Sept. 29, 1953

D. E. STRAITIFF

2,653,794

WELL DIGGING APPARATUS

Filed April 25, 1949

3 Sheets-Sheet 1

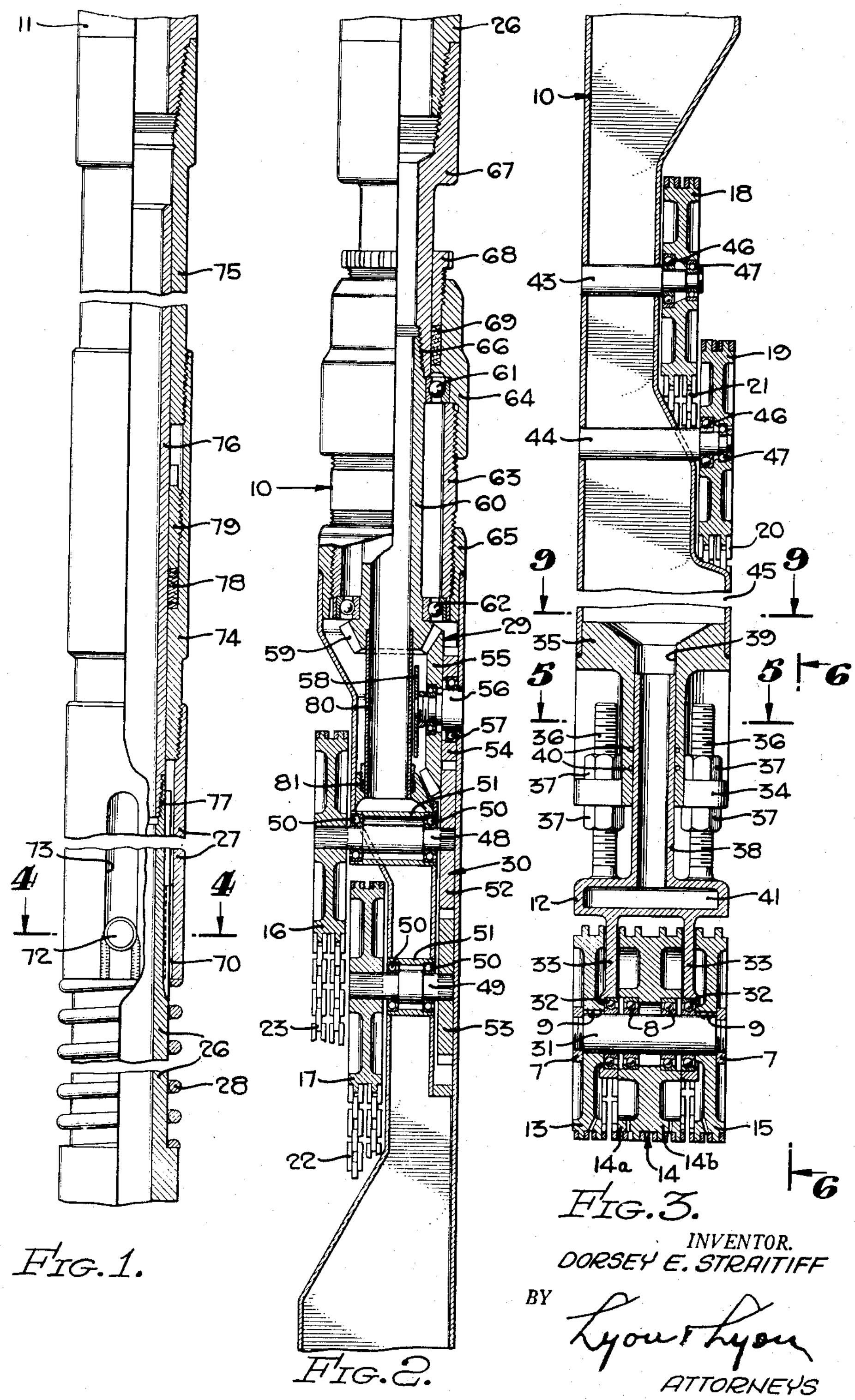


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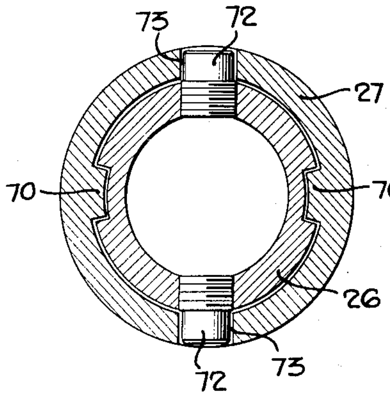
FIG. 4.



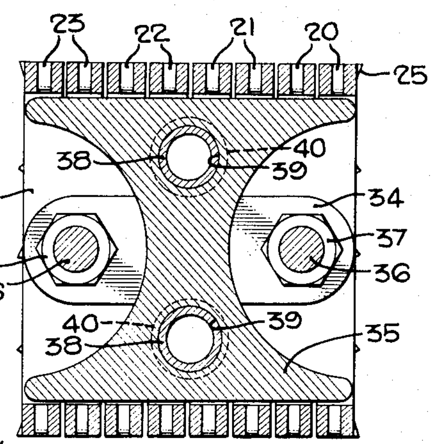




FIG. 5.

FIG. 6.

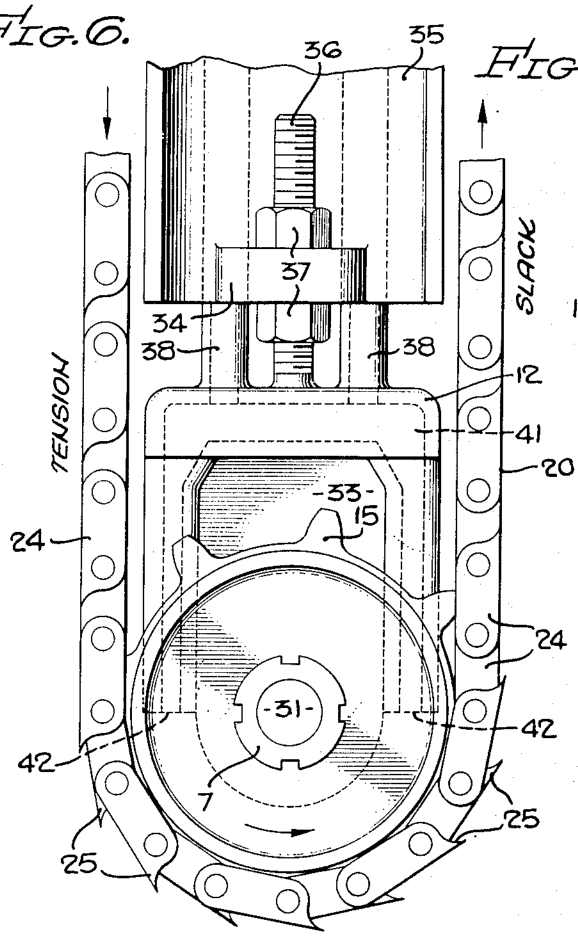



FIG. 7.

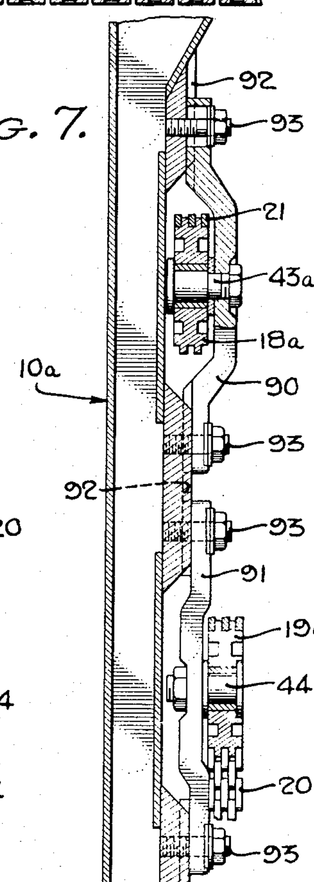



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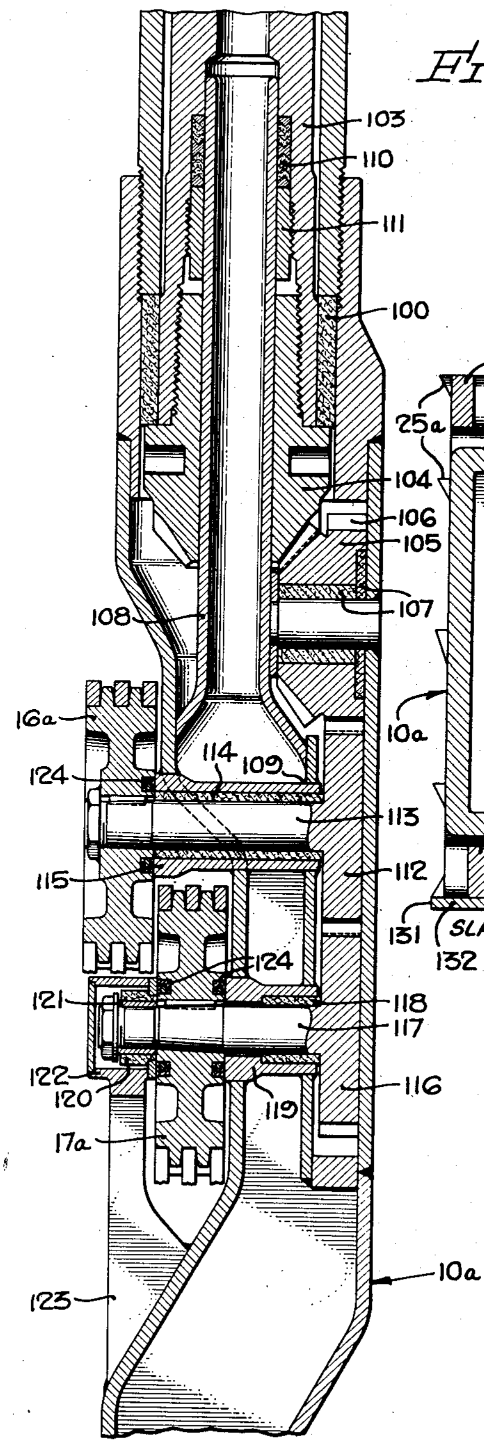
FIG. 8.



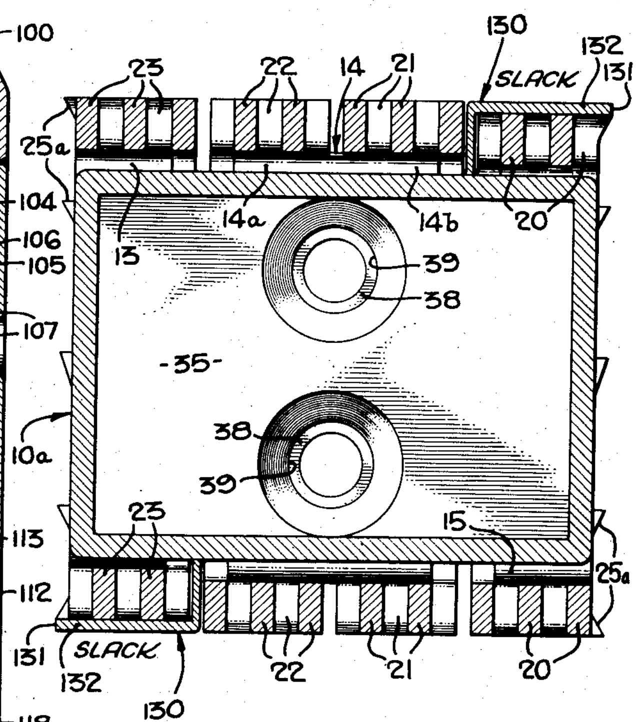




FIG. 9.

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# UNITED STATES PATENT OFFICE

2,653,794

## WELL DIGGING APPARATUS

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Application April 25, 1949, Serial No. 89,507

14 Claims. (Cl. 255—1)

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This invention relates to apparatus for the digging of wells and is particularly directed to a device having a relatively large number of power driven digging elements.

In a conventional rotary system for the boring of oil wells a bit is carried on the lower end of a drill pipe string and is rotated by power applied at the upper end of the drill pipe string near the surface of the ground. As the well hole is deepened, additional sections are added to the drill pipe string. Conventional drilling bits are provided with hard cutting edges or with rotary cutters each formed of hard material or having cutting teeth surfaced with hard metal such as, for example, tungsten carbide. The bit and cutters are subjected to very severe service and only a relatively small number of teeth can be provided on the cutters because of limitations of space. Accordingly, there are relatively few cutting elements which can be brought into play against the formation, and the result is that the bit must be withdrawn at frequent intervals and replaced by a new one. This requires that the drill pipe string be withdrawn from the hole and unjointed section by section and then reinserted in the same manner. As the well hole is deepened it is not uncommon to spend as much or more time withdrawing and reinserting the drill string as is spent during the drilling operation with the bit on bottom.

In accordance with my invention I provide a relatively large number of formation-contacting digging elements each formed of hard material or having a cutting edge surfaced with tungsten carbide or other hard metal. Since I employ a very large number of these digging elements, a much greater depth can be cut before it is necessary to withdraw the device for replacement. Indeed, under good drilling conditions it is contemplated that the device may operate satisfactorily for the full depth of the completed well.

Accordingly, it is the principal object of my invention to provide a large number of hard metal or hard surfaced digging elements engageable with the well formation.

Another object is to provide a plurality of vertically extending chains having links provided with hard metal teeth for engaging the formation at the bottom of the well hole.

A more detailed object is to provide such a device having a central chain rotating in one direction between side chains rotating in the opposite direction in order that the well hole may not vary from the vertical for any great extent.

Another object is to provide a well digging de-

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vice having vertically extending chains for contacting the well formation and having a novel form of power applying means for rotating the chains from a conventional rotary drill string.

Another object is to provide a well digging device of this type in which digging chains pass over coaxial sprockets for engaging the formation, certain of the chains being driven by driving sprockets positioned above the coaxial sprockets and certain other chains being driven by certain of the coaxial sprockets.

Another object is to provide a well digging device of this type for digging a noncircular hole, the device being provided with corner shoe elements for absorbing the reaction torque against the walls of the hole.

Another object is to provide a well digging device having parallel digging chains of varying length so that drive mechanism therefor does not overhang the outline of the hole dug by the chains.

Another object is to provide a well digging device having a plurality of vertically extending chains for contacting the well formation, each of the chains being trained over vertically spaced sprockets, the chains on the outer faces of the device being effective to dig either in an upward or downward direction.

Another object is to provide a well digging device having vertically extending formation-contacting chains, which device is adapted for vertical, horizontal, inclined or curved drilling.

Another object is to provide a device of this type incorporating shock absorbing means interposed between the rotary drill string and the hole deepening device at the lower end thereof.

Other and more detailed objects and advantages will appear hereinafter.

In the drawings:

Figures 1, 2 and 3 are elevation views partly in section showing a preferred embodiment of my invention. In practice the structure shown in Figure 2 is interposed between the structure shown in Figure 1 and Figure 3, the lower end of Figure 3 illustrating the lower end of the device. The formation-contacting chains have been largely omitted in Figures 2 and 3 for clarity of illustration.

Figure 4 is a transverse sectional view taken substantially on the lines **4—4** as shown in Figure 1.

Figure 5 is a transverse sectional view taken substantially on the lines **5—5** as shown in Figure 3.

Figure 6 is an enlarged side elevation taken in the direction 6—6 as shown in Figure 3 and illustrating the action of the digging teeth on the chains.

Figure 7 is a sectional elevation showing a modified form of mounting for the idler sprockets.

Figure 8 is a sectional elevation showing a modified form of gearing assembly.

Figure 9 is a transverse sectional view taken substantially on the lines 9—9 as shown in Figure 3.

Referring to the drawings, a nonrotary frame assembly generally designated 10 is carried at the lower end of a drill string 11 and supports a cutting head 12 at its lower end. A plurality of coaxial sprockets 13, 14 and 15 are mounted on the cutting head. A driving sprocket 16 is rotatably mounted on the upper portion of the frame assembly 10 and is aligned with the driven sprocket 13. A second driving sprocket 17 is rotatably mounted on the frame assembly 10 and is aligned with the sprocket 14*a* of the double sprocket member 14. The other sprocket 14*b* of the double sprocket member 14 is aligned with the idler sprocket 18 rotatably carried by the upper portion of the frame assembly 10. The sprocket 15 is aligned with the idler sprocket 19, also rotatably mounted on the frame assembly 10. A formation-contacting chain 20 is trained over aligned sprockets 15 and 19 and similar chains 21, 22 and 23 connect aligned sprockets 14*b* and 18, 14*a* and 17, and 13 and 16. The individual links 24 of each of the chains are each provided with hard digging teeth 25 which may be surfaced with tungsten carbide or other hard surfacing material. The digging chains operate with very little side clearance between them and engage substantially the full area of the bottom of the well hole. Since the individual links on each chain are staggered, and since each link carries a cutting tooth, the teeth cooperate to engage the entire area of the formation at the bottom of the hole. Power means is provided for rotating the outer chains 20 and 23 in one direction and for rotating the inner chains 22 and 21 in the other direction.

The frame assembly 10 and its associated parts are connected through telescoping members 26 and 27 to the lower end of a conventional rotary drill string 11. A coil spring 28 interposed between the telescoping parts 26 and 27 forms a shock absorbing device described more fully hereinafter.

The drill string 11 is supported from the surface in a conventional manner and is rotated by means of the usual rotary machine (not shown). Hydraulic fluid is pumped down the interior of the drill string, and this fluid emerges adjacent the lower end of the device near the sprockets 13, 14 and 15. The hydraulic fluid carries the cuttings from the bit up through the annular space between the drill string and the well hole in the usual manner. Rotation of the drill string acts through a bevel gear assembly generally designated 29 and a spur gear train generally designated 30 to rotate the driving sprockets 16 and 17 in opposite directions. The driven sprockets 13 and 15 are fixed to a common shaft 31 so that they rotate as a unit. Consequently when the sprockets 16 and 17 are rotated in opposite directions the outer chains 20 and 23 rotate in one direction while the inner chains 21 and 22 rotate in the other direction. As the chains pass around the lower portions of the driven sprockets the digging teeth 25 are exposed and contact the formation at the bottom of the well hole.

Considering the various elements of this embodiment of my invention in more detail, the shaft 31 is rotatably supported in axially spaced bearings 32 carried within parallel webs 33 which are formed integrally with the drilling head 12. The double sprocket member 14 is rotatably mounted on the shaft 31 by means of bearings 8, while the sprockets 13 and 15 are each fixed to the shaft by means of a suitable key 9. Retaining nuts 7 are threaded to the ends of the shaft 31 to hold the parts in assembled relationship. The drilling head 12 is mounted for relative longitudinal movement with respect to the lower end of the frame assembly 10, and as shown in the drawings the connecting parts include a cross-head 34 fixed on the lower end of the member 35 and having parallel openings for the reception of threaded elements 36. Lock nuts 37 cooperate with each of the threaded elements 36 so that the threaded elements are adjustably positioned with respect to the cross-head 34. The threaded elements 36 are fixed at their lower ends to the drilling head 12. The longitudinal adjustment provided by the threaded elements 36 and lock nuts 37 enables the chains 20, 21, 22 and 23 to be tensioned before the drilling or digging operation commences.

The drilling head 12 carries a pair of upwardly projecting tubular parts 38 which are slidably received within parallel bores 39 provided in the member 35. Sealing rings 40 may encircle the tubes 38 to prevent leakage. Hydraulic fluid passing downwardly through the interior of the frame assembly 10 enters the tubes 38 and passes into the chamber 41 within the drilling head 12. As shown in Figure 6 the hydraulic fluid is then directed against the interior surfaces of the digging chains by means of suitably oriented nozzles 42.

Stationary stub shafts 43 and 44 are carried on the frame assembly 10 at a location considerably above the location of the driven sprockets 13, 14 and 15. It will be noted that a break in the frame assembly 10 is indicated in the region of the numeral 45. The digging chains are relatively long and the stub shafts 43 and 44 may therefore be mounted a considerable distance away from the driven sprockets 13, 14 and 15. Suitable bearing assemblies 46 and 47 are provided for mounting each of the idler sprockets 18 and 19 on its respective stub shaft.

Near the upper end of the frame assembly 10 are positioned the power shafts 48 and 49 for driving the sprockets 16 and 17. Each of these sprockets is secured on its shaft by any convenient means such as, for example, a press fit. The shafts are supported in axially spaced bearings 50 carried in shells 51 secured to the frame assembly 10. A spur gear 52 fixed to the shaft 48 rotates the driving sprocket 16. Similarly, a spur gear 53 fixed to the shaft 49 rotates the driving sprocket 17. The gears 52 and 53 are in mesh so that the shafts 48 and 49 rotate in opposite directions. The gear 52 is driven from a spur pinion 54 secured on the side face of the bevel gear 55. The bevel gear 55 and pinion 54 are rotatably mounted by means of bearings 57 on a nonrotary stub shaft 56 which is supported at both ends on the frame assembly 10. The inner end of the stub shaft 56 is carried on a plate 58 fixed to the frame assembly 10. The bevel gear 55 is driven from the bevel pinion 59 carried at the lower end of the hollow drive shaft

60. The drive shaft 60 is rotatably mounted in axially spaced bearings 61 and 62. A sleeve 63 is threadedly connected at its upper end to the housing 64 for the bearing 62. The hollow drive shaft 60 is threadedly connected at 66 to the connector element 67. A gland 68 may encircle a portion of the connector element 67 for applying pressure to the packing 69.

The connector element 67 may be directly attached to the lower end of the drill string 11 or, as shown in the drawings, it may be connected to a shock absorbing device which includes the telescoping members 26 and 27 and the compression spring 28. As shown in Figure 4, drive splines 70 extend axially of the member 27 and fit within longitudinal recesses provided in the member 26. These splines carry the torque which is transmitted from the drill string 11 to the lower telescoping member 27. Radial pins 72 are threadedly mounted on the member 26 and extend outwardly into longitudinally extending slots 73 provided in the member 27. These pins cooperate with the slots to limit the extent of axial movement between the members 26 and 27. The member 27 is attached to the lower end of the drill string 11 by way of connection pieces 74 and 75. An upwardly extending tube 76 is received telescopically within the member 75, and this tube is connected at 77 to the member 26. Packing 78 may be provided between the members 74 and 76 and a gland 79 may be threaded within the member 74 for compressing the packing 78. The purpose of the packing is to prevent leakage of hydraulic fluid from the interior of the tube 76. The hydraulic fluid passes downwardly through the tube 76, member 26, connector 67 and hollow drive shaft 60. The tube 80 is fixed within the lower end of the hollow shaft 60 and extends downwardly into a stuffing box 81 carried on the frame assembly 10. The fluid then passes around the shells 51 and downward within the frame assembly 10 and into the bore 39 in the member 35 at the lower end of the frame assembly 10. Suitable seals may be provided for each of the shaft bearings if desired in order to retain lubricant and to exclude the hydraulic fluid.

From this description it will be understood that the drive means including the drive member 60, the gearing 29 and gear train 30, as well as the bearings for the drive sprockets 16 and 17, operate in a lubricant bath and are not exposed to the action of the hydraulic fluid which is pumped down the interior of the drill string 11. If desired a small lubricant-carrying pipe can be provided which communicates with the enclosed gear chamber and which extends downwardly through the frame assembly 10 and communicates at its lower end with the bearing assemblies 8 and 32 for the coaxial sprockets.

In the modified form of my invention shown in Figure 7 the idler sprockets 18*a* and 19*a* are mounted for independent vertical adjustment with respect to the frame assembly 10*a*. The pintles 43*a* and 44*a* for the sprockets 18*a* and 19*a* respectively are fixed to brackets 90 and 91 which are adapted to be slidably mounted in ways or grooves 92 provided on the frame assembly 10*a*. Clamping bolts 93 serve to hold the brackets 90 and 91 in adjusted position on the frame assembly 10*a*. Since the digging chains 20, 21, 22 and 23 are of different lengths, it is desirable to have independent means for adjusting the tension therein, and this is provided by means of the apparatus shown in Figure 7.



In the modified form of my invention shown in Figures 8 and 9, fiber bearings 100 replace the roller type bearings 61 and 62 shown in Figure 2. These bearings 100 rotatably support the hollow driving member 103 which is threadedly connected at its lower end to the bevel pinion 104. The bevel gear member 105 has the spur pinion 106 formed integrally therewith, and this member is rotatably mounted on fiber bearings 107. The wash pipe 108 is stationary and is secured to the frame assembly at 109 adjacent its lower end. This wash pipe 108 projects upwardly in telescopic relation through the bevel pinion 104 into the hollow drive member 103. Suitable packing 110 is provided in a recess in the driving member 103, and a gland 111 is provided for expanding the packing against the wash pipe 108.

The spur gear 112 which is driven by the spur pinion 105 is fixed on the drive shaft 113 and serves to turn the driving sprocket 16*a* which is keyed to the shaft 113. A fiber bearing 114 rotatably supports the shaft 113 within the stationary tubular housing 115.

The driving gear 116 which is driven by the gear 112 is fixed on the drive shaft 117 and serves to drive the driving sprocket 17*a* which is keyed to the shaft. A fiber bearing 118 encircles the shaft near the gear 116, and this bearing is supported in a tubular housing 119. An outboard bearing assembly 120 is provided for the end of the shaft 117 opposite the gear 116. This bearing assembly 120 includes a fiber bearing element 121 carried in a housing 122, and this housing is supported on diverging fins 123 carried on the frame assembly 10*a* at their lower ends.

Suitable sealing elements 124 are provided on the driving sprockets 16*a* and 17*a* for confining lubricant within the shaft bearings and for lubricating the gears.

The ground-engaging chains for the driving sprockets 16*a* and 17*a* may be the same as that shown generally in Figures 2 and 3 or may comprise a five element assembly instead of a double triple element assembly. In any event, each of the links of the chain carries a formation-engaging tooth as clearly shown in Figure 6.

Since the digging device is powered by a rotary drill string having an axis of rotation extending longitudinally of the hole, the frame assembly of the device tends to turn in the opposite direction from the direction of rotation of the drill string. This torque reaction may be carried directly on the outer chains 19 and 23 as described above or corner torque-receiving shoes may be provided on the frame assembly to absorb this torque reaction substantially independently of the digging chains. These torque-receiving shoes may be mounted at vertically spaced intervals on the frame assembly 10*a* between the drilling head 12 and the lower idler sprocket, and as shown in Figure 9 each of these shoes 130 may be secured on the frame assembly 10*a* and be provided with a face 131 which engages a corner of the noncircular hole. Each of the shoes 130 may be provided with a relatively thin outwardly extending section 132 which is positioned between a pair of the digging chains and a transversely extending portion 132 which extends to the face 13. These torque-absorbing shoes 130 are mounted only on diagonally opposite portions of the frame assembly 10*a* and on the slack sides of the digging chains 19 and 23. The working diameter of these digging chains when passing over their respective sprockets is substantially the same as the over-all lateral dimension of the device including the torque-absorbing shoes 130. Since one flight of each of the chains is slack during operation, these slack flights extend under the portions 132 of the shoes 130 and emerge therefrom at each end to pass around their respective sprockets. It will be noted that the outer links in each of the chains 20 and 23 have laterally extending teeth 25a which extend beyond the side face of the links to provide clearance for the frame assembly 10a.

In operation a shallow preliminary hole is drilled from the surface by conventional means. The frame assembly 10a and associated parts is then attached to the lower end of the drill string 11 below the rotary machine, and the drill string is lowered until the digging chains contact the bottom of the preliminary hole. Torque-resisting means are then applied to the frame assembly 10a. This may be accomplished by clamping suitable arms to the sleeve 63 or other part of the frame assembly 10a above the upper driving sprocket 16. Such torque arms (not shown) extend radially and contact fixed elements of the derrick or substructure commonly employed in rotary well drilling operations. The drill string 11 is then rotated by means of the rotary machine (not shown) and it is lowered into the hole so that pressure develops on the digging teeth 25. The digging teeth enter the formation and deepen the hole. The cuttings are carried upwardly out of the hole by means of the stream of hydraulic fluid supplied through the interior of the drill string. After the hole has been deepened for a number of feet by the digging chains, the torque resisting clamps are discarded. The hole which is produced by the digging chains is noncircular in outline and therefore the walls of the hole prevent rotation of the frame assembly 10a and digging chains about the axis of the drill string. Continued rotation of the drill string 11 continues the digging operation of the chains 20, 21, 22 and 23.

If the chains were all to rotate in the same direction, the action of the device would be to veer away from the vertical, but since the outer chains 20 and 23 rotate in one direction while the inner chains 21 and 22 rotate in the other direction, this tendency is eliminated. The torque imposed on the frame assembly 10 by the drill string 11 is resisted by the side walls of the hole as it is deepened, and accordingly there may be some tendency of the device to wind or spiral gradually as the hole is deepened. This has no disadvantageous effect, however.

Conventional rotary drill bits are ordinarily designed only for cutting on the bottom of the hole. Occasionally formations are encountered which swell upon contact with the drilling fluid with the result that the hole becomes smaller as the bit deepens the hole. When it is desired to withdraw the bit for replacement, difficulty is encountered under such conditions because the bit is ineffective to drill in an upward direction. My improved digging device overcomes this difficulty because the digging chains will dig upwardly as well as downwardly. Thus, the digging teeth 25 are exposed as the links 24 of the digging chains travel around the drive sprockets and idler sprockets. Accordingly, the device may be used to dig itself out in the event that "heaving shale" or other swelling formation should be encountered. Furthermore, the fact that these digging chains are also effective to dig in an upward direction prevents possible sticking of the drilling unit in the hole by deposit of filter cake or mud on the walls of the hole.

Since the digging chains may be made as long as is considered practicable, and since a very large number of digging teeth may therefore be employed, the hard surfaced teeth do not become dulled for a much greater length of time than is the case where only a few teeth are provided on the end of a conventional rock bit. Accordingly, it is unnecessary to withdraw the device from the well hole at frequent intervals for the purpose of replacing worn cutters.

While I have described my invention in connection with the digging of wells, it will be understood that the apparatus may also be used for digging horizontal, inclined or curved holes or for digging other holes in the earth such as, for example, footings for concrete foundations, bridge piers, etc. Furthermore, the essential features of my invention may be employed in devices for forming or cutting noncircular holes in various materials.

Having fully described my invention, it is to be understood that I do not wish to be limited to the details herein set forth, but my invention is of the full scope of the appended claims.

I claim:

1. In a well digging device of the class described, the combination of a frame, means carried on the lower end of the frame for supporting a plurality of coaxial sprockets, gearing carried on the upper portion of the frame and adapted to be driven by a rotary drill string, first and second vertically spaced driving sprockets rotatably mounted on the frame and driven from said gearing in opposite directions, parallel vertically extending digging chains having formation-engaging teeth, one of the digging chains being trained over the first driving sprocket and one of said coaxial sprockets and a second digging chain being trained over the second driving sprocket and another of said coaxial sprockets, and torque resisting means on the frame engaging the formation to prevent rotation of the frame within the bore hole formed by the teeth.

2. In a well digging device of the class described, the combination of a frame, means carried on the lower end of the frame for supporting a plurality of coaxial sprockets, gearing carried on the upper portion of the frame and adapted to be driven by a rotary drill string, a first driving sprocket rotatably mounted on the frame and driven in one direction from said gearing, a second driving sprocket rotatably mounted on the frame and being vertically spaced from the first driving sprocket, the second driving sprocket driven in the other direction from said gearing, parallel vertically extending digging chains having formation-engaging teeth, one of the digging chains being trained over the first driving sprocket and one of said coaxial sprockets and a second digging chain being trained over the second driving sprocket and another of said coaxial sprockets, and torque resisting means on the frame engaging the formation to prevent rotation of the frame within the bore hole formed by the teeth.

3. In a well digging device of the class described, the combination of a frame, means carried on the lower end of the frame for supporting four coaxial sprockets, gearing carried on the upper portion of the frame and adapted to be driven by a rotary drill string, means for supporting the frame from the drill string, a first driving sprocket rotatably mounted on the frame

and driven in one direction from said gearing, a second driving sprocket rotatably mounted on the frame and driven in the other direction from said gearing, four parallel vertically extending digging chains having formation-engaging teeth, one of the outer chains being trained over the first driving sprocket and one of said coaxial sprockets and one of the inner chains being trained over the second driving sprocket and another of said coaxial sprockets, the outer coaxial sprockets being connected for rotation as a unit, and the inner coaxial sprockets being connected for rotation as a separate unit, the other digging chains being trained over the other coaxial sprockets and driven thereby, and torque resisting means on the frame engaging the formation to prevent rotation of the frame within the well.

4. In a well digging device of the class described, the combination of a frame, means carried on the lower end of the frame for supporting a plurality of coaxial sprockets, bevel gearing carried on the upper portion of the frame and adapted to be driven by a rotary drill string, torque resisting means on the frame engaging the wall of the hole, a first driving sprocket rotatably mounted on the frame and driven directly by said bevel gearing, a second driving sprocket rotatably mounted on the frame vertically spaced from said first driving sprocket, gear means for driving the second driving sprocket in a reverse direction from said bevel gearing, and vertically extending digging chains having formation-engaging teeth, one of the digging chains being trained over the first driving sprocket and one of said coaxial sprockets and a second digging chain being trained over the second driving sprocket and another of said coaxial sprockets.

5. In a well digging device adapted to be carried on the lower end of a rotary drill string, the combination of a frame, a plurality of coaxially positioned sprockets carried at the lower end of the frame, a plurality of parallel vertically extending digging chains having formation-engaging teeth and trained over said sprockets, torque resisting means on the frame engaging the well formation to prevent rotation of the frame, drive means for driving the chains, the drive means including a pair of telescoping splined members positioned coaxially of the drill string, and a coil spring acting to separate the splined members in an axial direction.

6. In a well digging device for use on a rotary drill string, the combination of a frame, a driving member mounted in the frame for rotation about a vertical axis, means whereby the driving member may be driven from the rotary drill string, a pair of driving sprockets rotatably mounted on the frame, means including gear means for driving each of said sprockets in opposite directions from said driving member, a plurality of coaxial sprockets carried at the lower end of the frame, a pair of idler sprockets rotatably mounted on the frame below the location of the driving sprockets, parallel vertically extending digging chains having formation-engaging teeth and trained over the coaxial sprockets, certain of the chains being also trained over the driving sprockets, and certain other chains being also trained over the idler sprockets, the outermost coaxial sprockets being connected for rotation as a unit and the innermost coaxial sprockets being connected for rotation as a unit, and torque resisting means on the frame engaging the formation to resist rotation of the frame.



7. In a well digging device for use on a rotary drill string, the combination of a frame, a driving member mounted in the frame for rotation about a vertical axis, means whereby the driving member may be driven from the rotary drill string, a pair of driving sprockets rotatably mounted on the frame, means including gear means for driving each of said sprockets in opposite directions from said driving member, a plurality of coaxial sprockets carried on a drilling head at the lower end of the frame, a pair of idler sprockets rotatably mounted on the frame below the location of the driving sprockets, parallel vertically extending digging chains having formation-engaging teeth and trained over the coaxial sprockets, certain of the chains being also trained over the driving sprockets, and certain other chains being also trained over the idler sprockets, means for adjusting the position of the drilling head on the frame for tensioning the digging chains, the outermost coaxial sprockets being connected for rotation as a unit and the innermost coaxial sprockets being connected for rotation as a unit, and torque resisting means on the frame engaging the formation to resist rotation of the frame.

8. In a well digging device for use on a rotary drill string, the combination of a frame, a driving member rotatably mounted in the frame for rotation about a vertical axis, means whereby the driving member may be driven from the rotary drill string, a pair of driving sprockets rotatably mounted on the frame, means including gear means for driving each of said sprockets in opposite directions from said driving member, four coaxial sprockets carried at the lower end of the frame, two digging chains each having formation-engaging teeth trained over the driving sprockets and two of said coaxial sprockets, a pair of idler sprockets rotatably mounted on the frame below the location of the driving sprockets, and two additional digging chains having formation-engaging teeth and trained over the idler sprockets and the other two coaxial sprockets, the outermost coaxial sprockets being connected for rotation as a unit and the innermost coaxial sprockets being connected for rotation as a unit, and torque resisting means on the frame engaging the formation to resist rotation of the frame.

9. In a well digging device for use on a rotary drill string, the combination of a frame, a driving member rotatably mounted in the frame for rotation about a vertical axis, means whereby the driving member may be driven from the rotary drill string, a pair of driving sprockets rotatably mounted on the frame, means including gear means for driving each of said sprockets in opposite directions from said driving member, four coaxial sprockets carried at the lower end of the frame, two digging chains each having formation-engaging teeth trained over the driving sprockets and two of said coaxial sprockets, a pair of idler sprockets rotatably mounted on the frame below the location of the driving sprockets, and two additional digging chains having formation-engaging teeth and trained over the idler sprockets and the other two coaxial sprockets, the outermost coaxial sprockets being connected for rotation as a unit and the innermost coaxial sprockets being connected for rotation as a unit, means for conveying hydraulic fluid from the drill string to said coaxial sprockets, and torque resisting means on the frame engaging the wall of the bore formed by the teeth.

10. In a well digging device for use on a rotary

drill string, the combination of a frame, a driving member mounted in the frame for rotation about a vertical axis, means whereby the driving member may be driven from the rotary drill string, a pair of driving sprockets rotatably mounted on the frame, means including gear means for driving each of said sprockets in opposite directions from said driving member, a plurality of coaxial sprockets carried on a drilling head at the lower end of the frame, a pair of idler sprockets rotatably mounted on the frame below the location of the driving sprockets, parallel vertically extending digging chains having formation-engaging teeth and trained over the coaxial sprockets, certain of the chains being also trained over the driving sprockets, and certain other chains being also trained over the idler sprockets, means for adjusting the position of the drilling head on the frame for tensioning the digging chains, means for independently adjusting the position of the idler sprockets on the frame, the outermost coaxial sprockets being connected for rotation as a unit and the innermost coaxial sprockets being connected for rotation as a unit, and torque resisting means on the frame engaging the formation to resist rotation of the frame.

11. Well digging apparatus of the class described comprising in combination: a frame, a first driving sprocket rotatably mounted on the frame, a second driving sprocket rotatably mounted on the frame and spaced axially below and laterally offset from said first driving sprocket, a rotary driving element extending axially of the frame, bearing means supporting the driving element with respect to the frame, means including gear means whereby the driving element may drive both of said driving sprockets, a pair of coaxial sprockets rotatably mounted on the frame at the lower end thereof, a pair of endless chains of different length trained over said coaxial sprockets, the chains having formation-engaging teeth, the longer chain being trained over the first said driving sprocket and the shorter chain being trained over the second said driving sprocket, and torque resisting means on the frame for engaging the formation to prevent rotation of the frame.

12. Well digging apparatus of the class described comprising in combination: a frame, a transverse rotary member on the frame, a first driving sprocket fixed on said member, a second driving sprocket rotatably mounted on the frame and spaced axially below and laterally offset from said first driving sprocket, a rotary driving element extending axially of the frame, bearing means supporting the driving element with respect to the frame, means including gear means whereby the driving element may drive said member, additional means whereby the second driving sprocket may be driven from said member, a pair of coaxial sprockets rotatably mounted on the frame at the lower end thereof, a pair of endless chains of different length trained over said coaxial sprockets, the chains having formation-engaging teeth, the longer chain being trained over the first said driving sprocket and



the shorter chain being trained over the second said driving sprocket, and torque resisting means on the frame for engaging the formation to prevent rotation of the frame.

13. Digging apparatus of the class described, comprising in combination: a frame, a first driving sprocket rotatably mounted on the frame, a second driving sprocket rotatably mounted on the frame and spaced axially below and laterally offset from said first driving sprocket, chain support means rotatably mounted on the frame at the lower end thereof, a plurality of parallel endless chains including a pair of endless chains of different length trained over said support means, the chains having formation-engaging teeth, the longer chain being trained over the first said driving sprocket and the shorter chain being trained over the second driving sprocket, a rotary driving element extending axially of the frame, bearing means supporting the driving element with respect to the frame, means including gear means whereby said driving element may drive both of said driving sprockets, the driving element and gear means being confined within the outline of the hole produced in the formation by said teeth of the chains, said chains by lateral engagement with the formation providing torque resisting means to prevent rotation of the digging apparatus.

14. Digging apparatus of the class described, comprising in combination: a frame, a first sprocket rotatably mounted on the frame, a second sprocket rotatably mounted on the frame and spaced axially below and laterally offset from said first sprocket, chain support means rotatably mounted on the frame at the lower end thereof, a plurality of parallel endless chains including a pair of endless chains of different lengths trained over said support means, the chains having formation-engaging teeth, the longer chain being trained over the first said sprocket and the shorter chain being trained over the second sprocket, a rotary driving element extending axially of the frame, bearing means supporting the driving element with respect to the frame, means including gear means whereby said driving element may drive the first said sprocket and the longer chain, the shorter chain being driven by said chain support means, the driving element and gear means being confined within the outline of the hole produced in the formation by said teeth of the chains, and said chains by lateral engagement with the formation providing torque resisting means to prevent rotation of the digging apparatus.

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