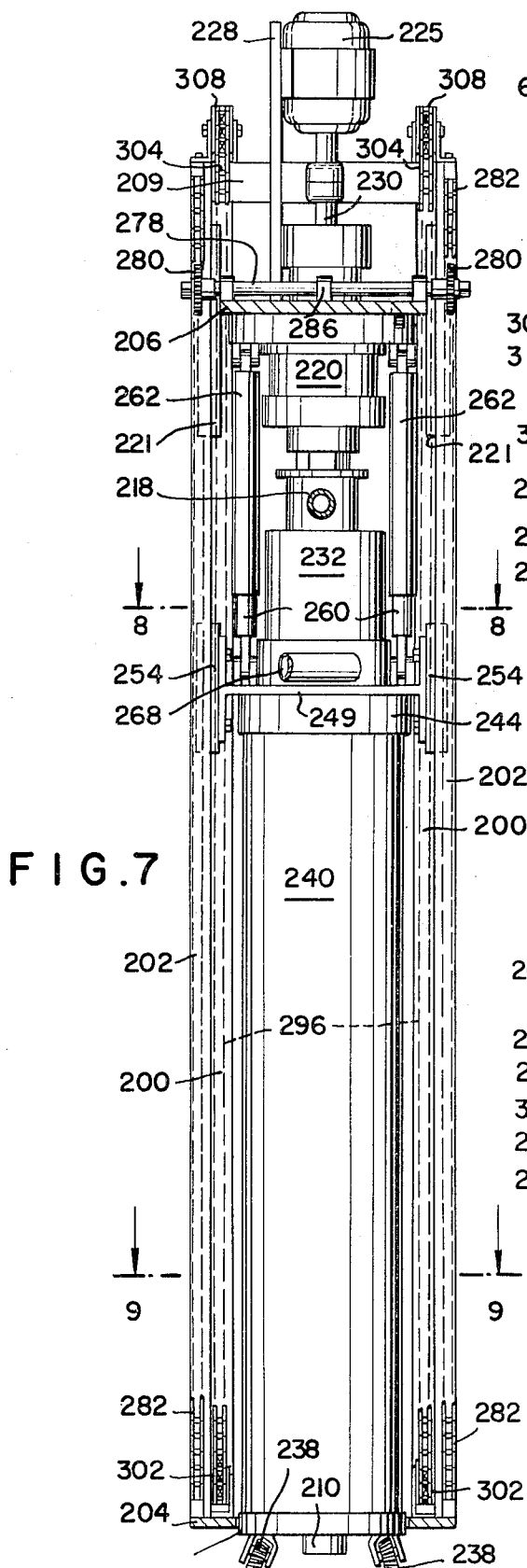
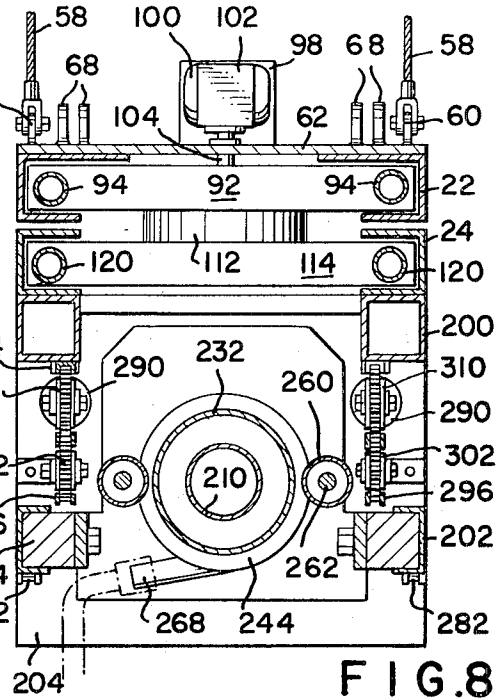
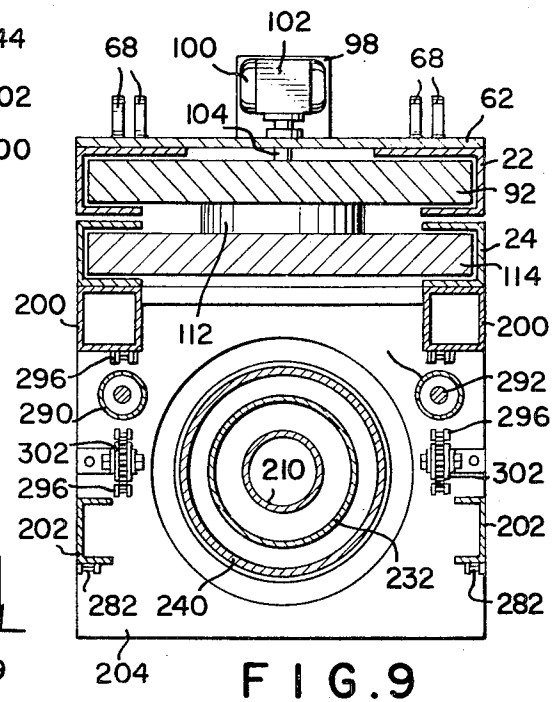
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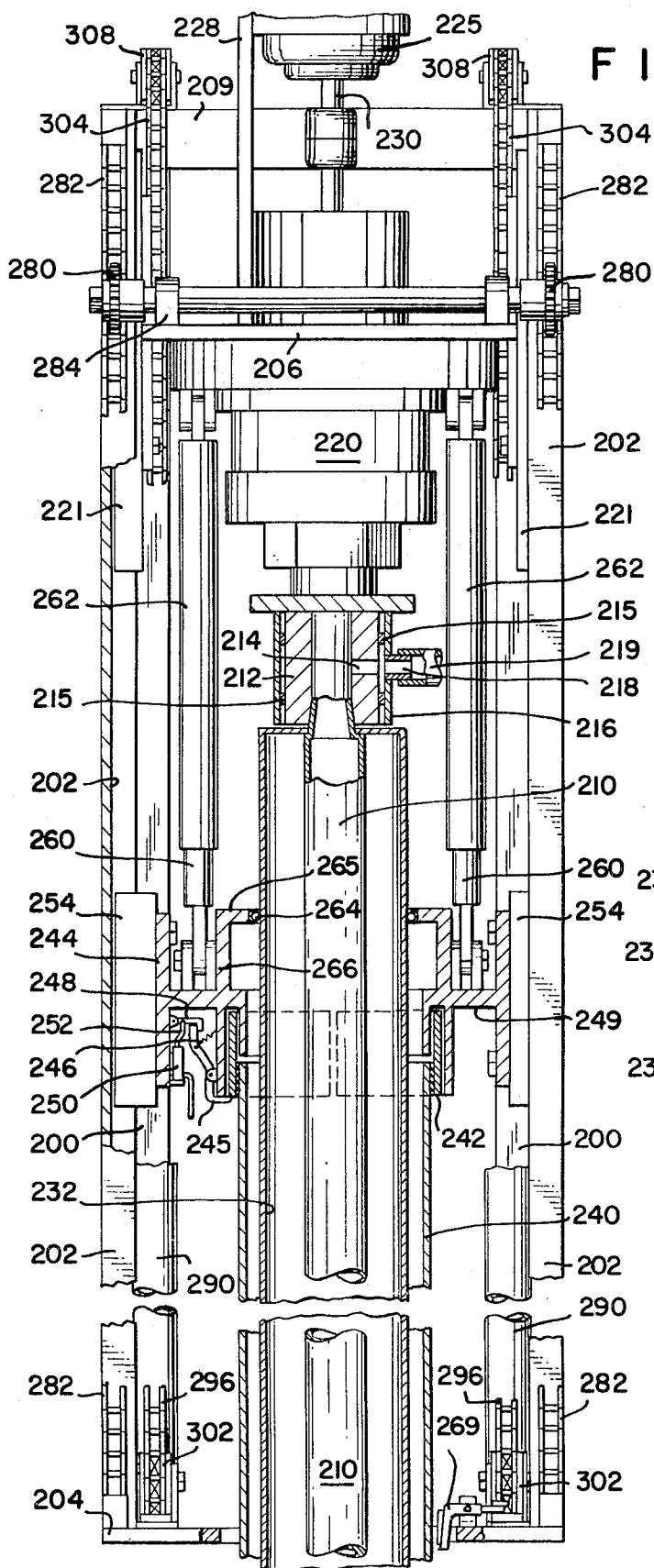


FIG. 10

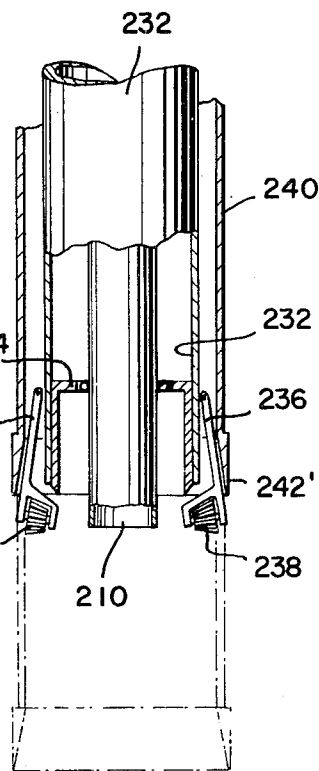
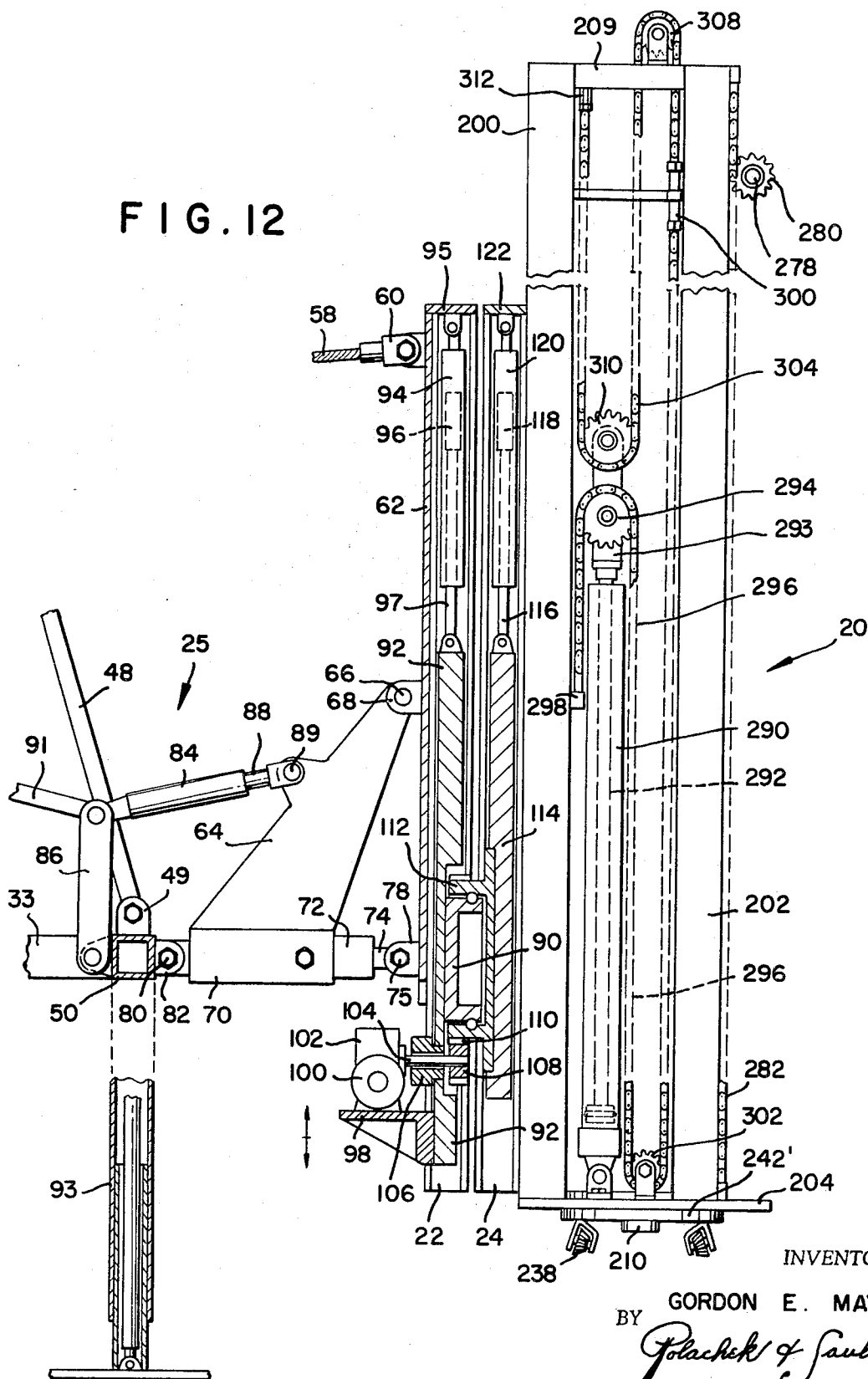


FIG. 11

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FIG. 12



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ROTARY DRILLING MACHINE

The present invention concerns a rotary drilling machine of versatile nature capable of heavy duty drilling under difficult field conditions.

Prior rotary drilling machines have been severely limited in the types of drilling they can do. In some the range of drilling angles is very limited. Other drilling machines require uniform soil conditions. Some drilling machines cannot be used to install a casing or caisson along with the advancing drill bit. Some can drill holes only a few inches in diameter. Other machines cannot do heavy duty drilling at all.

The present invention has as its principal object to provide a rotary drilling machine which overcomes the shortcomings of prior drilling machines mentioned above, and which in addition extends the range of versatility and utility of a rotary drilling machine to perform such drilling operations in the earth's surface as are not feasible nor possible with drilling machines now known. The present drilling machine can for example bore large holes in areas of difficult, hazardous and nonuniform formations, such as partly rock, partly dirt, mud, sand, silt, boulders, and other heterogeneous or non-homogeneous, unconsolidated earth structures. The machine can be used to install a casing or caisson in a bore along with the advancing drill bit. Holes can be drilled ranging from a few inches to several feet in diameter. An important feature of the invention is its ability to employ a conventional type of heavy duty rotatable mounting on carrier such as used for power shovels, cranes and other large lifting, hauling and earth moving devices. By this arrangement, the drilling mast assembly which constitutes the essential working part of the machine can be shipped to a drilling area and mounted upon suitable shovel or crane carrier already at the site. This is an important advantage over prior drilling machines which had to be provided with a massive mounting platform which was shipped with the machine and/or specially erected at the drilling site.

According to the invention the drilling machine comprises a drilling mast assembly which includes working parts to perform drilling and casing or caisson installation. The mast assembly is provided with mounting fixtures which enable it to be attached directly to a self-propelled shovel or crane carrier upon removal of the shovel or crane structure. The mast assembly can be mounted on a crawler type of carrier for increased maneuverability, or it can be mounted on a rotary crane carrier where the drilling machine is rotated about a fixed, central axis and the utmost in stability, strength, mass, weight, and hoisting ability are required. The mast assembly can also be mounted on a trailer, truck or any other self-propelled vehicle of adequate size, strength, mass and weight, equipped with appropriate draw and hoist works including suitable winches, hydraulic jacks, and the like, required by the drilling machine.

A further important feature of the machine embodying the invention is its ability to drill in a wider range of positions and directions than has heretofore been possible. For example it can be rotated in a field of 360° to drill in any direction between horizontally forward and horizontally rearward when in an elevated position. The drilling mast of the machine can be rotated 360° in vertical planes to drill in any direction. The machine can drill at compound angles to horizontal and vertical planes. The drilling mast can be set to drill at any fixed angle from plumb with any specified deviation to horizontal with any other specified deviation.

Another important feature of the invention is the ability to hold a casing in fixed relation to a drill bit and to advance the casing along with the drill bit. Also the casing can be advanced or pushed ahead of the drill bit where the earth formation is soft due to silt, sand, mud or other loose material. Here the casing will shield the unstable formation preventing bore wall collapse. The advanced casing will also seal the bore far enough below the drill bit to prevent blowout of flushing fluid under the casing. In boulder laden formations the drill bit can run directly below and ahead of the casing but close enough thereto to utilize the casing as a guide to help maintain align-

ment of the drill mechanism. In very sticky materials which also have hard strata or boulders the bit and casing can alternately be advanced in steps.

The machine is provided with a setting and holding fixture for the casing which includes means for clamping and holding the casing concentric with a drill pipe while the outside of the casing is guided at the top by the fixture and at the bottom suitable table guides allow passage of casing splices. The drill string mechanism is maintained concentric with the casing at the top by the casing holding fixture and by an exhaust collector ring assembly. The bottom of the drill string mechanism is centered by means of a roller bearing guide mechanism. By this arrangement it becomes practical and feasible to drill large diameter holes lined with casing sections in difficult, nonuniform formations where prior conventional drilling machines have not been able to operate at all.

Other and further features, objects and advantages of the invention will become apparent from the following detailed description taken together with the drawings, wherein:

FIG. 1 is a side view partially diagrammatic in form of a drilling machine embodying the invention, with mast assembly shown in vertical position.

FIG. 2 is an enlarged partially diagrammatic side view of parts of the drilling machine, with mast assembly shown in an elevated horizontal position.

FIG. 3 is a side view similar to FIG. 3 showing the mast assembly in a lowered horizontal position.

FIG. 4 is a further side view similar to FIG. 2 showing the mast assembly in elevated horizontal position axially perpendicular to its positions in FIGS. 1, 2 and 3.

FIG. 5 is fragmentary side view similar to FIG. 2 showing the mast assembly in a higher elevated horizontal position.

FIG. 6 is an enlarged top plan view of the machine taken on line 6—6 of FIG. 1.

FIG. 7 is a vertical sectional view taken on line 7—7 of FIG. 6.

FIG. 8 and FIG. 9 are horizontal cross-sectional views taken on lines 8—8 and 9—9 respectively of FIG. 6.

FIG. 10 is a fragmentary vertical sectional view similar to parts of FIG. 7 but on a larger scale showing details of internal construction.

FIG. 11 is a fragmentary sectional view similar to a part of FIG. 7 showing further details of internal construction.

FIG. 12 is a side elevational view, partially in section and partially in diagrammatic taken on line 12—12 of FIG. 6.

Referring first to FIG. 1 there is shown a rotary drilling machine embodying the invention. The machine comprises a mast assembly 20 supported by two mutually rotatable rectangular frames 22, 24 and a joint structure 25 upon a carrier 30. The carrier may be a self-propelled automotive vehicle having a platform 32 carrying baseplate 33 upon which is a cab 34 and counterweight 35 rotatably supported by a motor driven gear assembly 36 on platform 32. The carrier may have draw works 40 such as used for a hoisting crane or power shovel. These draw works may include vertical posts 42, brace bars 43 and frame bars 45 carrying sheaves 44, 46. Gantry bars 48 are pivotally secured to brackets 49 on a crossbeam 50 on secured platform 32. The gantry bars 48 carry sheaves 52. Entrained on the sheaves 44, 46 and 52 and secured to a motor driven winch 54 is a cable 56. Another cable 58 is secured between sheave bracket 59 carried by the gantry bars 48 and a bracket plate 60 secured near the top of a vertical mounting plate 62. Frame 22 is secured to and supported by the mounting plate. A pair of generally triangular bracket plates 64 are pivotally secured by pivot pins 66 to bracket plates 68 on plate 62. Lower ends of the bracket members 64 are secured to tubes 70 joined by plate 71; see FIG. 6. In tubes 70 are hydraulic cylinders 72. Pistons 74 extend axially of the cylinders and are secured by bolts 78 to bracket plates 75 on mounting plate 62. Rear ends of tubes 70 carry plates 79 pivotally secured by bolts 80 to bracket plates 82 on crossbeam 50. Further hydraulic cylinders 84 are pivotally secured by pins 87 to vertical posts 86 secured to the crossbeam 50. Pistons 88 are

pivotaly connected by pins 89 to rearwardly projecting ears 85 on bracket plates 64. Post 86 are stabilized by bars 91. Leveling jacks 93 can be placed under crossbeam 50. By the arrangement described the mast assembly can assume various positions illustrated in FIGS. 1-5 and described further below. The mast assembly can be rotated on an axis perpendicular to mounting plate 62 and frames 22, 24 by means which will now be described with particular reference to FIGS. 6, 8, 9 and 12.

A cylindrical ball bearing ring or race 90 is shown in FIG. 12 secured to a massive plate 92 which is slidably mounted in frame 22. Two hydraulic cylinders 94 are shown in FIGS. 6, 8 and 12 secured to top plate 95 of frame 22. Pistons 96 slide axially in the cylinders and their piston rods 97 are secured to the top of plate 92. Plate 92 also carries a lower platform 98 on which is a motor 100 and a speed reducer 102. The speed reducer is driven by the motor and drives a shaft 104 journaled in a bearing 106 set in plate 92. Shaft 104 carries a drive gear 108 which is meshed with a ring gear 110 integral with cylindrical bearing race 112. Bearing ring or race 112 is set in another massive plate 114 shown in FIGS. 8, 9 and 12 slidably mounted in frame 24. Plate 114 is connected to two piston rods 116 which in turn are connected to pistons 118 in two hydraulic cylinders 120 secured to plate 122 at the top of frame 24. By this arrangement the mast assembly 20 can rotate on the axis of the nested bearing races 90, 112 when the motor 100 is operated. Frame 24 will rotate with the mast assembly 20 while frame 22 will remain upright and stationary. It will be apparent that operation of the rear hydraulic cylinders 94 in frame 22 will raise and lower plate 92, bearing races 90, 112, motor 100, frame 24 and mast assembly 20 as a unit with respect to vertical frame 22 regardless of the rotational position of the mast assembly. If the mast assembly is horizontal, operation of cylinders 94 will move the mast assembly to bore at higher or lower levels. If the mast assembly 20 is vertical as shown in FIG. 12, hydraulic cylinders 120 can be simultaneously operated to raise and lower the mast assembly. The massive plate 114 will remain stationary while frame 24 moves up or down with cylinders 120 and with the mast assembly. If the mast assembly 20 is in the horizontal position, as shown in FIG. 4, to drill laterally right or left into a wall or bank, cylinders 120 may be operated to move guides 24 and mast assembly 20 up to or away from the wall to obtain closer proximity of drilling string guides 269 and the face of the drilled surface. The construction of the mast assembly 20 is shown to best advantage in FIGS. 6 through 12 to which reference is now made. The mast assembly has a frame structure including two vertical rectangular beams 200 located rearwardly and secured to frame 24; see FIG. 6. Two channel beams 202 are located forwardly. The beams are connected by a rectangular bottom table 204 and by a plurality of diagonal cross braces 208 shown in FIGS. 1, 2, 3 and 5. Crossbars or crossbeams 209 further reinforce the structure.

A vertical drill core 210 shown in FIG. 10 is connected to a rotatable chuck 212. This chuck is hollow and has a lateral opening 214. Surrounding this chuck and sealed by upper and lower sealing gaskets 215 is a stationary collar 216. The chuck rotates while the collar remains stationary. The collar has a nipple 218 connected via a conduit 219 to a source of compressed air, drilling oil or mud, water coolant pump or any other device which supplies air or fluid to the drill core.

The chuck is rotated by speed reducing gearing contained in stationary housing 220 secured to a moveable upper platform 206 guided by blocks 221 in beams 202. A motor 225 mounted on upper table 206 is supported by a frame plate 228 in axially vertical position. Motor drive shaft 230 drives the speed reducing gearing which in turn drives the chuck and drill core. The bottom end of the drill core 210 is open as best shown in FIG. 11.

Surrounding the drill core is a drill pipe 232 which rotates with the core. This pipe is closed at its upper end as shown in FIG. 10. At its lower end as shown in FIG. 11, the drill pipe carries a cylindrical bit 234. Secured on the lower end of the drill pipe are pivotable arms 236 carrying hard cutting bits

238. The arms 236 normally extend radially outwardly so that bits 238 are aligned longitudinally with casing 240. The casing has a hard tapered bottom end 242. The casing can be advanced with the drill pipe or either the casing or drill pipe can be advanced independently of each other in steps by means which will now be described. FIG. 11 shows in dotted lines that the casing can be advanced downwardly ahead of the drill core and drill pipe. The drill pipe and drill core of course advance together since they are secured together at their upper end.

The casing 240 is welded to a collar 242 at its upper end as best shown in FIGS. 7 and 10. This collar fits into a cylindrical fixture 244. A suitable releasable lock assembly is provided for holding the casing in the fixture. This assembly shown in simplified form in FIG. 10 may include a lever 245 biased by a spring 246 to engage under collar 244. The lever is held in engagement by a catch 248 pivotally supported by the fixture 244. A hydraulic cylinder 250 is carried by the fixture. Its piston rod 252 is engaged with catch 248 to raise the catch for releasing the lever 245. If desired a hydraulic cylinder can replace spring 246 for engaging and disengaging lever 245 with respect to the casing. Fixture 244 has a table 249 secured to guide blocks 254 which move vertically in channel beams 202 as shown in FIG. 8. The fixture is attached to piston rods 260 of two hydraulic cylinders 262 carried by upper moveable platform 206. A fluid seal 264 is provided in top ring 265 of fixture 244 surrounding the drill pipe 232. By this arrangement the drill pipe and core can rotate without turning the casing. The casing can be advanced downwardly or retracted by operating the hydraulic cylinders. The casing can move down or up simultaneously with or independently of the drill pipe and core. The fixture 244 includes a collector ring 266 and tangential discharge tube 268. A suction pump can be applied to this tube for removing cuttings and material collecting between the casing 240 and drill pipe 232. A casing guide fixture 269 is mounted on platform 204 as shown in FIG. 10.

In order to move the entire assembly of casing, drill core and drill pipe up and down simultaneously there is provided a pair of long hydraulic cylinders 290 mounted at sides of mast assembly on bottom plate 204; see FIGS. 7, 9 and 12. Piston rods 292 of these cylinders carry bracket 293 rotatably supporting sprockets 294 on which are engaged chains 296. Chains 296 are secured at one end to stationary blocks 298 on beams 200. At their other ends the chains are secured by couplings 300 to platform 206. Chains 296 extend around idler sprockets 302 rotatably mounted on bottom plate or table 204. Further supporting chains 304 extend upwardly from platform 206, around idler sprockets 308 rotatably mounted on cross bars 209 and then down around sprockets 310 rotatably mounted on brackets 293. The chains 304 then extend upwardly to couplings 312 secured on crossbars 209; see FIG. 12.

The top ends of cylinders 262 are attached to thrust plate 206 by suitable brackets and at the lower end piston rods 260 are likewise attached to casing fixture 244 through plate 249. The operator, by the use of suitable hydraulic control valves, traps fluid within both ends of hydraulic cylinder 262. This trapped fluid renders cylinder 262 and piston rod 260 as a solid member. Thus any downward pressure or thrust on plate 206 is not only transmitted to drill pipe 210 and bit 242 but also through cylinder 262 and shaft 260 to plate 249 and thence to casing 240. This arrangement provides that movement of rotation drive 220 and plate 206 will advance drill string 220, 232 and bit 244 at the same rate as casing fixture 244 and casing 240. Thereby, maintaining the proper clearance between cutting edge 242 and support arms 236 and cutters 238.

Of course, as will sometimes be the case when drilling into irregular formations, for which this drilling machine design is particularly well adapted, all will not always go as expected. Let us assume now that the drilling operation has proceeded through a very unstable formation such as a combination of loose rock or boulders, mud, sticky clay or any other material

which would be the cause of high skin friction acting upon the outside of the casing. This condition would, of necessity, require a great amount of down pressure to advance said casing. Let us further assume, in addition to above condition, that the drill bit is now advancing into a hard formation which will require also a great amount of down pressure to advance the bit satisfactorily.

With the combined amount of down pressure required to satisfy both the drill bit and casing advance, the capacity of the drilling machine may be exceeded and result in its inability to continue the drilling operation. It is for this mentioned condition that this particular design of casing installing mechanism is embodied herein.

As stated before, the operator can control at will the trapping of fluid within cylinder 262 or he can release said fluid or apply pressure within said cylinder to either end of piston. Now, by releasing fluid from within cylinder 262, piston and rod 260 are made free to move further into cylinder 262. By doing this, the rotation drive and thrust assembly may continue to rotate and advance drill string without the advancing of casing 240. It therefore becomes apparent that the entire available down pressure of the drilling machine may be applied to the drill bit 242 to make possible the drilling of the harder formations. Also, since the bit 242 is in the harder formation, the immediate use of the casing 240 to shield cutter bit 242 may not be required. Therefore, the bit 242 can be advanced either a few inches or a few feet ahead of the casing 240 at one time. Now, after having advanced said drill bit 242 ahead of the casing 240, it becomes necessary to bring casing 240 up behind the drill bit 242. To do this the drill operator has but to place the feed control valve in the neutral position to trap the hydraulic fluid within hydraulic cylinders 290, thereby rendering said cylinder 290 and piston rod 292 inoperative and for practical purposes making them a solid member. This action will hold the drill string and cutter bit 242 on the bottom of the hole while allowing the action of hydraulic fluid as controlled by the operator to push piston and rod 260 from cylinder 262, thereby utilizing the entire weight and strength of the drilling machine to advance the casing.

With the above described technique, the casing may be fed along with or walked down separately from the drill string and tools.

In extreme conditions, even the total pressure which may be applied by the steady push of the casing by the drilling machine may not be sufficient to advance the said casing. This would require the addition of a heavy plate (not shown) which is supplied with suitable guides to travel within guide channels 202, directly above the rotation drive mechanism. It is now evident that by the use of a suitable pile driving hammer, (of either steam, compressed air or diesel operation) which is mounted with suitable guides to travel above said plate and within guide channels 202 and connected through heavy bars, around and not touching rotation drive mechanism 220 to rest upon the casing holding and setting fixture 244, a very heavy driving or vibratory force may be added to the push of the casing setting mechanism 244. Even under the most extreme conditions, the advance of said casing 240 should be possible.

FIGS. 6, 10 and 12 show a mechanism including shaft 278, sprockets 280 and chains 282. This mechanism serves to keep the rotation drive mechanism in perfect alignment with the drill string. It is very important to maintain perfect alignment of shaft 212, FIG. 10, and tube 210, as this joint should be a tapered, threaded, tool joint connection. Due to the necessarily large diameter of these parts, any small misalignment would damage the threads on this joint.

The feed or travel of the rotary drive and thence the drill string is effected by a hydraulic cylinder and roller chain arrangement shown in FIG. 12. As may be noted in FIGS. 6 and 10, guide bars 221 which slide within guide channels 202 serve to maintain fore and aft alignment of rotary drive assembly 220. But due to the nature of any hydraulic system, pressure is applied to all cylinders within a particular circuit equally. Due

to this nature, either the right cylinder or the left cylinder 290 travels slightly faster or slower than the mating cylinder, due to a slightly different resistance in mechanism. In this case a little looseness in guide bars 221 and channel 202 may be amplified in allowing lateral misalignment of threaded connections in parts 210 and 212.

To prevent this misalignment heavy roller chains 282 are prestressed to exactly the same length and attached to guides 202 left and right respectively. Therefore, chains 282 and sprockets 280 become as a rack-and-pinion arrangement. Sprockets 280 left and right are secured to shaft 278 to turn as one. Mounting bearings 284, which are secured to plate 206, causes plate 206 to be held in exact perpendicular alignment with guides 202. Since rotary drive mechanism is perpendicularly mounted to plate 206, the axis of shaft 212 and 210 are in alignment.

Another very important advantage of the present drilling machine lies in the fact that even with a very large and massive machine it can be broken down into very small and manageable components or subassemblies for the purpose of shipping and even more important for servicing the various components, as well as to promote versatility of said machine. In view of these features it is possible to remove rotary drive assembly and/or casing holding fixture out the top of the mast assembly without disturbing the connections or tension of the feed chains 304.

To set up the machine for operation, the mast assembly 20 will be brought to a drilling site and disposed on the ground in a horizontal position as shown in FIG. 2. The joint structure 25 will be assembled and attached to platform 33 of a suitable carrier.

Mounting guides 22, plates 90, 114 and bearing rings 90, 112, which comprise a subassembly, may now be attached to subassembly 64 by means of parts 74 and 78 being secured by pins 75. Cable 58 will now be secured to guide 22 with pins at point 60. While subassembly is still in the horizontal position the mast assembly 20 may be slidably connected to mounting subassembly by means of guide 24 and plate 114. Guide 24 is part of mast assembly 20. Pins at and ends of cylinder 120 and rod 116 connected rod 116 to plate 114. Also, pins 66 will now be inserted to secure plate 64 to guide 22, making the entire mechanism very stable. The cable 56 shown in FIG. 3 will then be retracted. Bracket plates 62 will be rotated around pivot bolts 78 in a vertical plane to elevate the mast assembly to the vertical position shown in FIG. 1. It should be noted that bolts 78 serve as a horizontal axis of rotation so that the mast assembly can be rotated in a vertical plane between horizontal and vertical positions for boring or drilling in any angular position in this vertical plane.

With mast assembly 20 in the vertical position of FIG. 1, any minor adjustment to provide exact fore and aft alignment of mast assembly may be made by extending or retracting hydraulic cylinder within tube 20 to cause guide 22 to be rotated about pin 66 in a vertical plane to tilt mast assembly 20 forward or backward slightly. When this adjustment is completed cables 56 and 58 will be drawn taut to stabilize mast assembly 20. It is also possible to rotate the mast assembly on the ring bearing assembly 90, 112. If the mast assembly is initially vertical as shown in FIG. 1, then the mast assembly will rotate in a vertical plane perpendicular to the vertical plane in which it is rotatable on pivot bolts 80. The mast assembly can thus drill or bore holes in any angle to the right or left of vertical. By rotating the mast assembly with draw works 40 and by further rotation by means of rotation motor 100, the mast assembly can be disposed to drill or bore obliquely to the ground at any compound angle.

FIG. 2 shows one of a pair of auxiliary hydraulic cylinders 350 and piston rods 352 connected between pivot bolt 66 and bracket plate 68 on mounting plate 62. This arrangement makes it possible to dispose the mast assembly horizontally and to drill in a position located closer to the level of platform 33. FIG. 4 shows the mast assembly rotated to a horizontal position with respect to the vertical frame 22 for boring to the

right looking forwardly from the frame 22. The mast assembly can be rotated 180° or more from its position in FIG. 4 to bore to the left. The horizontal mast assembly rotates on a horizontal axis since the bearing race assembly 90, 112 is axially horizontal. FIG. 5 shows the mast assembly horizontal but elevated above platform 30. This can be done by providing auxiliary hydraulic cylinders 350' having piston rods 352'. The cylinders and piston rods will be connected between piston rod 74 and bracket plate 78 on mounting plate 62. The mast assembly can be used in this position to drill or bore in a plane elevated above the platform.

By use of the draw works 40, the mast assembly can be tilted to bore at an angle to the horizontal from all positions shown in FIGS. 1, 2, 3 and 5. By rotating the mast assembly with cab 34, the mast assembly can be rotated in a horizontal plane through a field of 360°. By rotating the mast assembly on the ring bearing structure 90, 112 the mast assembly can be rotated around an axis perpendicular to the mast assembly. It will be apparent therefore that the mast assembly is capable of being rotated on three mutually perpendicular axes, namely the vertical axis of platform bearing 36, the axis of the bearing ring structure 90, 112 and the axis of pivot bolts 80. The mast assembly can drill or bore down, up or sideways at any desired angle in any horizontal and vertical plane.

The versatility of the machine during a boring operation will now be explained with particular reference to FIGS. 1 and 6-12. While the drive motor 225 is running, the drill pipe 232 rotates cylindrical bit 234 and cutting bits 238. These bits may be disposed as shown in FIG. 11. The assembly of drill pipe and bit moves down.

The downward thrust provided by hydraulic cylinders 290 acting through rods 292, bracket 293, pins and sprockets 294 transmitting a rolling action to sprocket 294, chain 296 is fixed to mast member 200 at point 298 making this end immovable. Thus pull is applied to other end of chain 296 which passes around sprocket 302 at the bottom of mast member 202 and thence to plate 206, which is attached to rotation drive and thrust assembly 220 and to rotating member 212, to drill pipe 210 and 232, thence to bit 242. Also, said down pull thrust is applied from plate 206 through hydraulic cylinder 262, rod 260, plate 249, fixture 244 to casing splice 242 and to casing 240. Uplift is effected by the reverse action of hydraulic cylinder 290, rod 292 and other above described parts, acting through chains 304 which are secured at one end to member 209 and 200 by means of connection at 312. The opposite end of chain is attached to plate 206 as is chain 296. Therefore, by down pull on rod 292 acting through associated parts, the drill string and mechanism are lifted from the hole. The motor 225, casing 240, cylinders 262 and associated structures add to the weight so that good penetration of the earth formation being drilled is effected. If desired, the casing 240 can be retracted by operation of cylinders 262 so that the drill pipe 232 advances ahead of the casing. In soft loose or sandy soil, the casing can be advanced ahead of the drill pipe, again by use of cylinders 262. The sharp cutting end 242 of the casing will penetrate the soft soil easily. The casing can be disengaged from the holding fixture 244 to leave it in the soil while the drill pipe and core are withdrawn by operating cylinders 290. Then another casing can be attached to the casing in the ground and engaged by the holding fixture 244. The drill pipe and core can be advanced in steps alternately with the casing, either the casing or the drill pipe can lead the way. Since the cutting bits 238 rotate in a path whose diameter is at least as large as that of the casing, the casing can always move down easily. Cuttings can be carried up by fluid flow between the casing and drill pipe. Flushing fluid or compressed air can be fed through the drill core down to the surface being drilled or bored.

The present machine can be used at a drilling or boring site to perform work heretofore requiring a plurality of different machines. In addition it can perform drilling functions at oblique angles frequently found impossible or impracticable with prior drilling machines. The machine can drill holes in a

wide range from a few inches in diameter to several feet depending on the dimensions of the drill pipe and bit.

Important features of the invention are its ease of transportation to a drilling site; ease of assembly at the drilling site; compactness in width with respect to the size of holes it can bore; use of conventional carriers and winches to rotate and elevate the mast assembly, versatility, etc.

In order to simplify the drawings, connections of hydraulic or/and fluid pressure sources to the several hydraulic cylinders have been omitted, but it will be understood that they will be provided in ways well known in the art. The showing of power cables and controls for energizing and operating the various motors have also been omitted to simplify the drawings.

While a single preferred embodiment has been disclosed many variations and modifications are possible in all mechanical parts. If desired, it is possible to mount a vibrating or oscillating type of ram or motor on upper platform 206 to loosen the drill pipe or core or to force down through a particularly hard or resistant formation. Other modifications will readily occur to those skilled in the art.

I claim:

1. A rotary drilling machine, comprising a first rectangular frame; a second rectangular frame; rotary bearing means interconnecting the frames so that the second frame is rotatable with respect to the first frame on a first axis perpendicular to the two frames; a first movable support in said first frame carrying the bearing means to move the same longitudinally in the first frame, so that the second frame and mast assembly are movable longitudinally with the bearing means with respect to the first frame; and a drilling mast assembly secured to the second frame to rotate therewith, said drilling mast assembly having a longitudinal drilling axis perpendicular to said first axis so that the drilling mast assembly can be rotated to drill in any direction in a plane perpendicular to said first axis and including the drilling axis.

2. A rotary drilling machine as defined in claim 1, further comprising a crossbeam attachable to a platform of a carrier of a gantry and cable draw works; and a rotary joint structure connecting the first frame to the crossbeam for rotation on a horizontal second axis, so that the mast assembly can be rotated with the first and second frames on both the first and second axes to dispose the drilling axis at any angle with respect to a horizontal plane for drilling at said angle.

3. A rotary drilling machine as defined in claim 1, further comprising a mounting and lifting apparatus operatively arranged to carry said mast assembly at one end thereof, said apparatus including a hoist drum; a hoist line carried by said hoist drum; anchoring means on said mast assembly; and means operatively carrying said hoist line over and above said mast assembly to said anchoring means for changing said apparatus from a lifting apparatus to a holddown apparatus for said mast assembly by weight transfer from the other end of said apparatus to said one end where the mast assembly is mounted.

4. A rotary drilling machine as defined in claim 1, further comprising mounting apparatus for said mast assembly, said apparatus including a load line drum operated by said apparatus to lift and handle loads such as drill pipes, casings, drilling tools, and the like.

5. A rotary drilling machine as defined in claim 1, wherein said frame and mast assembly comprise a plurality of subassemblies arranged so that the frame and mast assembly can be taken apart into said subassemblies for easy shipment from one site to another, for convenience in storage of parts and the like.

6. A rotary drilling machine as defined in claim 1, wherein said frame and mast assembly comprise a plurality of subassemblies arranged so that any one of the subassemblies can be removed or broken apart for servicing or to promote versatility of the machine without disturbing or dismantling others of said subassemblies.

7. A rotary drilling machine as defined in claim 1, further comprising means for self-erecting the machine under its own power.

8. A rotary drilling machine as defined in claim 1, further comprising mounting apparatus for said mast assembly; and means slidably mounting the mast assembly so that the mast assembly can be elevated above ground level to bring a lower guide mechanism in close proximity to the earth's surface whether the spot to be drilled is either lower or higher than the particular area upon which the mounting apparatus rests.

9. A rotary drilling machine as defined in claim 1, further comprising a second moveable support in the second frame engaging said rotary bearing means so that the second frame and drilling mast assembly are moveable longitudinally with respect to said first frame.

10. A rotary drilling machine, as defined in claim 9, further comprising a crossbeam attachable to a platform of a carrier of a gantry and cable draw works; and a rotary joint structure connecting the first frame to the crossbeam for rotation on a horizontal second axis, so that the mast assembly can be rotated with the first and second frames on both the first and second axes, and so that the mast assembly can be moved laterally in a plane perpendicular to the first axis while the first frame remains stationary.

11. A rotary drilling machine as defined in claim 10, further comprising a carrier platform rotatable on a vertical third axis; and a gantry and cable draw works mounted on said platform and connected to said first frame and rotary joint structure for rotating the frames and mast assembly on said horizontal second axis and for rotating the frames and mast assembly on said vertical third axis.

12. A rotary drilling machine as defined in claim 1, wherein said drilling mast assembly comprises a rectangular frame structure; a platform moveably supported to move longitudinally inside said frame structure; a drill pipe rotatably carried at one end by said platform and extending longitudinally of said frame structure; drill bits carried by said drill pipe at its other end for drilling in an earth formation; and means for raising and lowering said platform for raising and lowering the drill pipe.

13. A rotary drilling machine as defined in claim 12, further comprising a hollow drill core inside the drill pipe, said core

having an open bottom end adjacent the drill bits; means for supplying fluid to the drill core; means for drawing the fluid upwardly between the casing and drill pipe and out of said casing fixture; and motor means on said platform operatively connected to said drill pipe and drill core for rotating the same inside of and independently of the casing.

14. A rotary drilling machine as defined in claim 12, further comprising a casing concentric with drill pipe; and a casing fixture releasably carrying the casing and carried by said platform so that the casing and drill pipe both move longitudinally of frame structure with the platform.

15. A rotary drilling machine as defined in claim 14, further comprising means to permit the casing to be removed from the mast assembly to permit drilling without the casing.

16. A rotary drilling machine as defined in claim 14, having means arranged so that a pile driving hammer may be placed thereon to apply a vibratory or impact action upon the upper end of said casing in addition to normal pressure which may be applied to advance said casing when required.

17. A rotary drilling machine as defined in claim 14, further comprising means for installing the casing along with drill bit mechanism, and means for selectively applying downward pressure of the entire machine only on the bit cutters or only on the casing.

18. A rotary drilling machine as defined in claim 14, further comprising longitudinally expansible and retractable support means connecting the casing fixture to said platform so that the casing and casing fixture are moveable longitudinally of the frame structure independently of the drill pipe.

19. A rotary drilling machine as defined in claim 18, a hollow drill core inside the drill pipe, said core having an open bottom end adjacent the drill bits; means for supplying fluid to the drill core; and means for drawing the fluid upwardly between the casing and drill pipe and out of said casing fixture.

20. A rotary drilling machine as defined in claim 19, further comprising means for applying the entire available downward pressure of the machine to advance selectively either the drill pipe and bits or the casing.

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