United States Patent

[11] 3,565,192

[72] Inventor **Frank W. McLarty**
337 S. Edgefield Ave., Dallas, Tex. 75208

[21] Appl. No. **755,471**
[22] Filed **Aug. 27, 1968**
[45] Patented **Feb. 23, 1971**

[54] **EARTH BORING MECHANISM AND COORDINATED PILOT HOLE DRILLING AND CORING MECHANISMS**
12 Claims, 55 Drawing Figs.

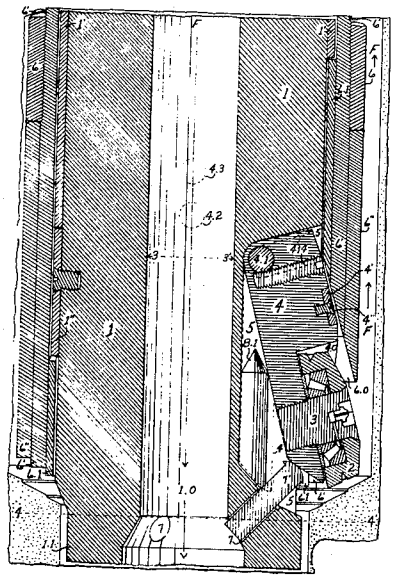
[52] **U.S. Cl.** **175/246,** 175/258, 175/330, 175/387, 175/334
[51] **Int. Cl.** **E21b 9/18,** E21b 9/32, E21b 9/36
[50] **Field of Search** ..... 175/246-—248, 258, 329, 330, 334, 385, 387

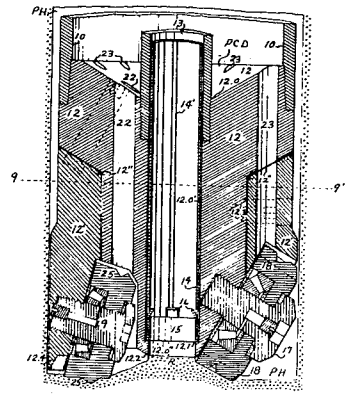
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Primary Examiner—Stephen J. Novosad
Assistant Examiner—Ian A. Calvert

ABSTRACT: A cylindrical member is lowerable through a drill pipe and latched thereto. Cutters carried on arms hinged to slots in the cylindrical member move outwardly under pressure of the drill fluid through gaps in the lower end of a shoe at the bottom of the drill pipe to underream under the shoe. The cylindrical member has a pilot bit at its lower end and a core barrel in its bore. Roller or diamond cutters may be used.





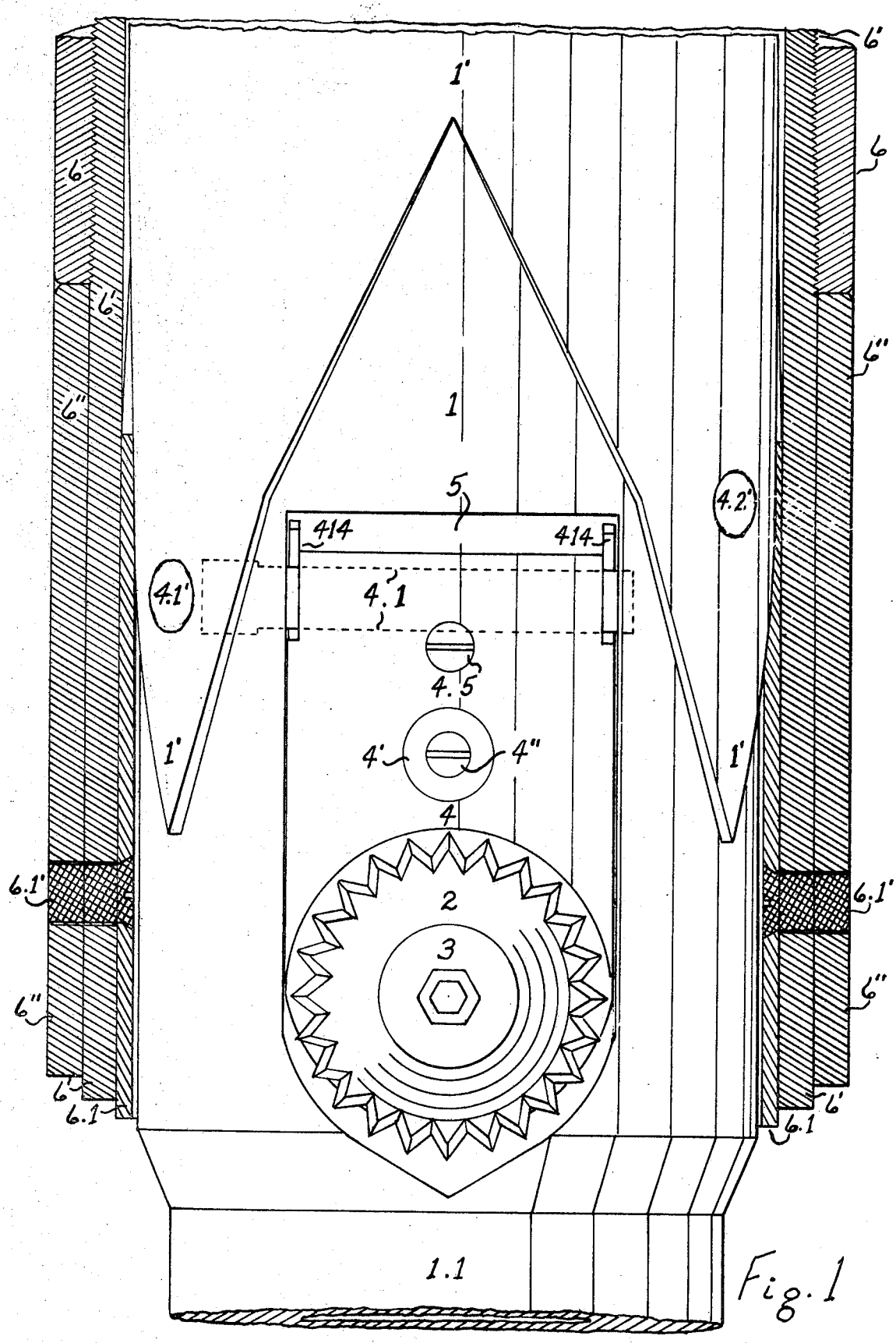


Fig. 1

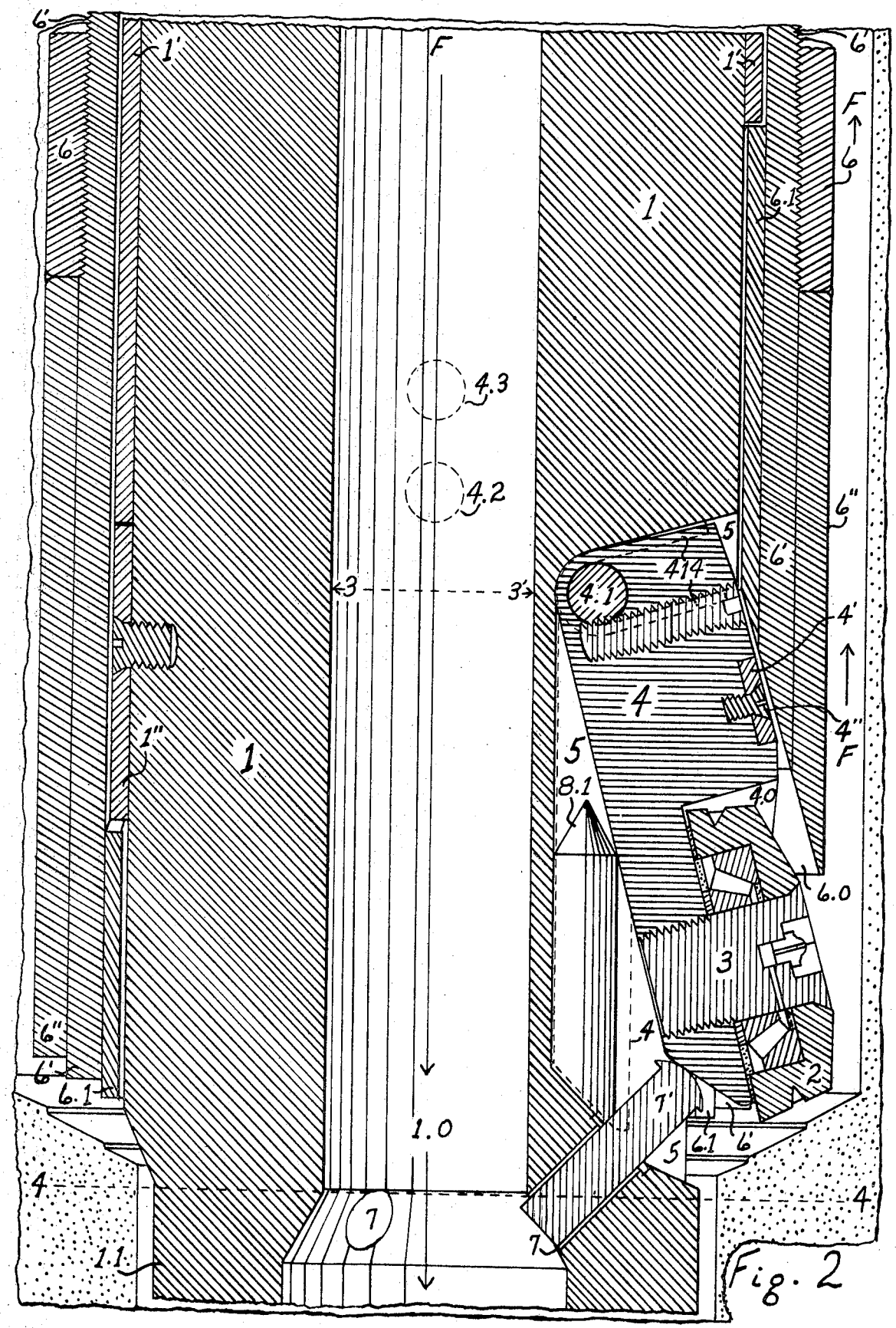

6'
1'
F
1'
6'
F
6
6
6.1
1
4.3
4.2
6"
5
4.1
4
6'
3
3'
4'
4
4"
F
1"
1
5
8.1
4.0
6.0
3
6"
6'
6.1
4
2
7'
6.1
6'
5
4
4
1.0
7
7
1.1

Fig. 2

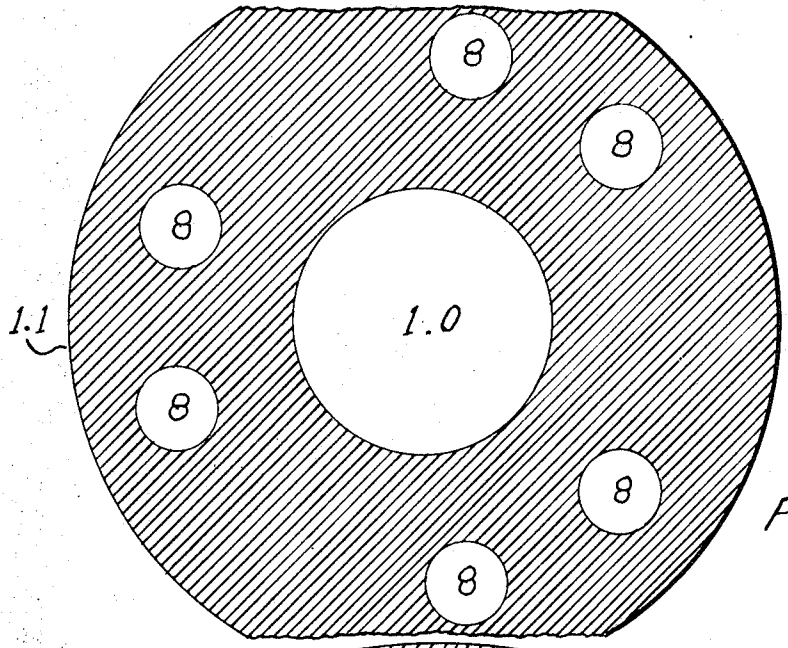
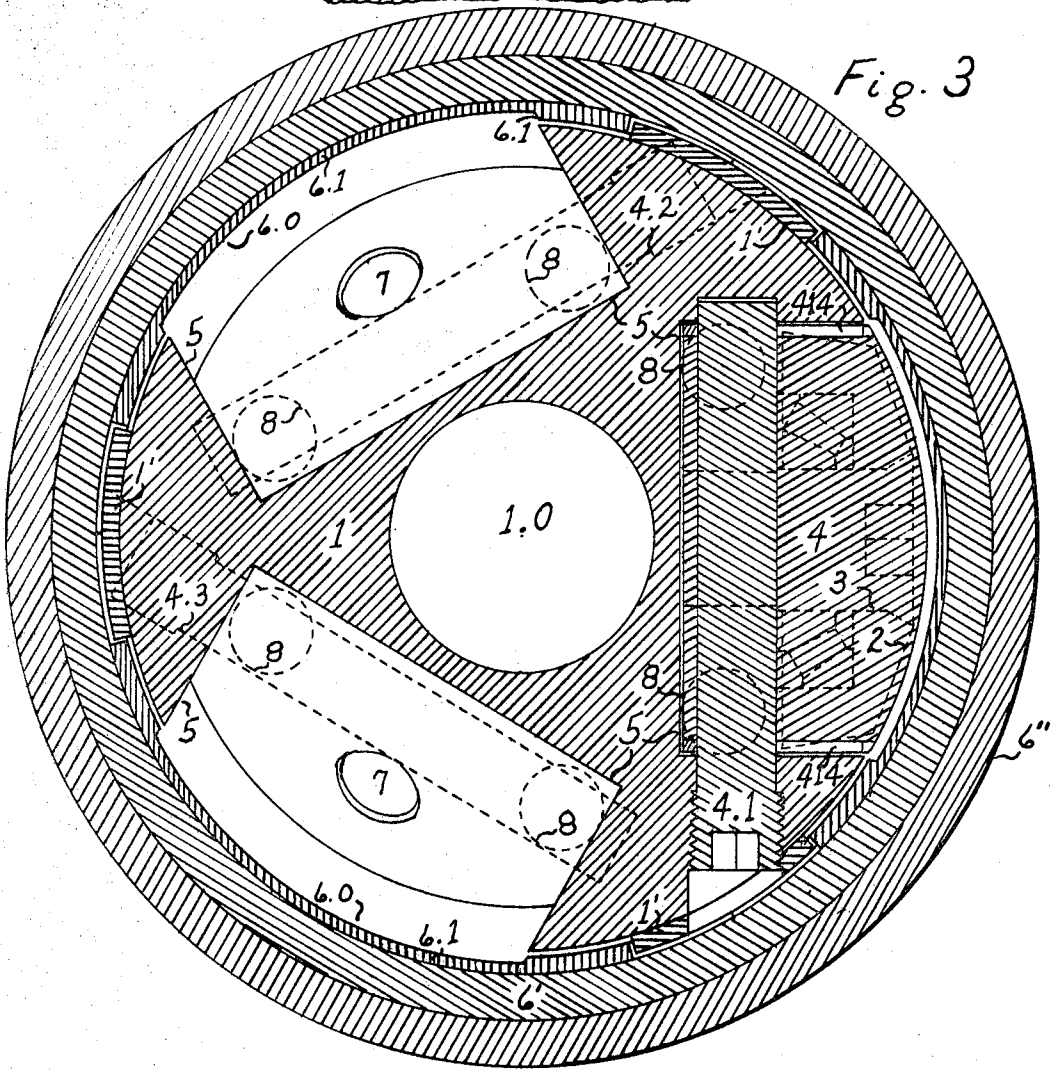


Fig. 4

Fig. 3



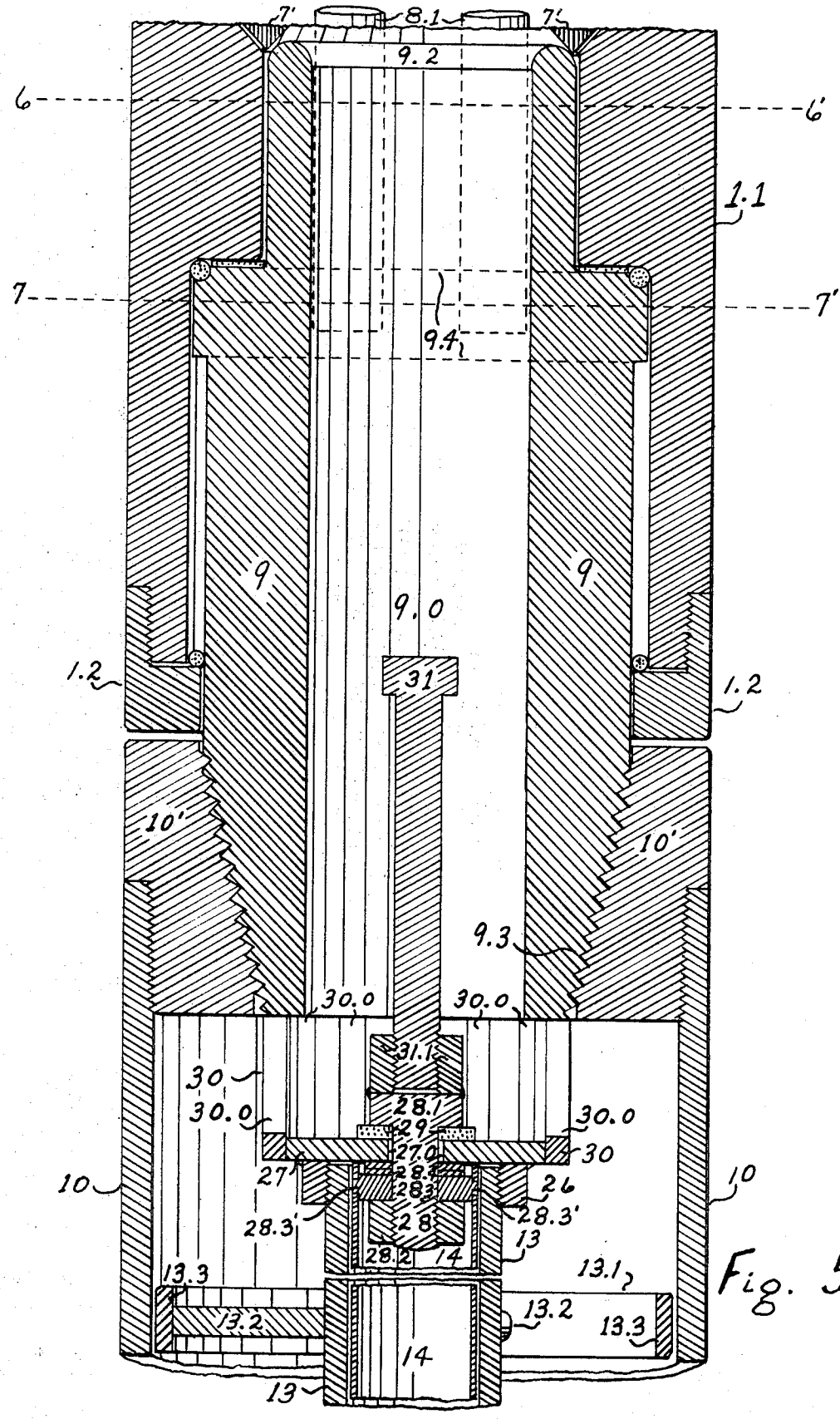

7'
8.1
7'
9.2
6
6'
1.1
7
7'
9.4
9
9
9.0
31
1.2
1.2
10'
10'
9.3
30.0
30.0
31.1
30
30.0
28.1
29
30.0
27.0
30
10
27
28.4
28.3
26
10
28.3'
28.3'
28
13
28.2
14
13.3
13.1
13.2
13.2
13.3
14
13

Fig. 5

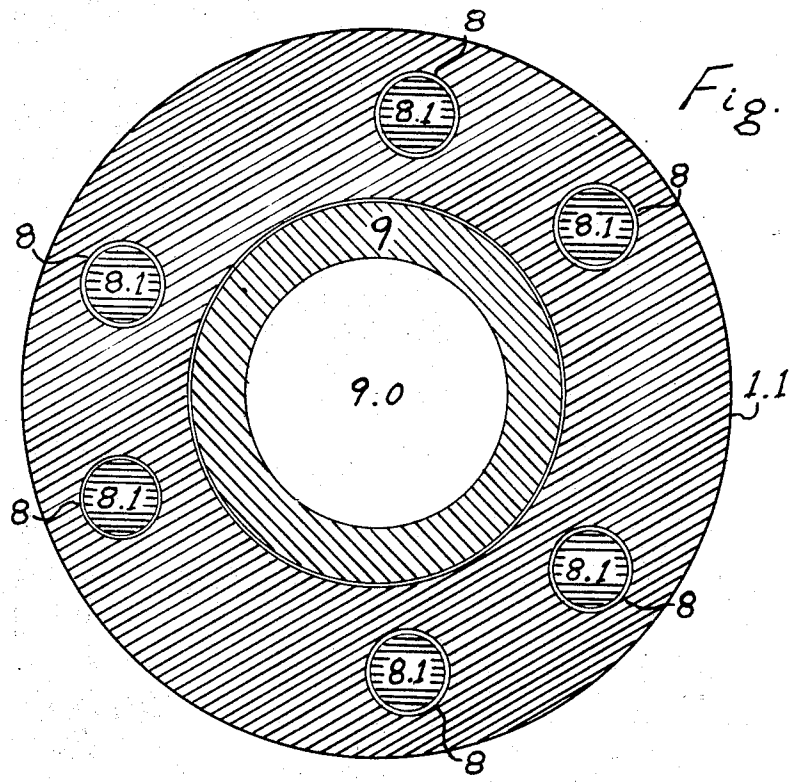

8
8.1
8
8.1
8
9
9.0
1.1
8.1
8
8.1
8
8.1
8

Fig. 6

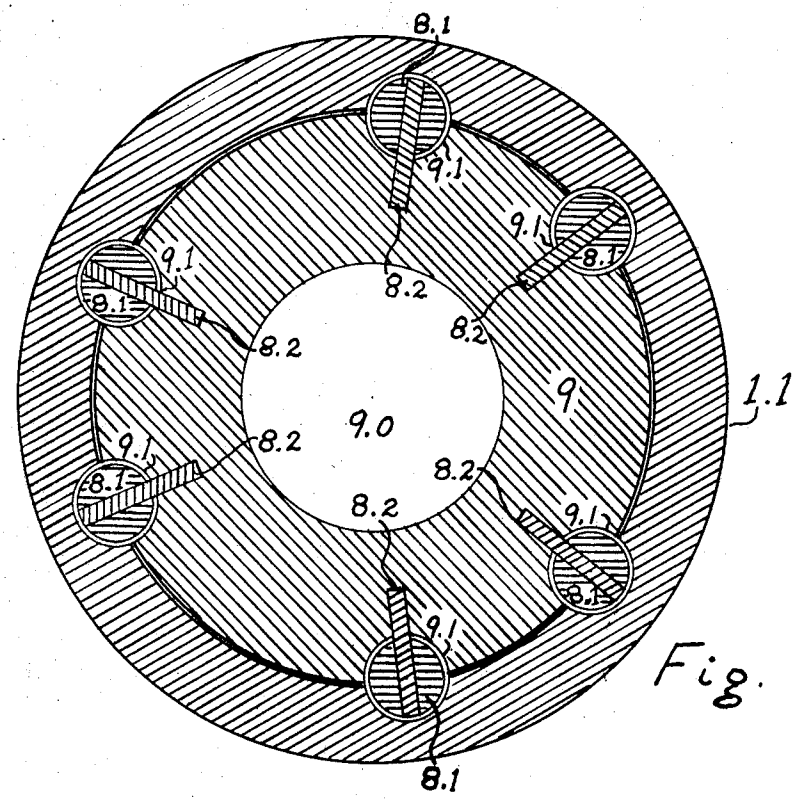

8.1
9.1
9.1
8.1
9.1
8.1
8.2
8.2
8.2
9
1.1
9.0
9.1
8.2
8.2
8.1
8.2
9.1
8.1
9.1
8.1

Fig. 7

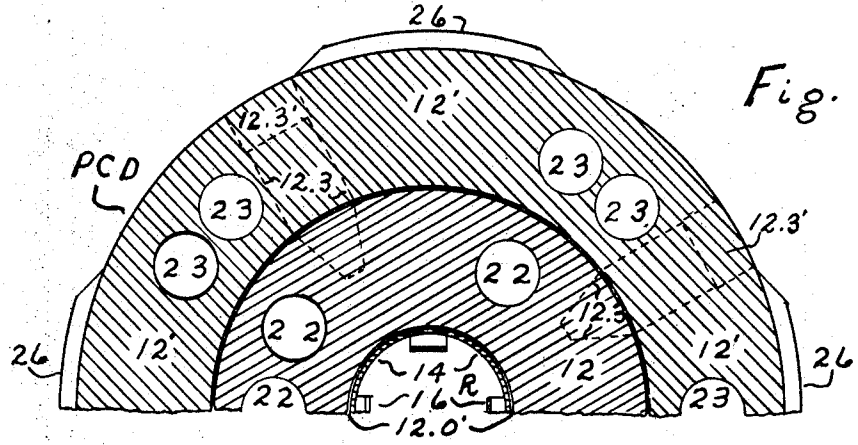

26
12'
12.3'
PCD
23
22
12
14
R
16
12.0'
24

Fig. 9

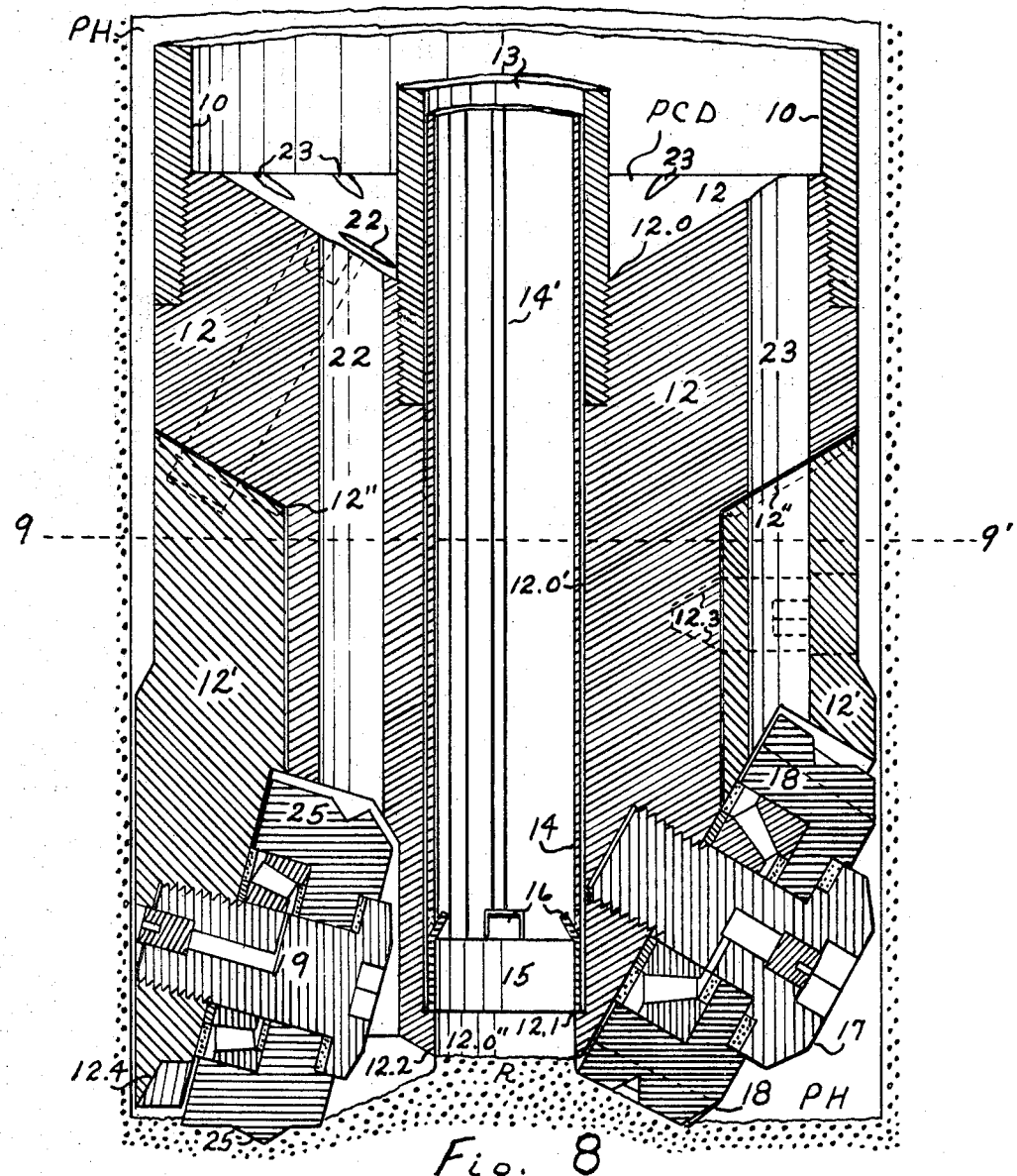
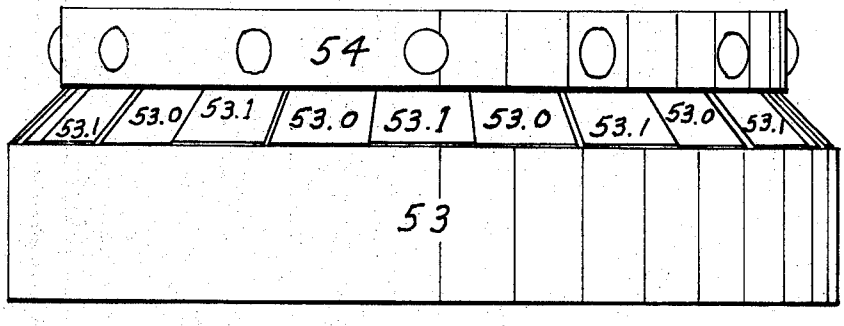

PH
13
10
PCD
23
22
12
12.0
14'
12"
9
9'
12.0'
12.3
25
14
16
15
12.0"
12.1
12.2
R
17
18
PH

Fig. 8

Fig. 14


54
53.1
53.0
53.1
53.0
53.1
53.0
53.1
53.0
53.1
53

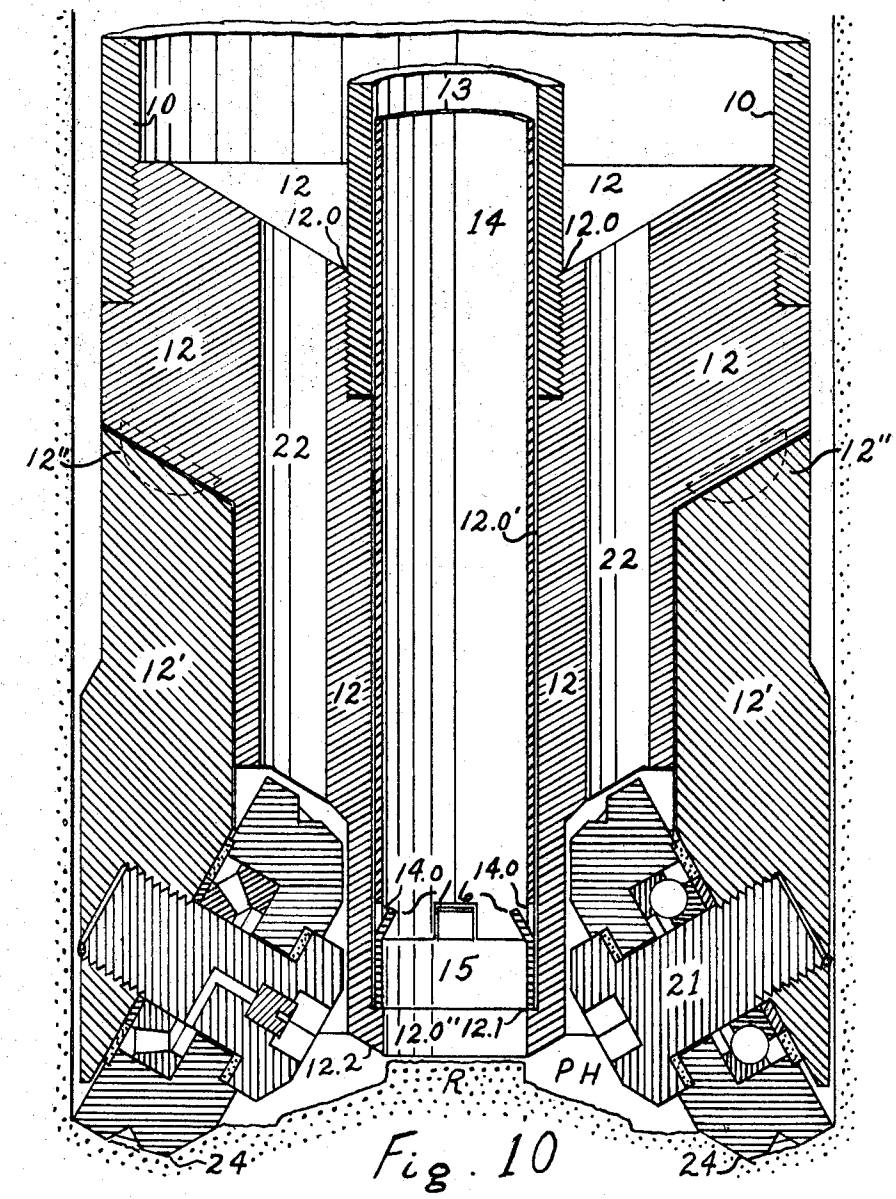

10
13
10
12
12.0
14
12.0
12
12
12"
22
12"
12.0'
22
12'
12
12
12'
14.0
14.0
15
21
12.0"12.1
12.2
R
PH
24
24

Fig. 10

Fig. 12

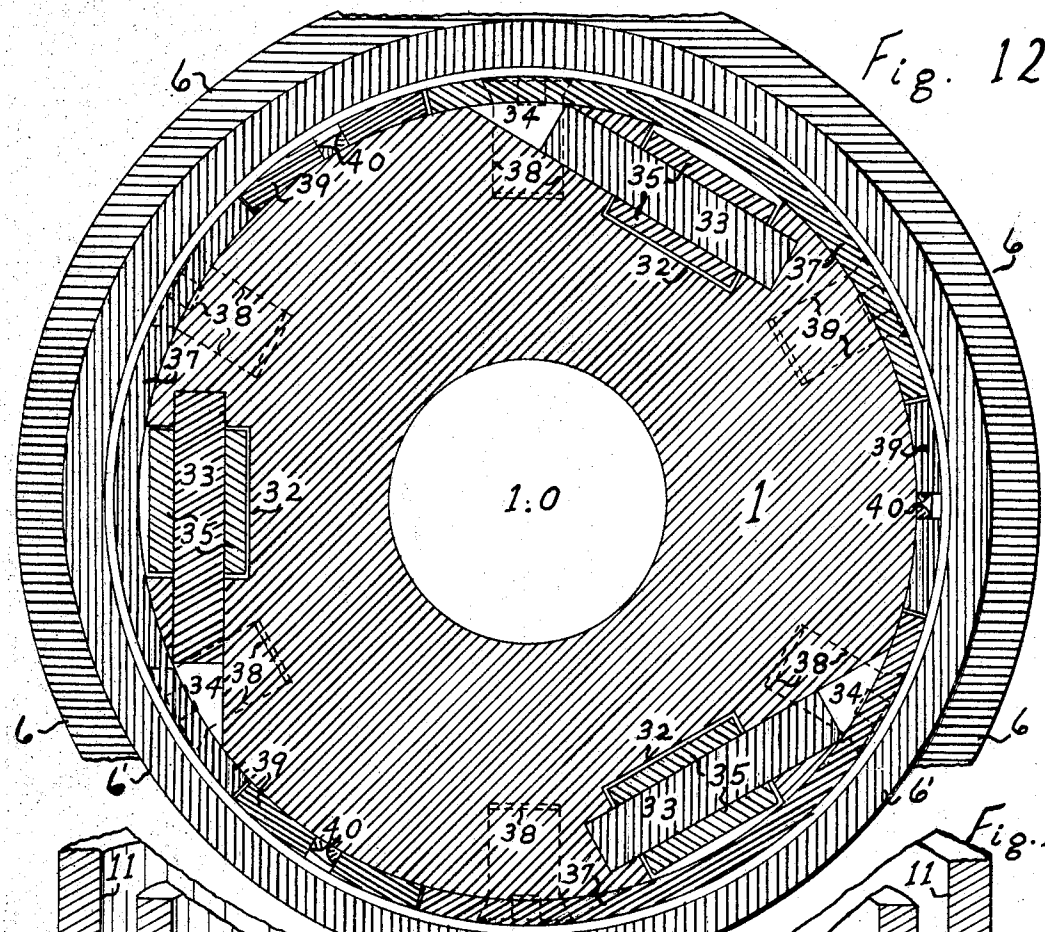

6
34
40
39
38
35
33
32
37
1.0
1
6'

Fig. 11

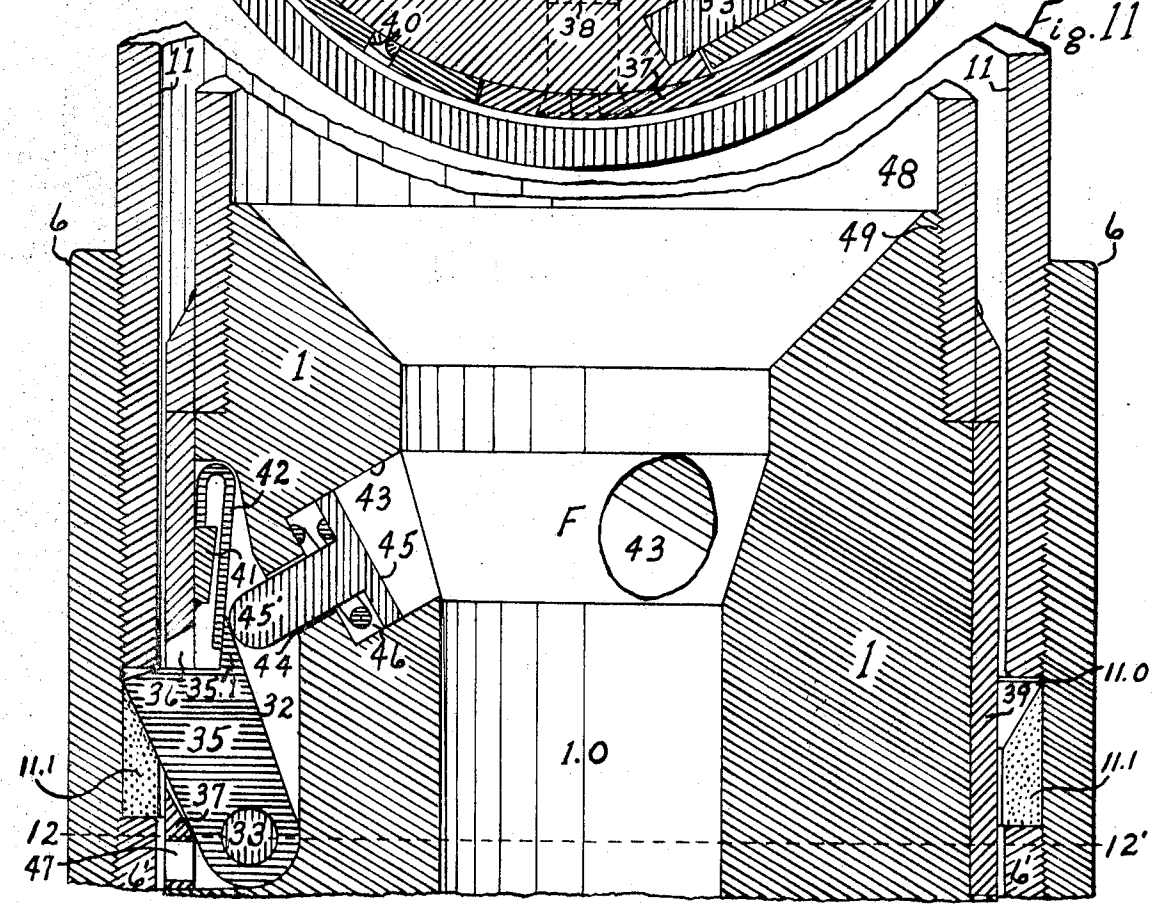

11
48
49
6
1
42
43
45
41
44
46
F
43
35.1
36
32
35
37
33
11.1
12
47
1.0
11.0
39
12'

Fig. 13

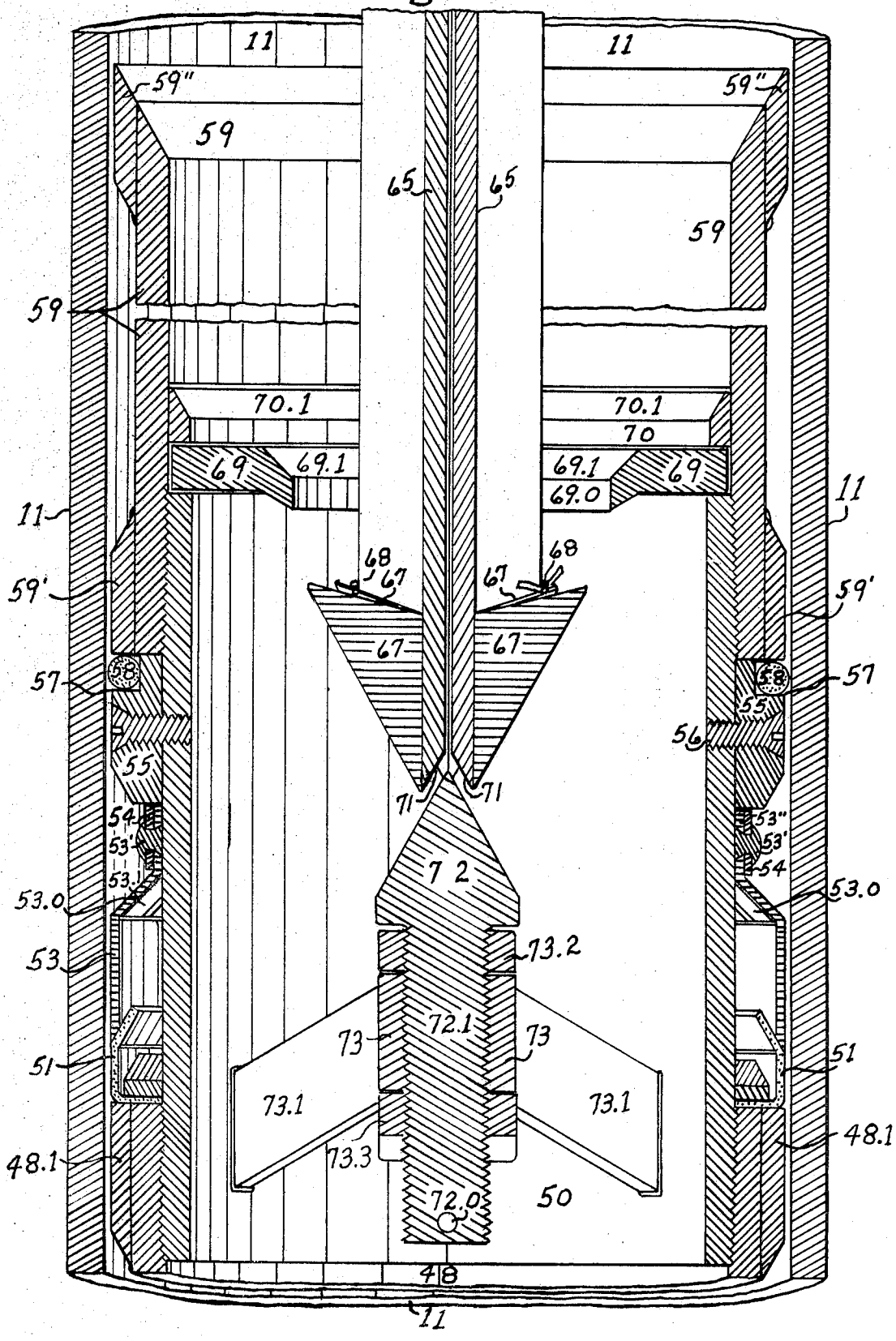

11
11
59"
59"
59
65
65
59
59
70.1
70.1
70
69
69.1
69.1
69.0
69
11
11
59'
59'
68
67
68
67
67
67
57
58
58
57
55
55
56
54
53"
53'
53.1
54
53.0
53.0
53
71
71
72
73.2
72.1
73
73
51
51
73.1
73.1
48.1
48.1
73.3
72.0
50
48
11

Fig. 22

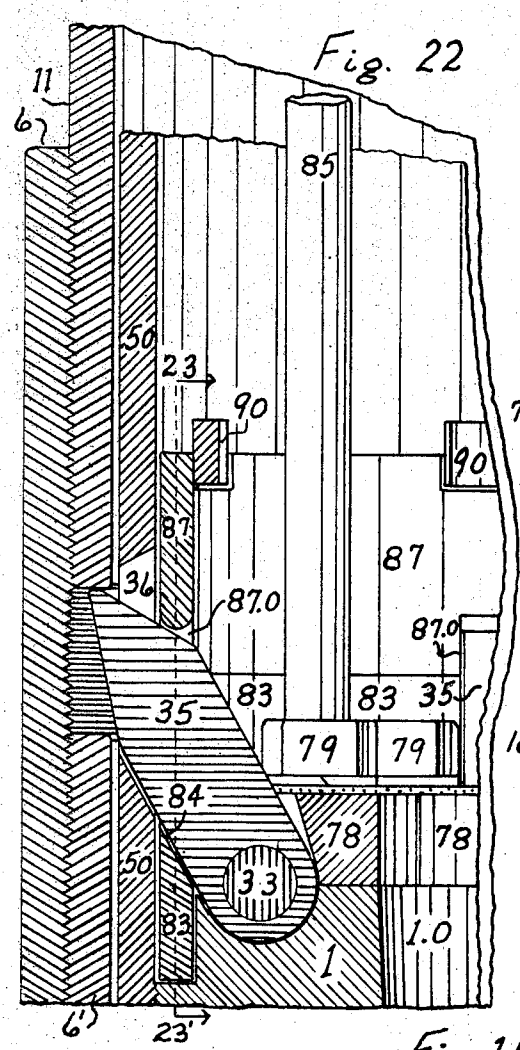


Fig. 15-16

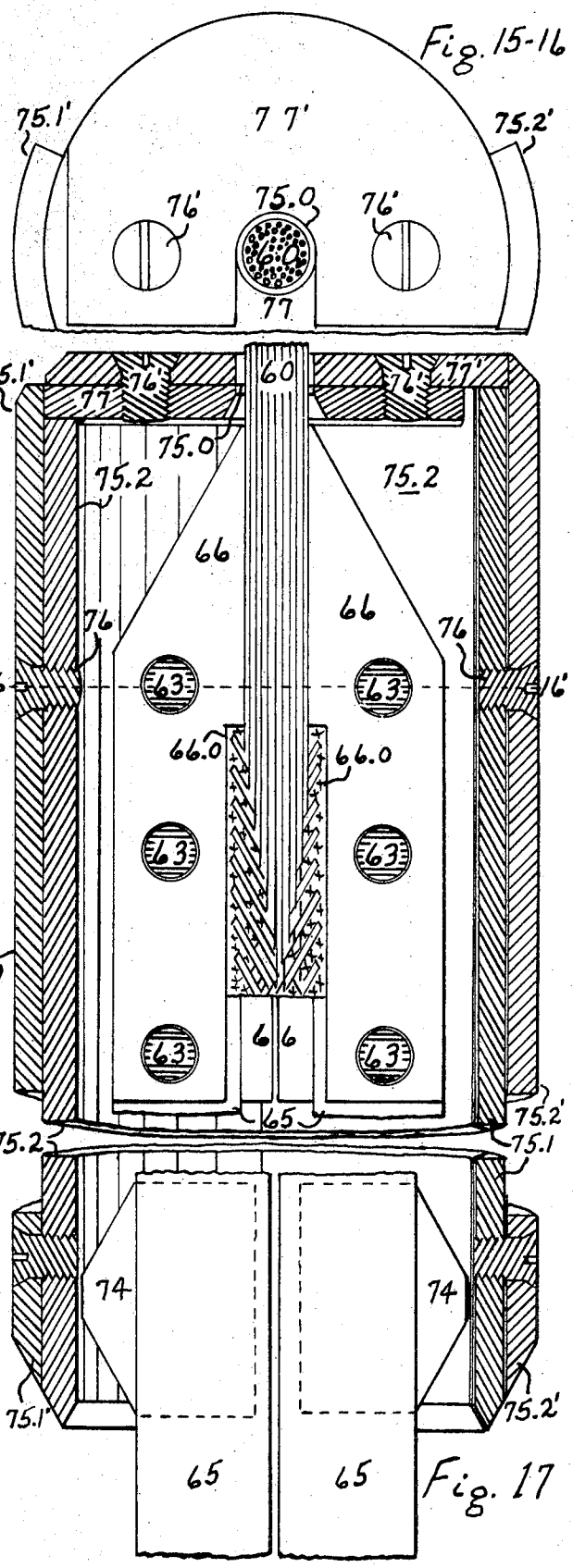
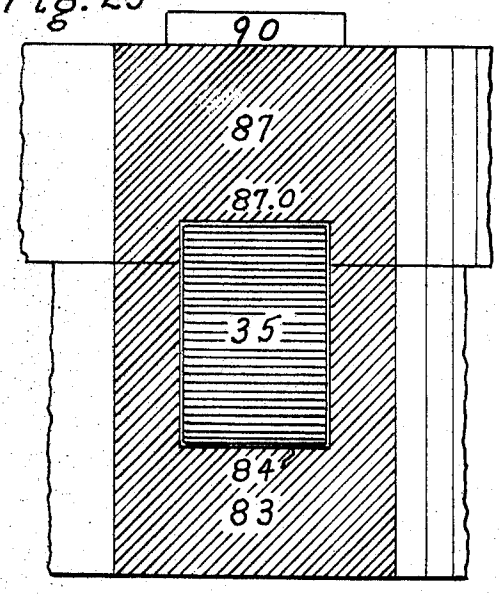


Fig. 15

Fig. 17

Fig. 23



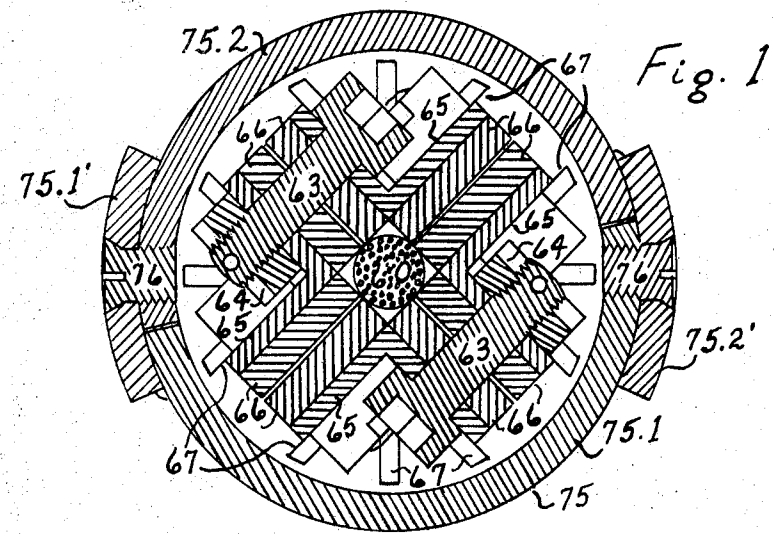

75.2
67
65
66
63
64
75.1'
76
75.2'
75.1
75

Fig. 16

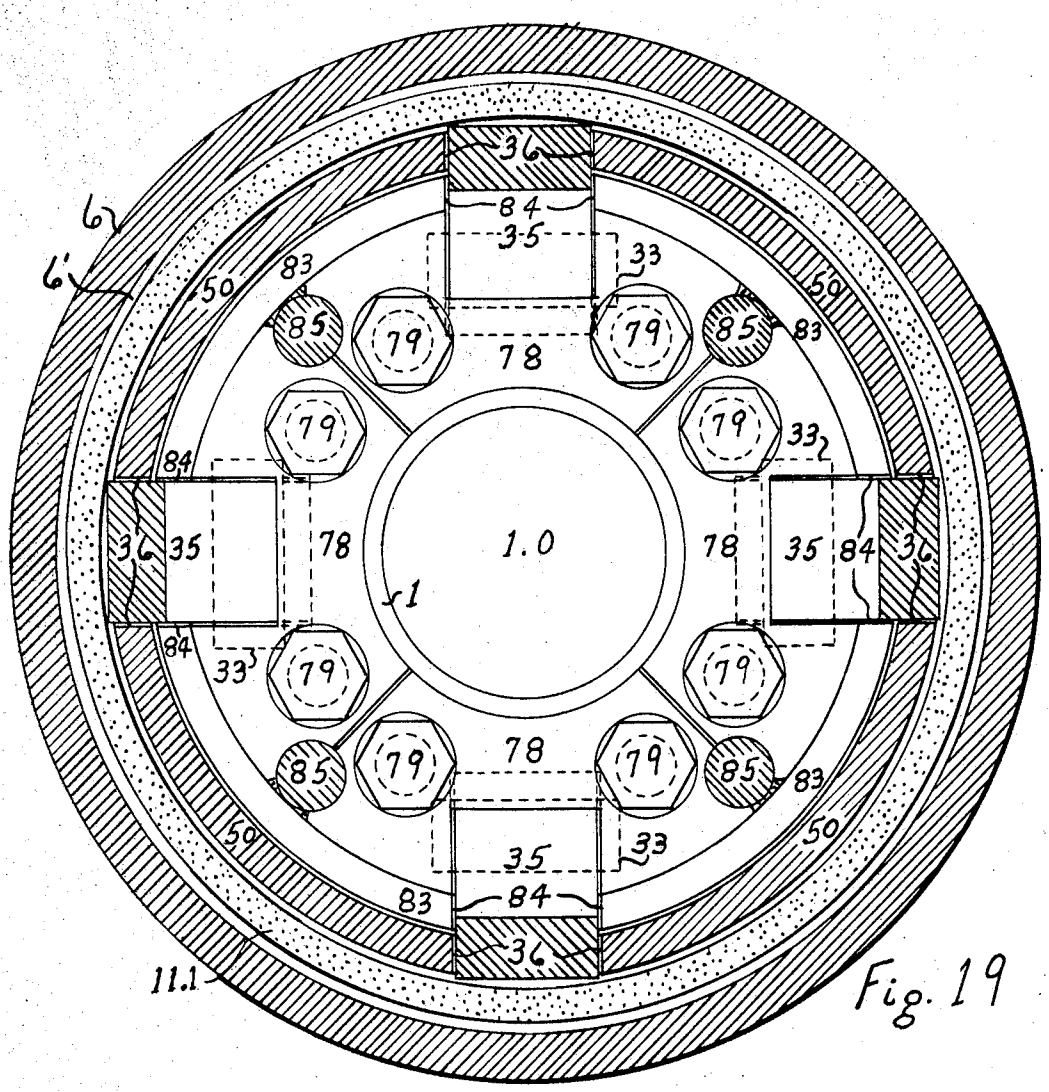

6
6'
36
84
35
33
50
83
85
79
78
1.0
1
11.1

Fig. 19

Fig. 18

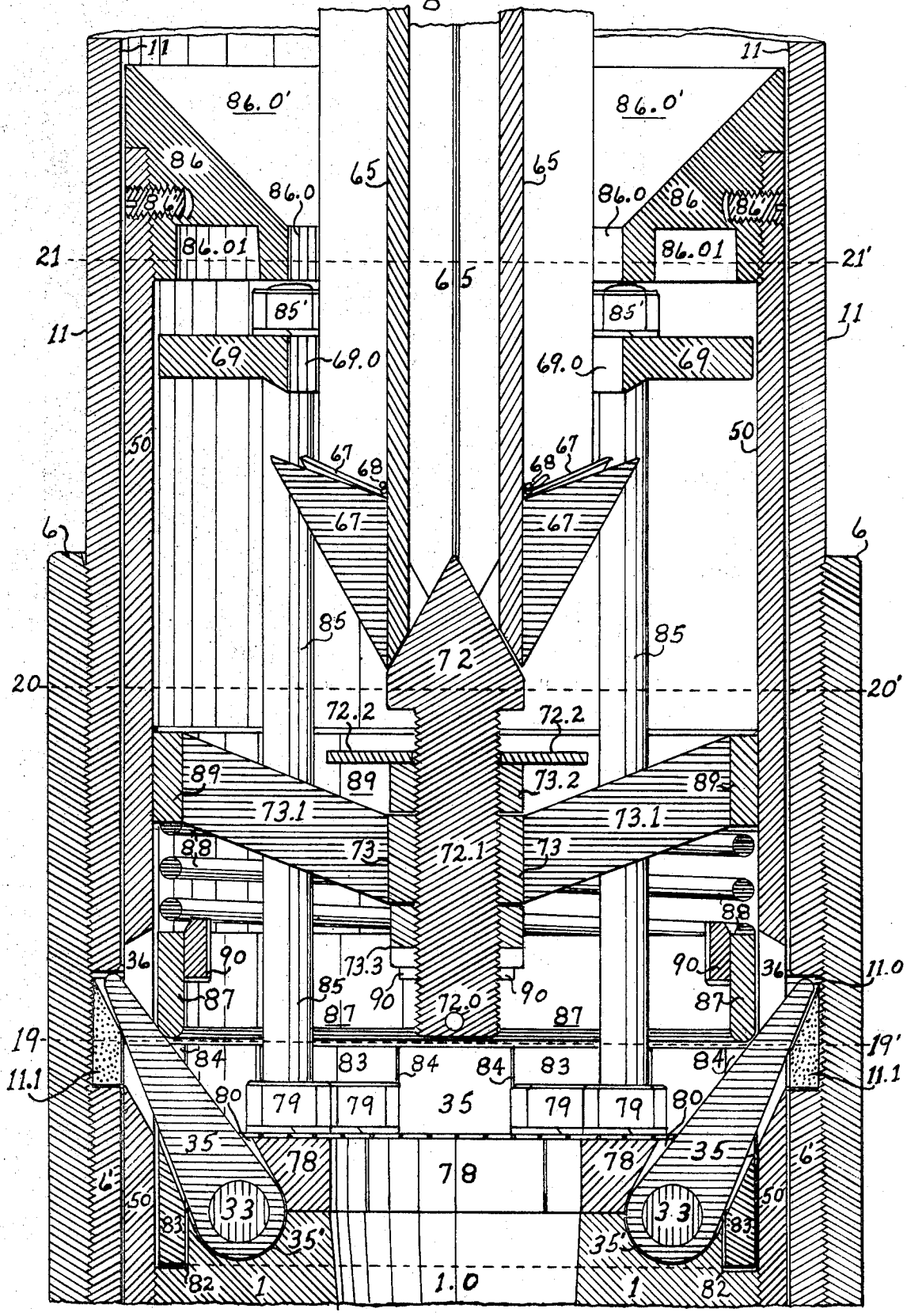
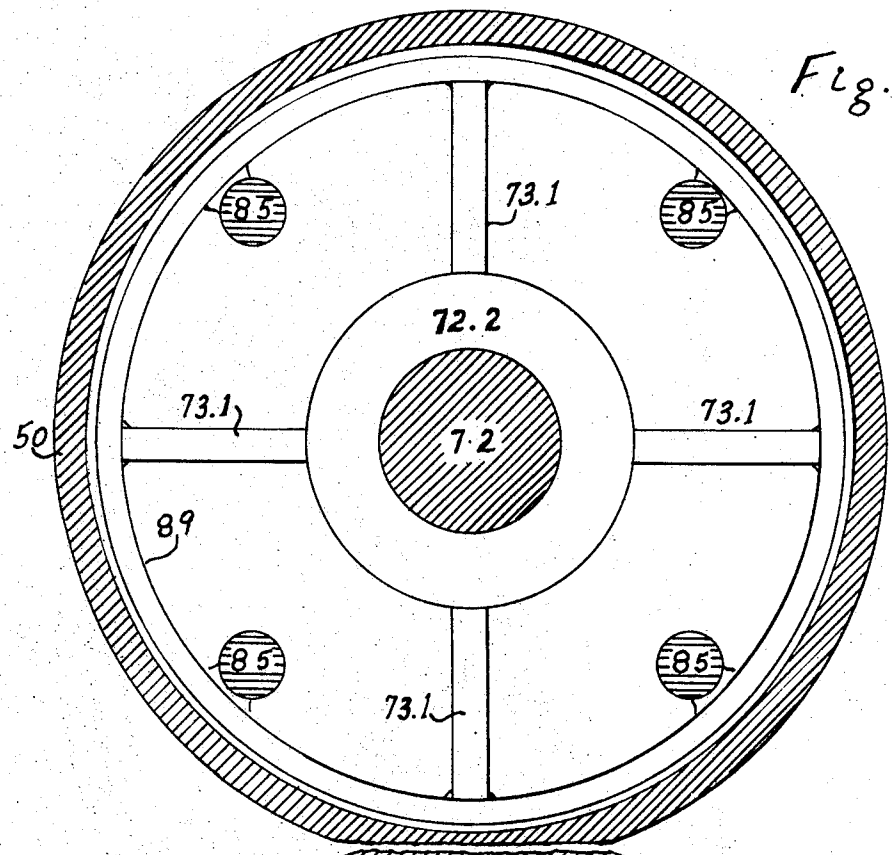

11
86.0'
86
86.0
65
86.01
21
85'
69
69.0
50
67
68
6
85
72
20
72.2
89
73.1
73
72.1
88
36
90
87
73.3
72.0
19
84
83
11.1
80
79
35
78
33
6'
82
1.0
1
11.0
19'
21'
20'

Fig. 20


85
73.1
85
72.2
73.1
7.2
73.1
50
89
85
85
73.1

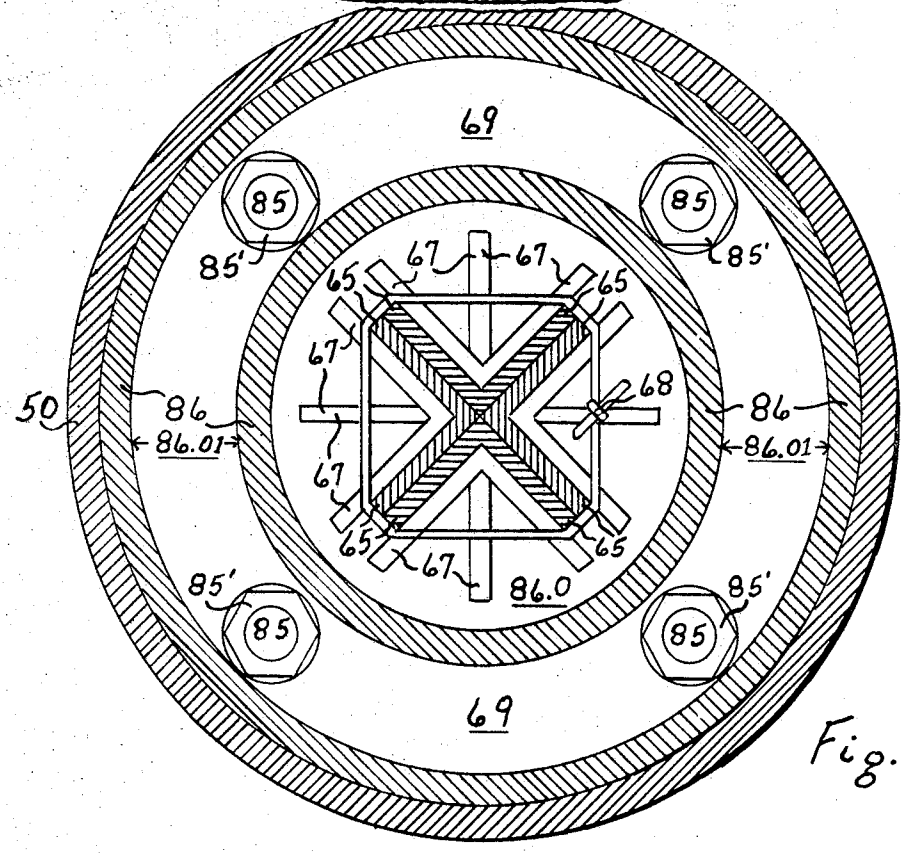
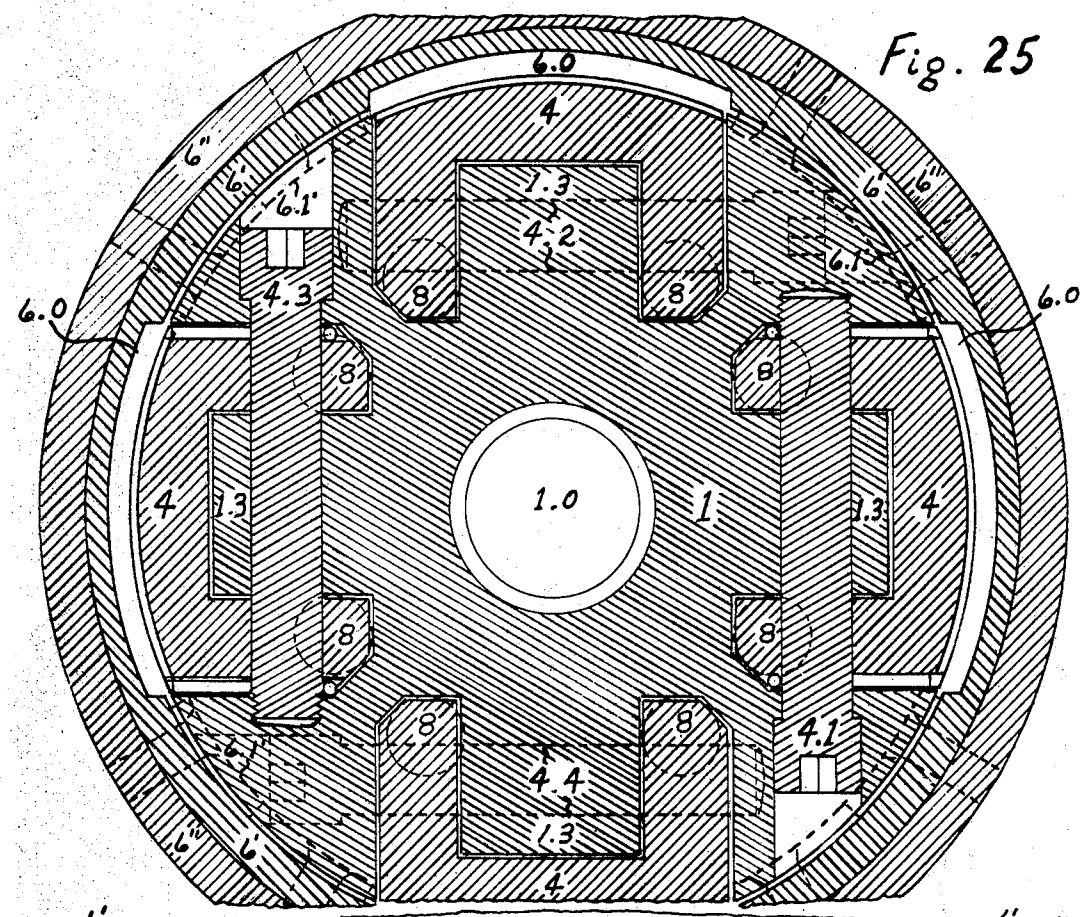

69
85
85
85'
85'
65
67
67
65
67
68
50
86
86
86.01
86.01
67
65
67
65
67
86.0
85'
85'
85
85
69

Fig. 21

Fig. 25


6.0
4
6"
6'
6.1'
1.3
4.2
6.1
4.3
8
8
8
8
8
8
1.0
1
4
1.3
1.3
4
8
8
8
8
4.1
4.4
1.3
4
6'
6"

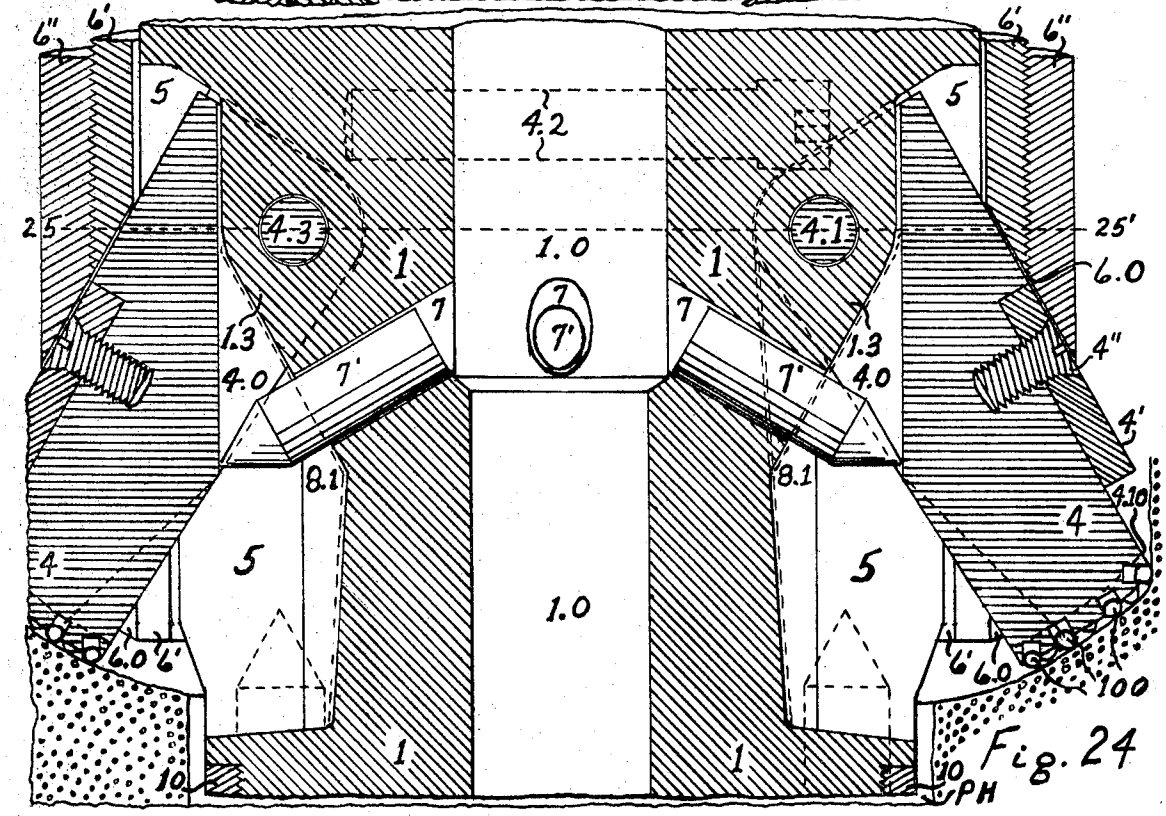

6"
6'
6'
6"
5
5
4.2
25
25'
4-3
4-1
1
1.0
1
6.0
7
7
7'
1.3
4.0
7'
1.3
4.0
4"
4'
8.1
8.1
4.10
4
4
5
5
1.0
6.0
6'
6'
6.0
100
1
1
10
10
PH

Fig. 24

Fig. 26

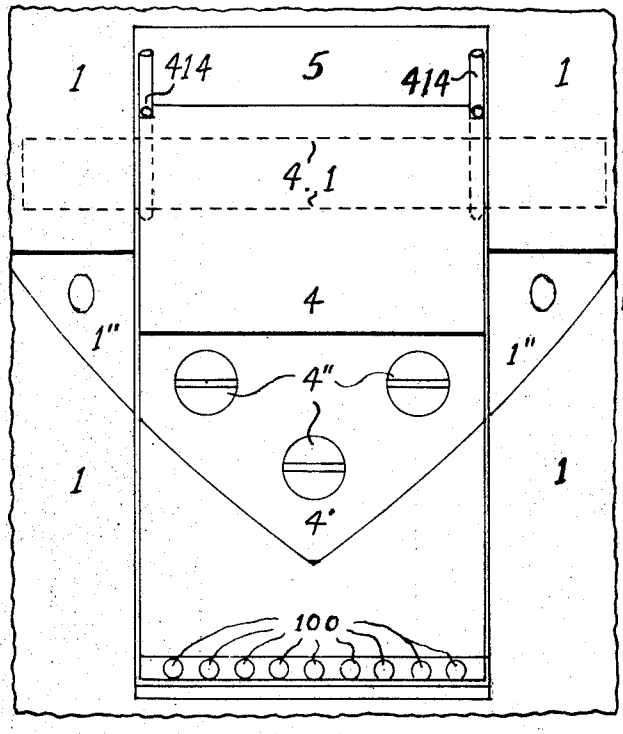
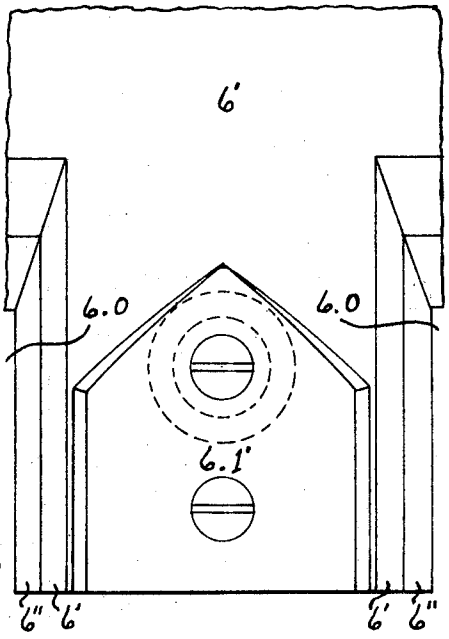


Fig. 27



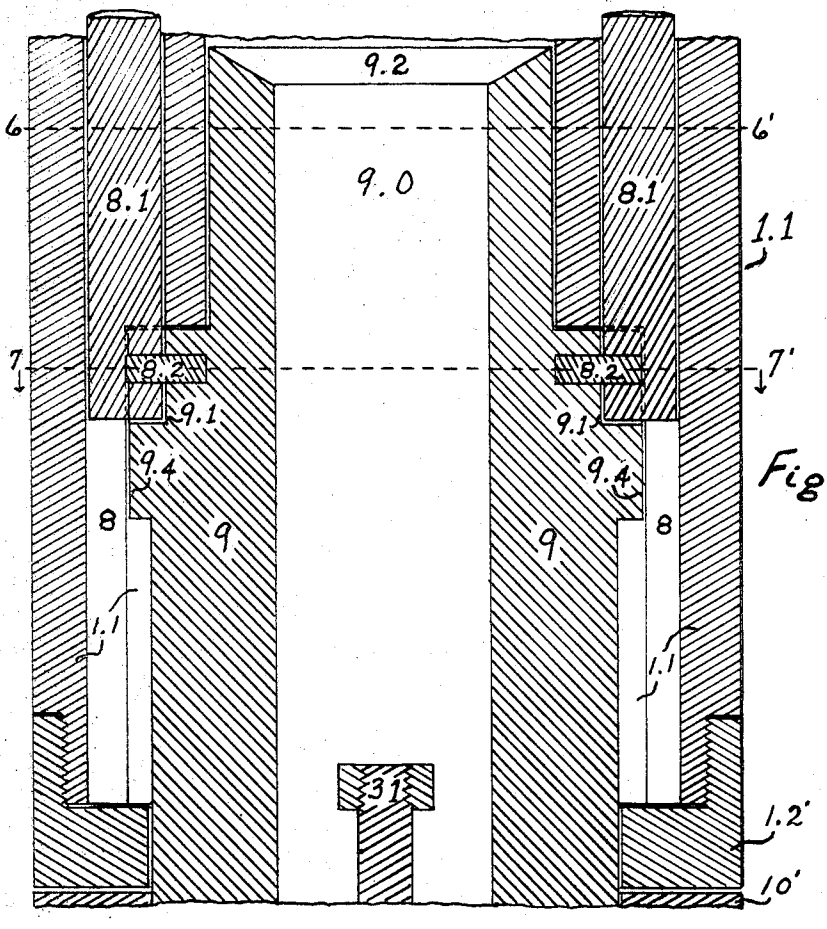


Fig. 28

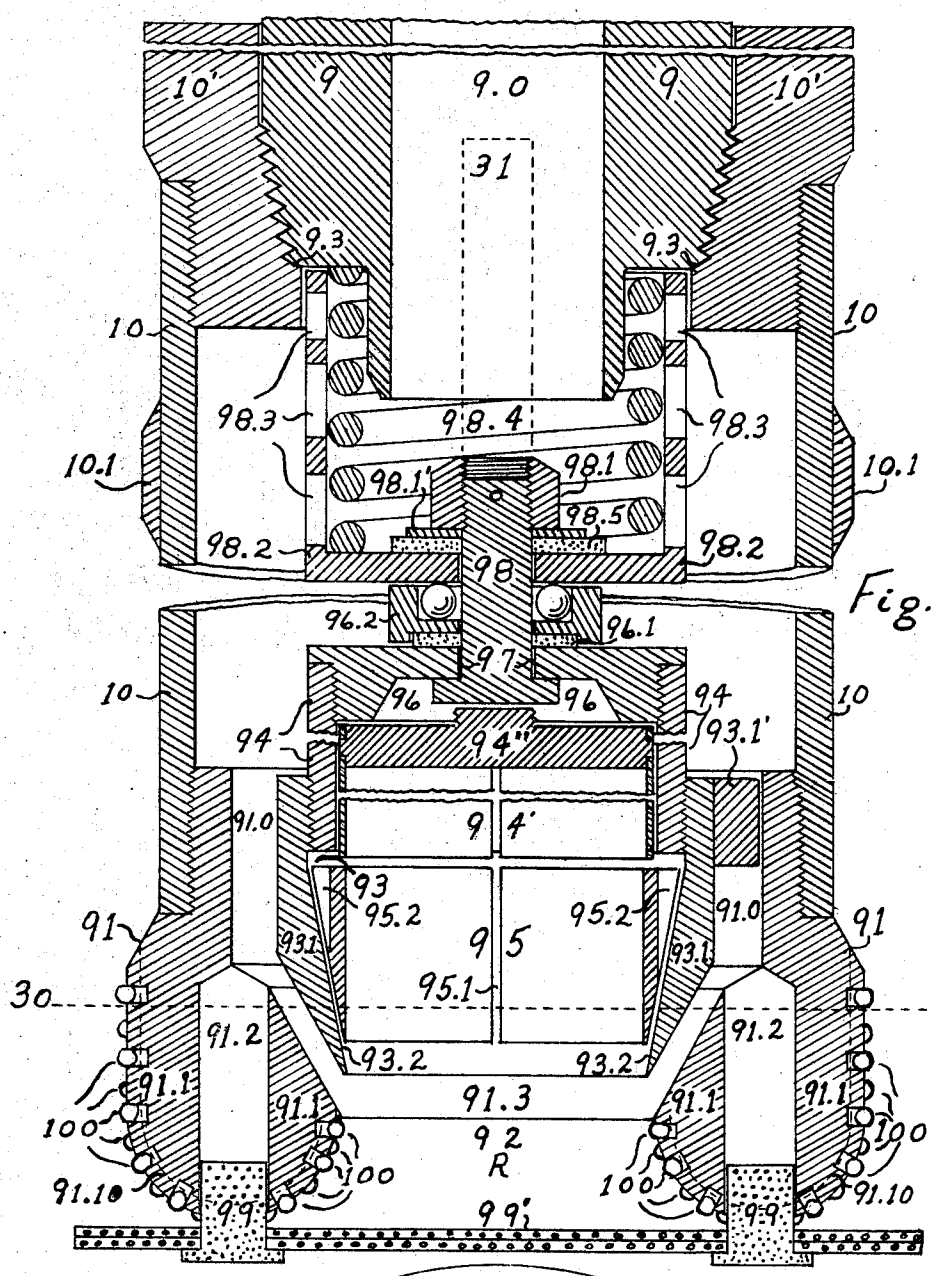

10'
9
9.0
9
10'
31
9.3
9.3
10
10
98.3
98.4
98.3
10.1
98.1'
98.1
10.1
98.5
98.2
98.2
98
96.2
96.1
97
10
96
96
94
10
94
94"
93.1'
91.0
9 4'
93
95.2
95.2
91.0
91
91
93.1
9 5
93.1
95.1
30
30'
91.2
91.2
93.2
93.2
91.1
91.3
91.1
91.1
91.1
100
9 2
100
100
R
91.10
91.10
99'
99'

Fig. 29

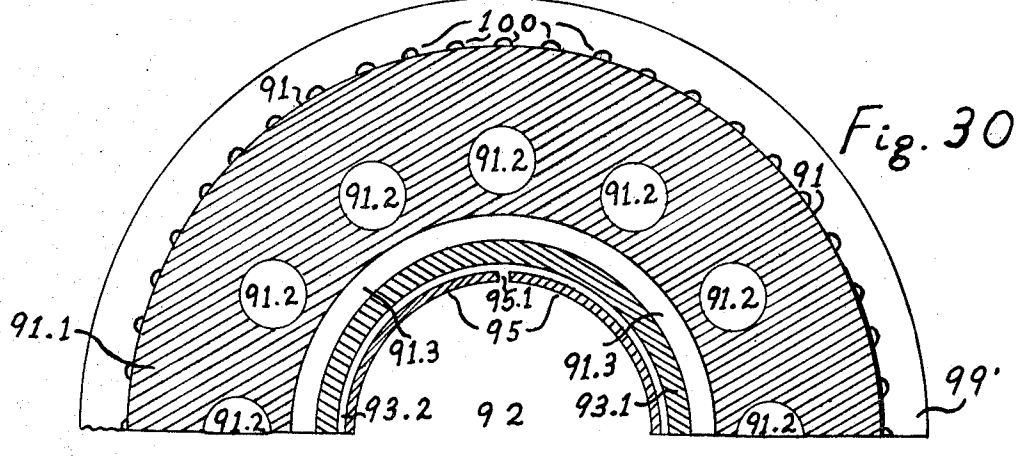

100
91
91.2
91.2
91.2
91
91.2
91.2
91.1
95.1
95
91.3
91.3
99'
91.2
93.2
9 2
93.1
91.2

Fig. 30

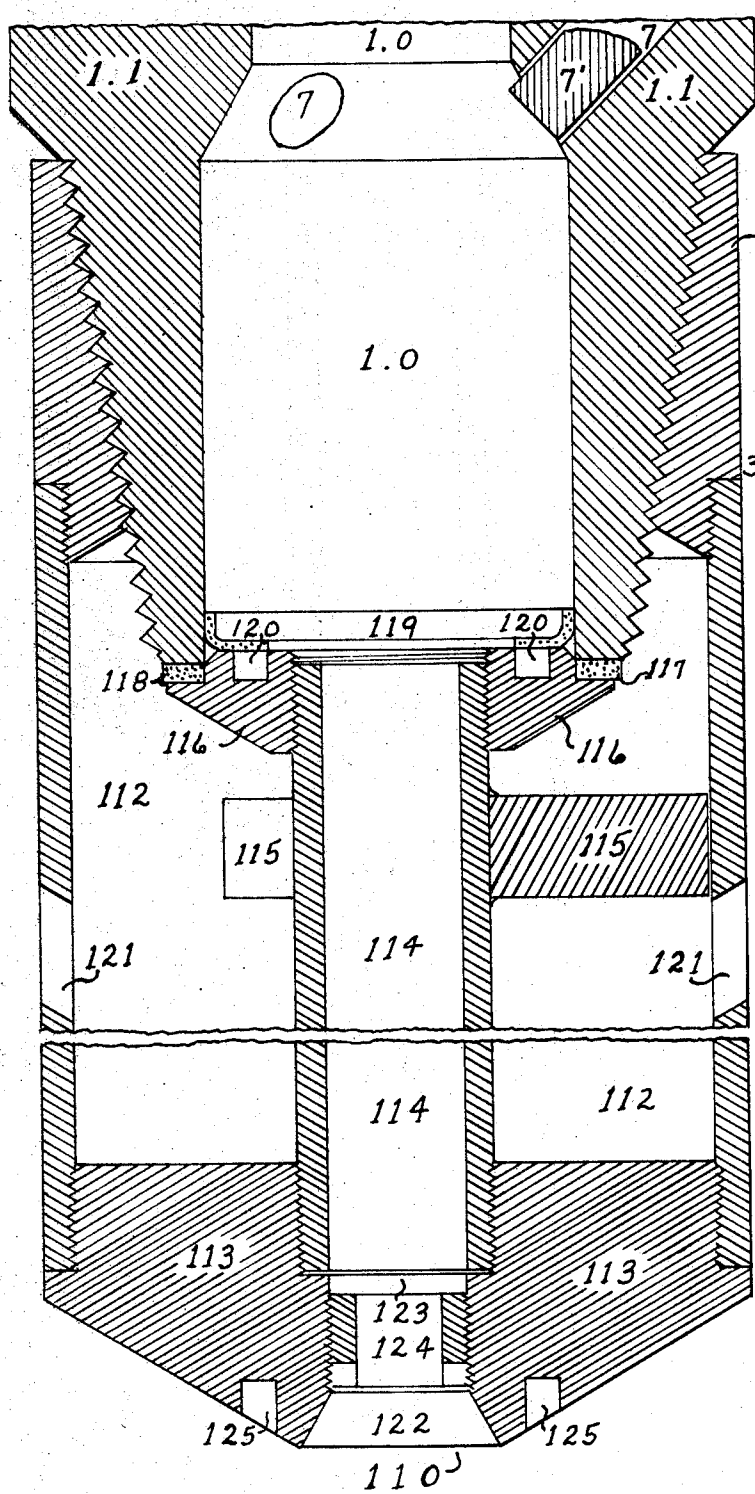


Fig. 31

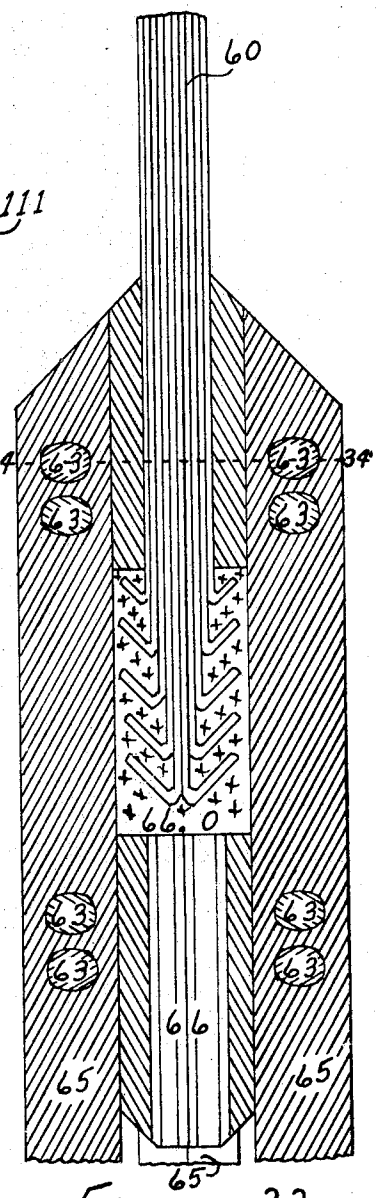
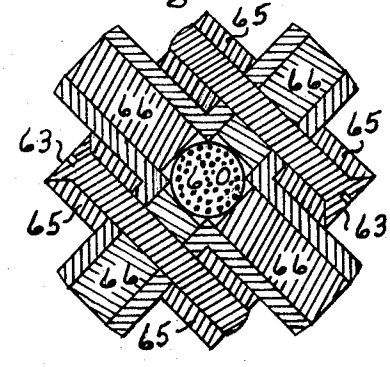


Fig. 33

Fig. 34



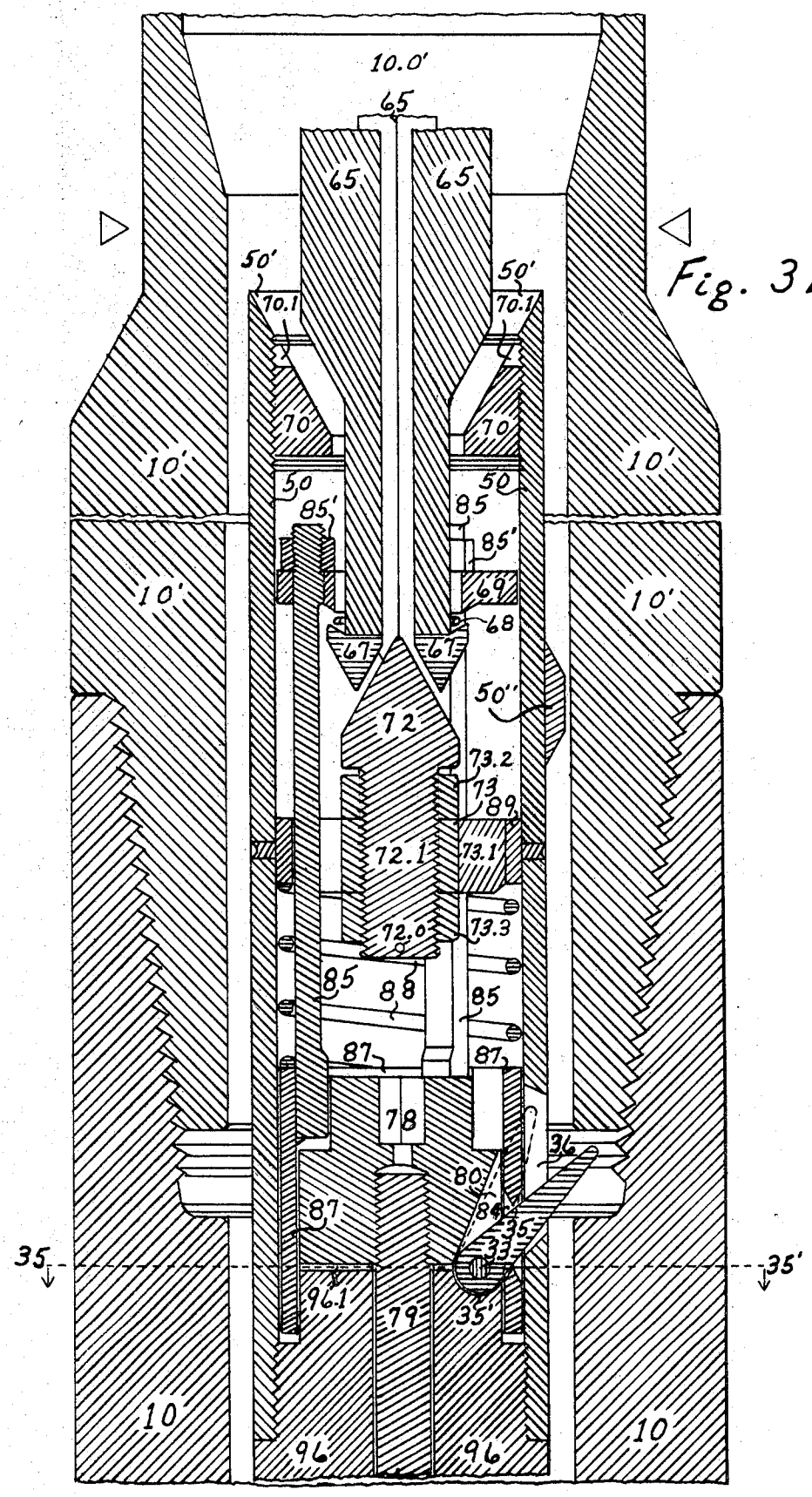
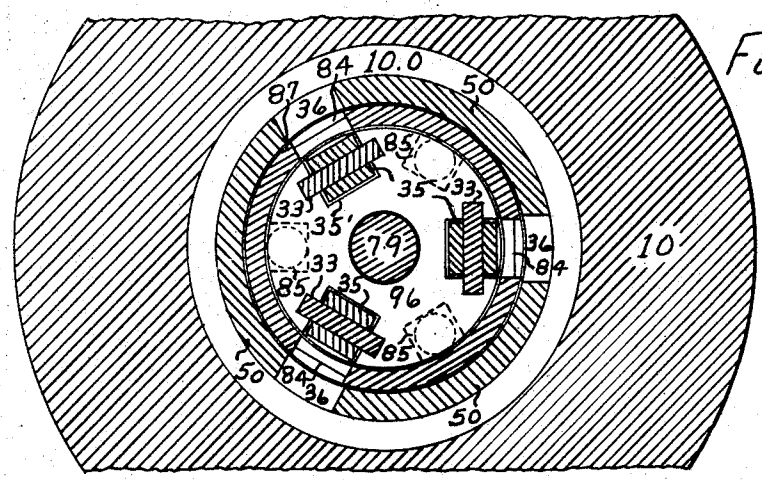

10.0'
65
65
65
50'
70.1
50'
70.1
70'
70'
10'
10'
10'
10'
50
85'
50
85
85'
69
68
67
67
50''
72
73.2
73
89
72.1
73.1
72.0
73.3
85
88
85
87
87
78
36
80
84
87
35
33
35'
35
96.1
79
35'
10
96
96
10

Fig. 32

Fig. 35


84
10.0
50
87
36
85
35
33
35'
79
34
84
10
33
85
35
96
85
50
84
36
50

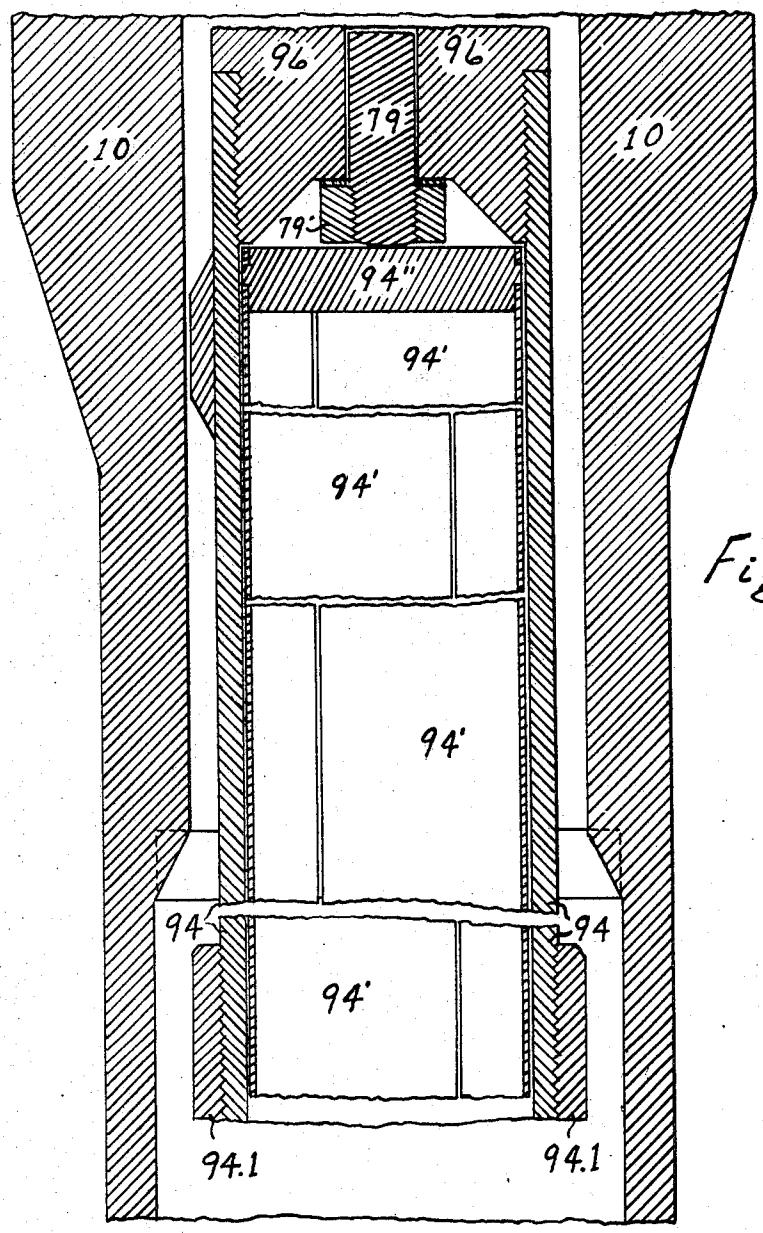

96
96
79
10
10
79'
94"
94'
94'
94'
94'
94
94
94.1
94.1

Fig. 36

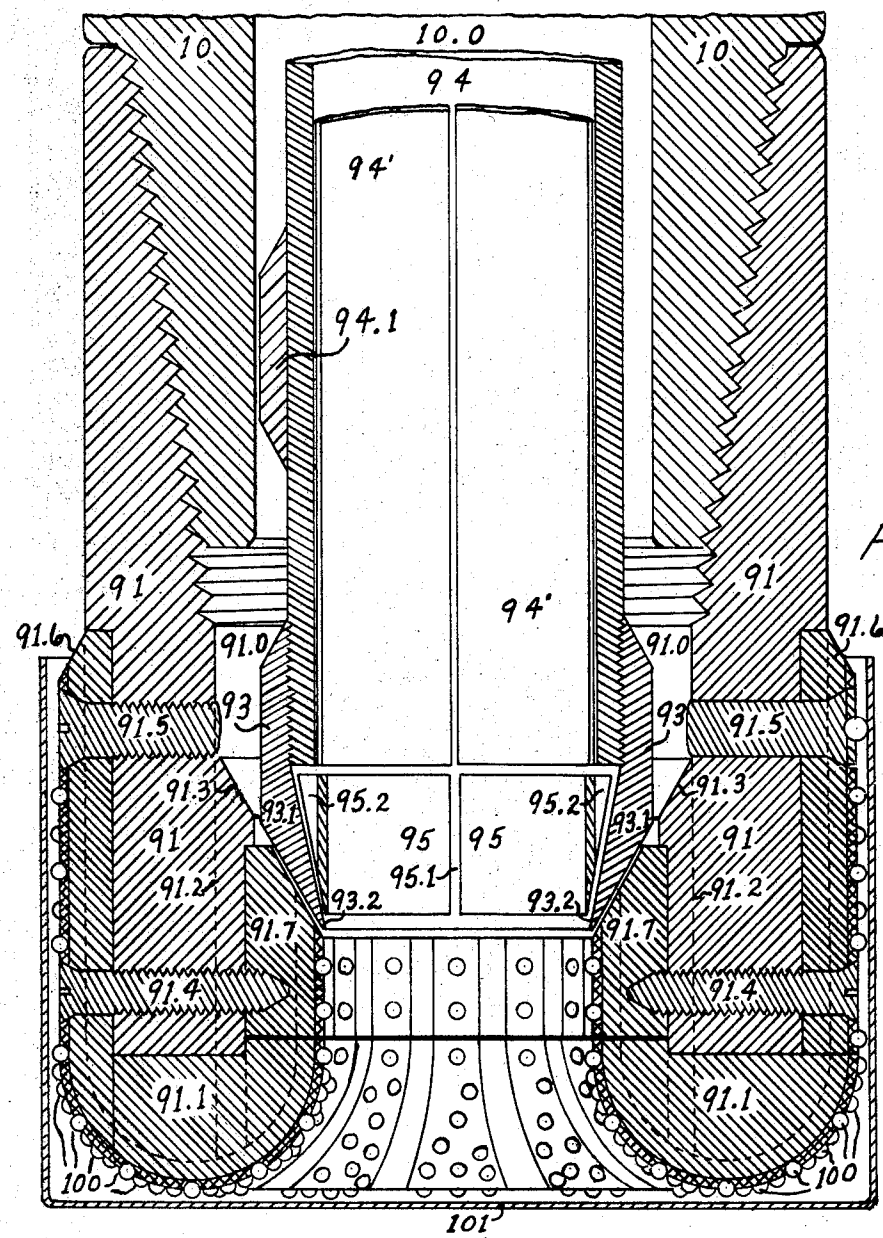

10
10.0
10
94
94'
94.1
94'
91
91
91.6
91.0
91.0
91.6
91.5
93
93
91.5
91.3
93.1
95.2
95.2
91.3
91
95
95
91
91.2
95.1
91.2
93.2
93.2
91.7
91.7
91.4
91.4
91.1
91.1
100
100
101
101

Fig. 37

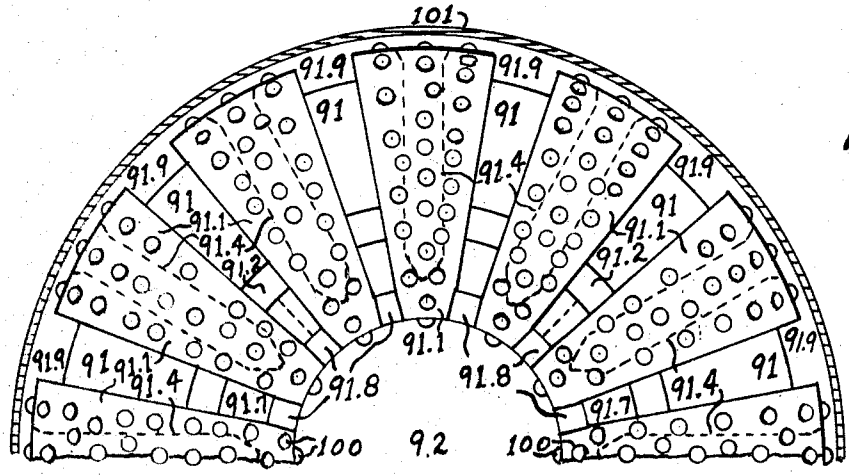

91.9
91.9
91
91
91.4
91.9
91.9
91
91.1
91.1
91.4
91.2
91.2
91.1
91.9
91.9
91
91
91.1
91.4
91.4
91.8
91.8
91.7
91.7
100
9.2
100

Fig. 38

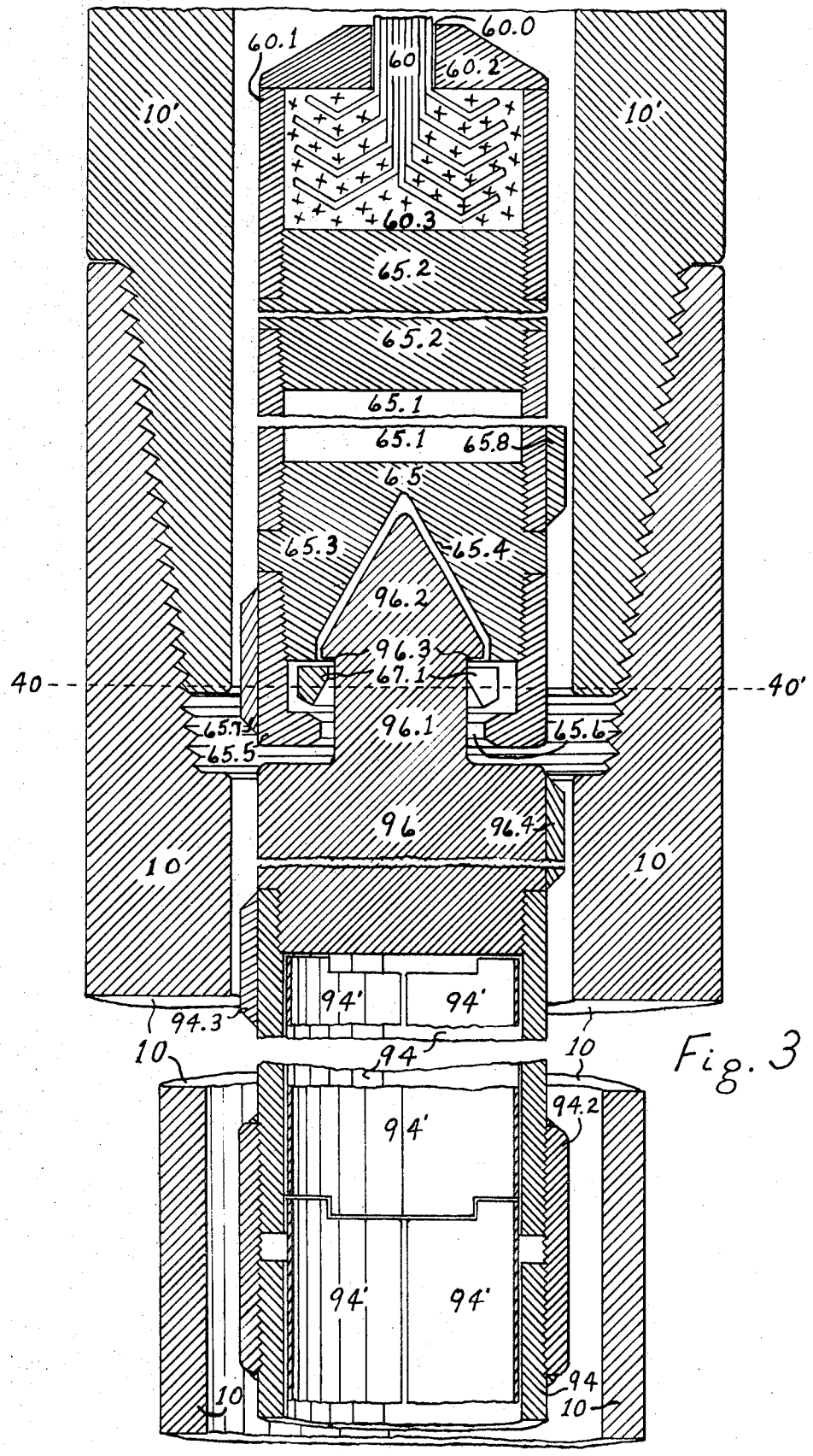
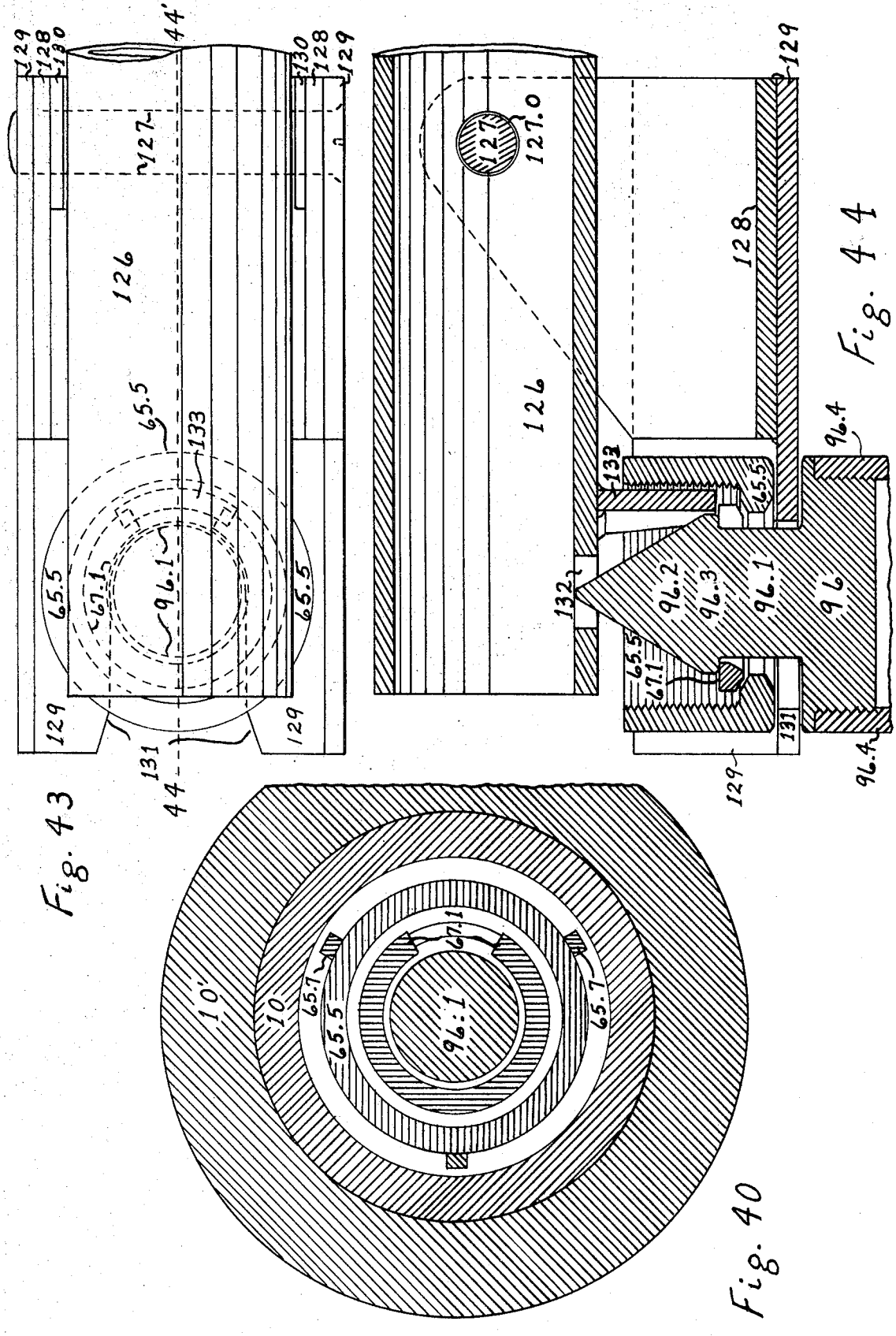

60.1
60
60.0
60.2
10'
10'
60.3
65.2
65.2
65.1
65.1
65.8
65.5
65.3
65.4
96.2
96.3
67.1
40
40'
65.7
65.5
96.1
65.6
96
96.4
10
10
94'
94'
94.3
10
94
10
94.2
94'
94'
94'
94
10
10

Fig. 39


129
128
130
44'
127
126
65.5
133
96.1
67.1
131
44
Fig. 43
127.0
132
65.5
96.2
96.3
96.1
96
96.4
Fig. 44
10'
65.7
65.5
Fig. 40

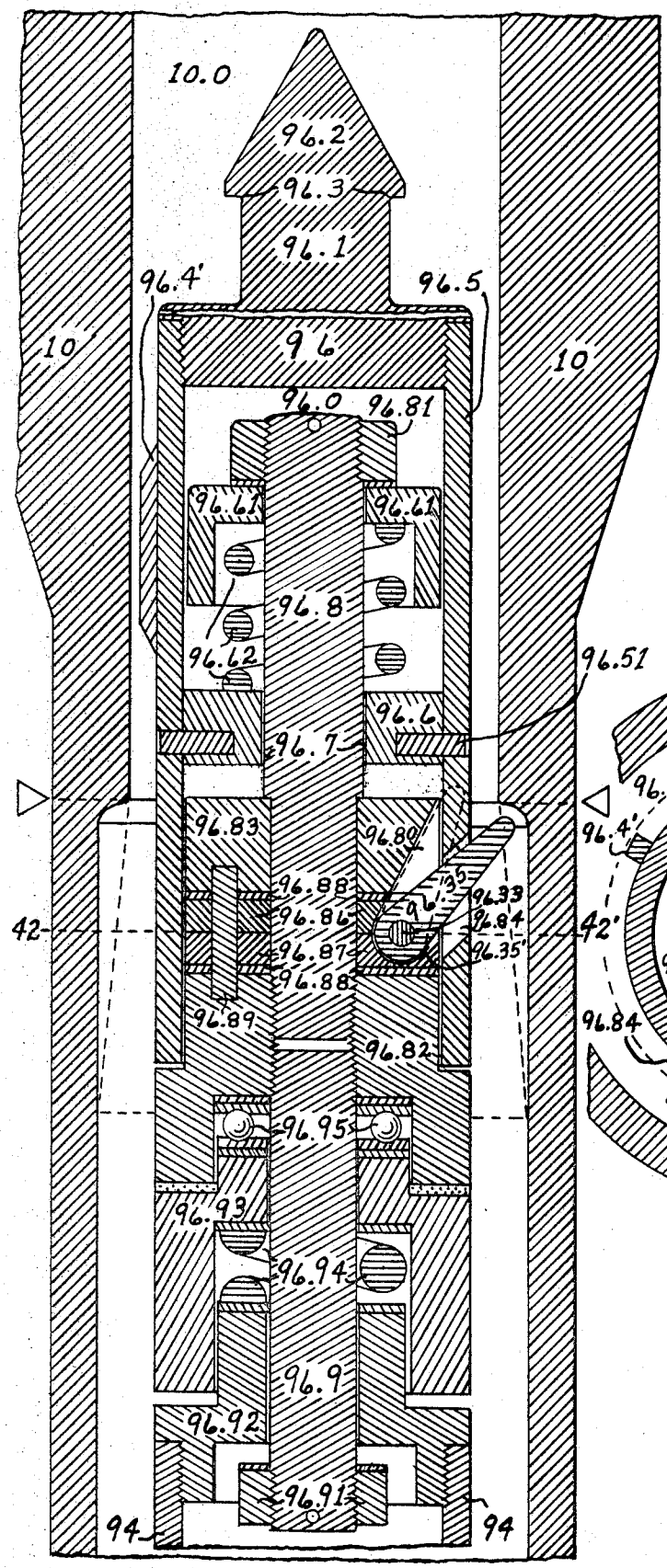

10.0
96.2
96.3
96.1
96.4'
96.5
10
96
10
96.0
96.81
96.61
96.61
96.8
96.62
96.51
96.6
96.7
96.83
96.80
96.88
96.86
96.87
96.88
96.89
96.82
96.95
96.93
96.94
96.9
96.92
96.91
94
94
42
42'

Fig. 41

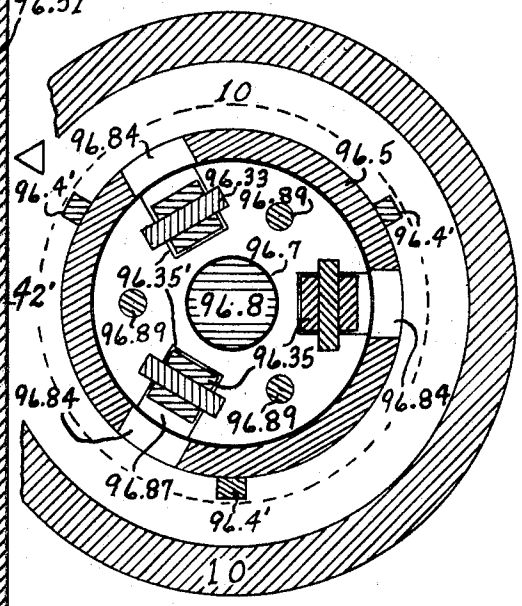

10
96.84
96.5
96.4'
96.33
96.89
96.4'
96.7
96.35'
96.8
96.89
96.35
96.84
96.89
96.84
96.87
96.4'
10

Fig. 42

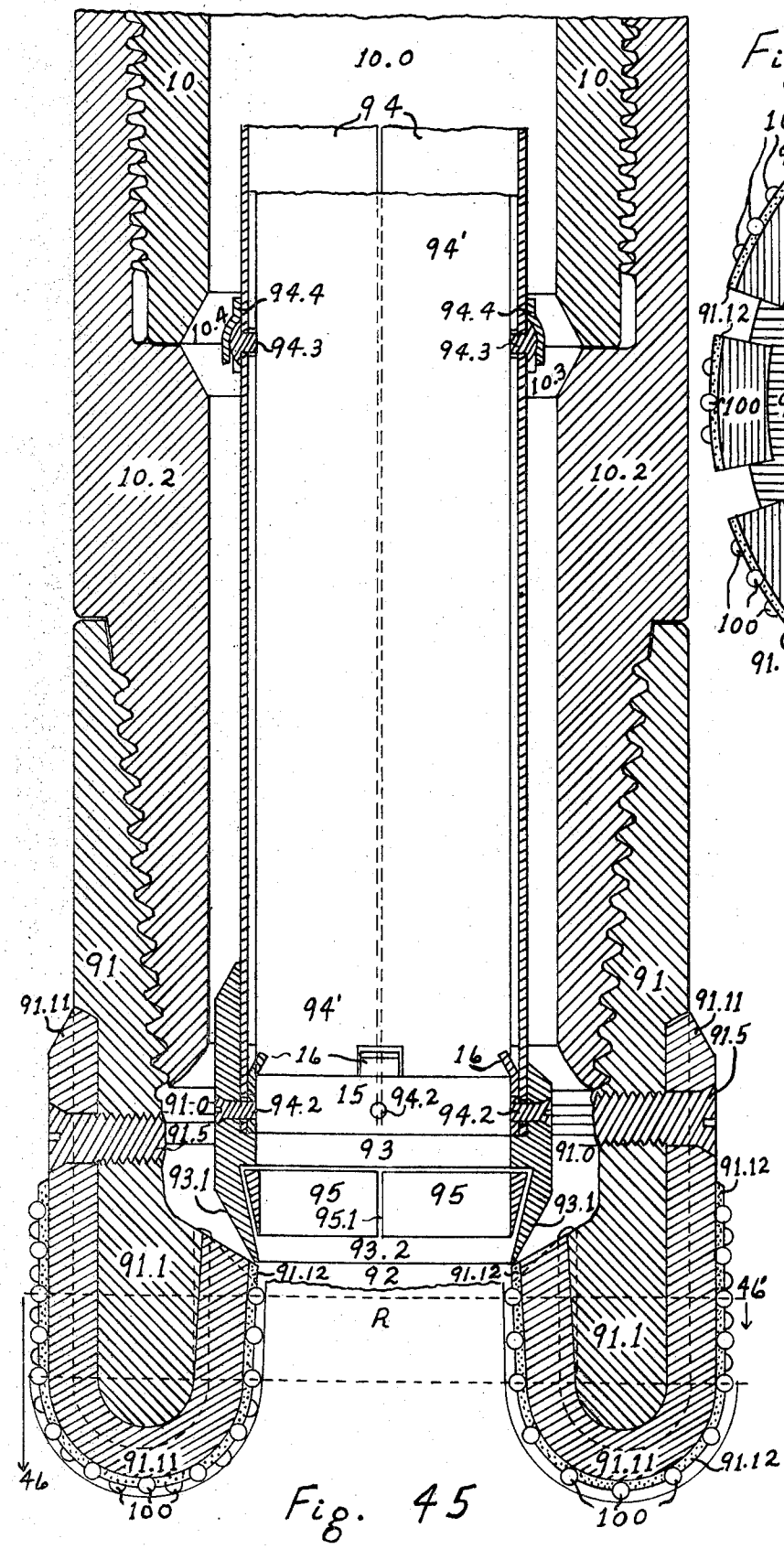

10.0
10
10
94
94'
94.4
94.3
10.4
94.4
94.3
10.3
10.2
10.2
91
91
91.11
91.11
94'
16
16
91.0
94.2
15
94.2
94.2
91.5
93
91.0
91.5
93.1
95
95
95.1
93.1
93.2
91.1
91.12
92
91.12
R
91.1
46
46
91.11
91.11
91.12
100
100

Fig. 45

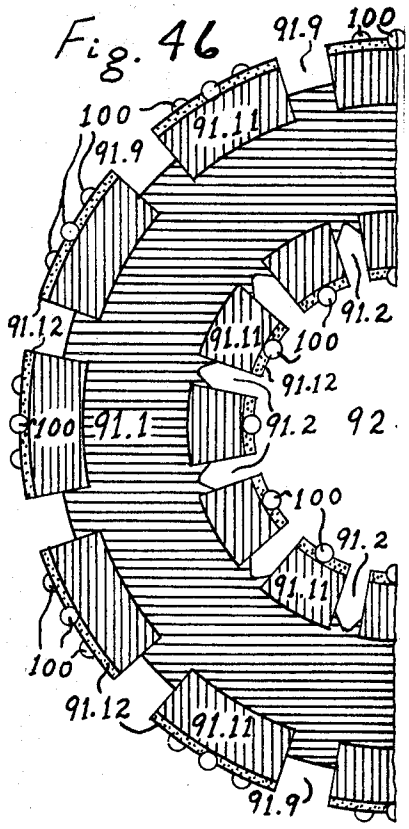

91.9
100
100
91.11
91.9
91.2
91.12
91.11
100
91.12
100
91.1
91.2
92
100
91.2
91.11
100
91.12
91.11
91.9

Fig. 46

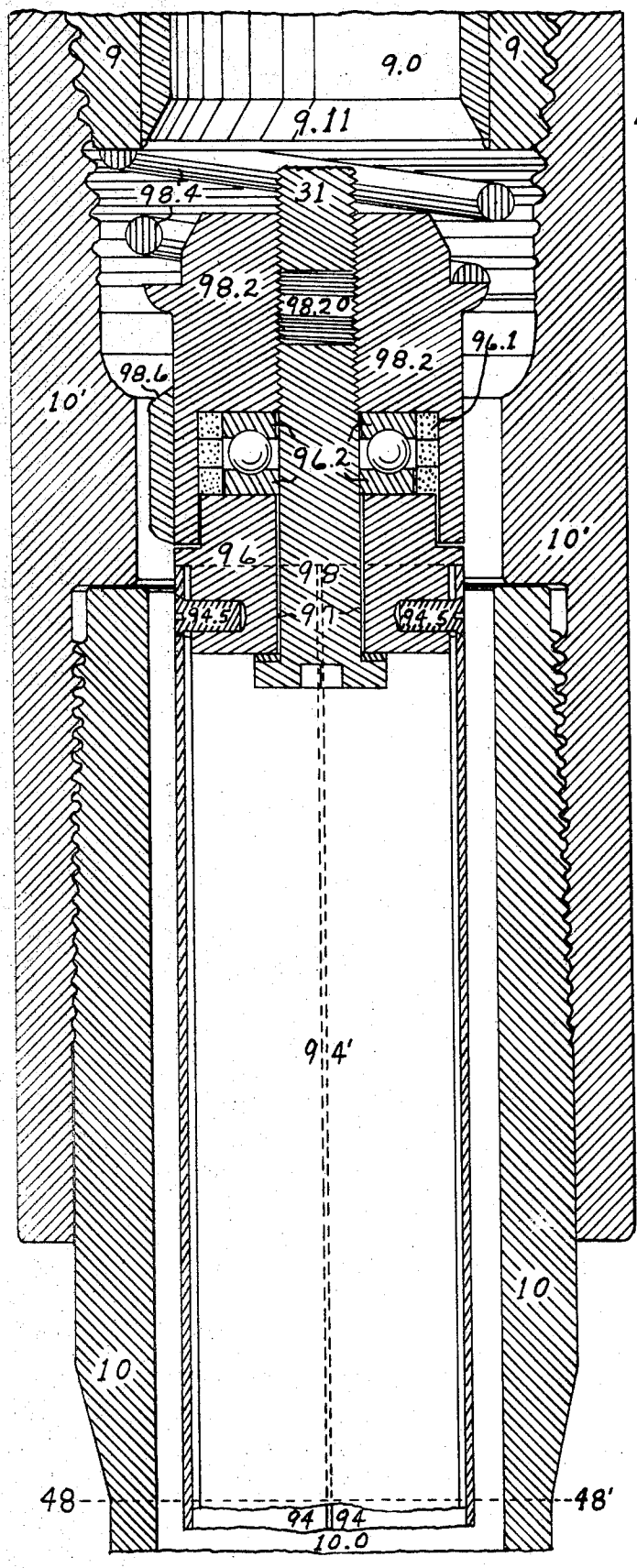


Fig. 47

Fig. 49

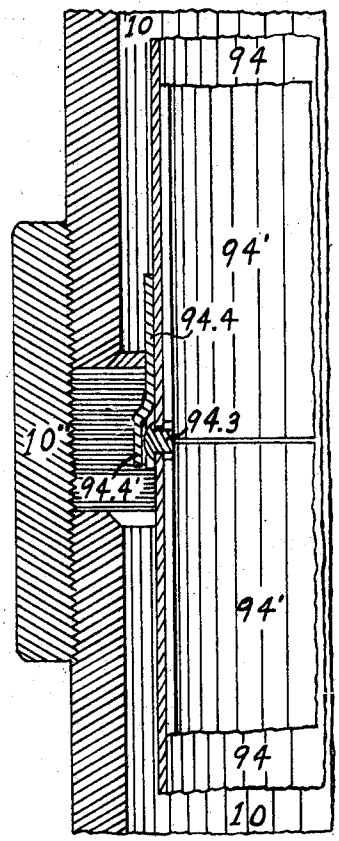
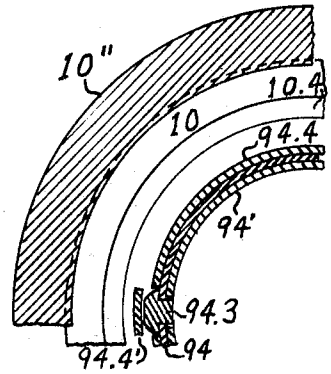


Fig. 48



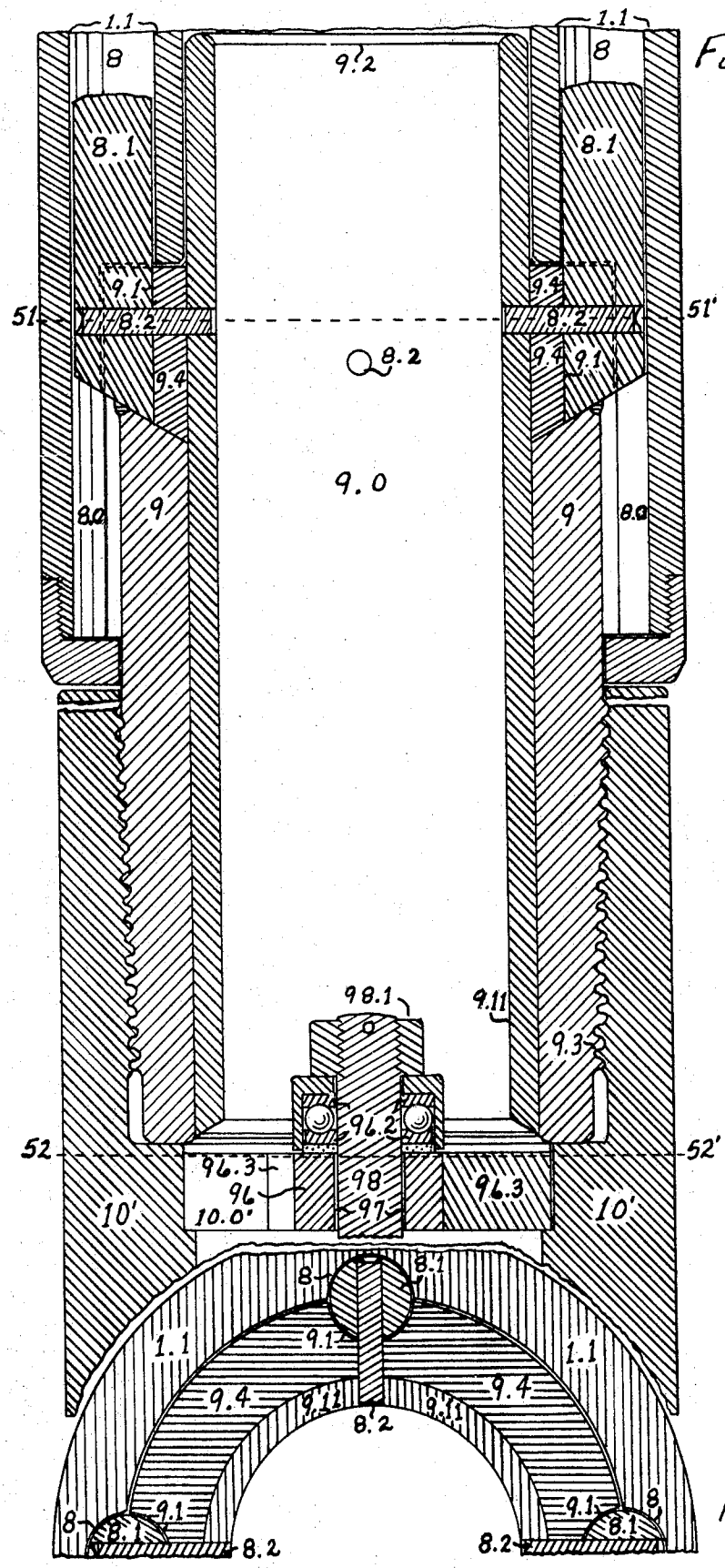
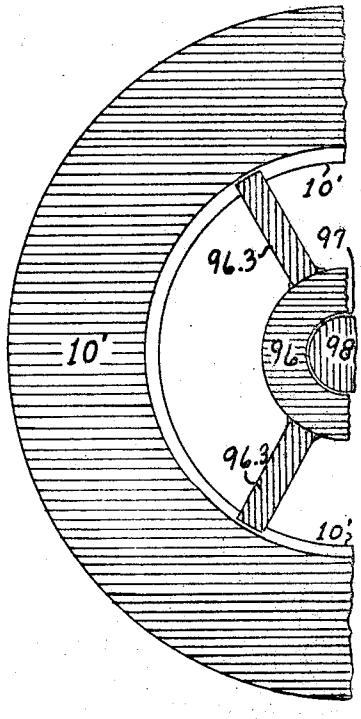


Fig. 50

Fig. 51

Fig. 52



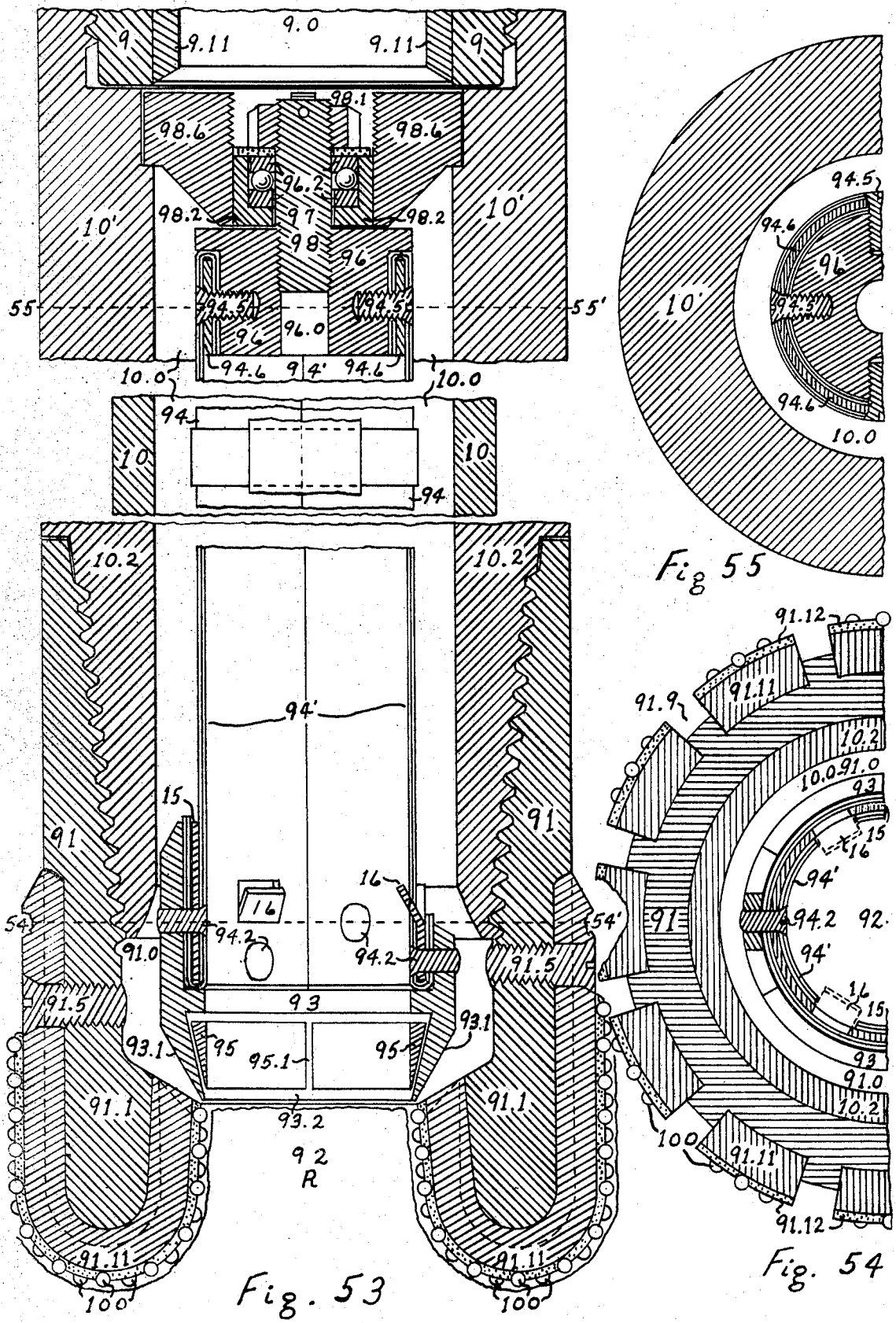


Fig. 53

Fig 55

Fig. 54

EARTH BORING MECHANISM AND COORDINATED PILOT HOLE DRILLING AND CORING MECHANISMS

This invention relates to improvements in the art of drilling holes in the earth for mining oil, gas, sulfur, gypsum, salt, water, uranium, aluminum, and other such products and metals. A reading of the description of the invention will disclose that, while the invention has been devised in the drawings primarily for use in producing water, oil, and gas, the principles of construction disclosed may be employed in many other ways for drilling in igneous and metamorphic as well as sedimentary rock systems of the earth both vertically and at angles with respect thereto.

A primary purpose of the invention is to make a very strong rotary bit assembly, capable of very practical application in speedily and economically drilling oil, gas, and water wells of suitable diameter for efficient production of such products and even to very great depths, which assembly can be retrieved very speedily and economically on the end of a hoisting cable from the hole being drilled after repeated installations on the end of the rotatable jointed drill stem pipe, on whose lower threaded tip is screwed a novel very strong, quite simple, and inexpensive internally threaded cylindrical retaining-shoe segment of the assembly, through which tubular segment (screwed on the lower end of the rotatable drill pipe before the drilling operation is begun) the remaining segments of the bit assembly may be installed and withdrawn through the drill pipe very rapidly without need for the time-consuming and thus very expensive removal from the said hole of the usually quite long and correspondingly heavy jointed drill pipe string, on whose lower tip said novel retaining shoe, having rigidly installed in its lower half a novel serrated cylindrical sleeve of smaller diameter than the internal diameter of the drill pipe, has been screwed before insertion in said hole being drilled.

A simultaneous and correlative purpose is to install rigidly on the exterior of the removable portion of said bit assembly serrated segments of an inversely corresponding sleeve, whose outer diameter is slightly less than the internal diameter of the drill pipe on which the retaining shoe is screwed but is somewhat greater than the internal diameter of the serrated cylindrical sleeve of the retaining shoe, the purpose of said inverse serrations being that the removable portion of the bit assembly is thereby pivotally oscillated on its vertical axis (as much as required) on reaching the retaining shoe to such extent that, in its extreme lower position in said retaining shoe, drilling segments pivotally attached to the main body portion of the removable bit assembly can swing outward hingeably at their lower tips under compulsion of novel mechanisms to be described herein for underreaming the retaining shoe, whose lower tip is provided with vertical-walled notches or gaps, into which those hingeably mounted drilling arm segments swing and are thereby rotated directly by said vertically-notched retaining shoe and the rotating drill pipe string on which that shoe is screwed, even when tremendous downward pressure is exerted on said shoe by said drill string and tremendous torque on the removable segment of the drill bit assembly is required for rotation of the drilling segments under such vertical pressure.

Another purpose of the invention is to provide simple but positive alternative means whereby the removable segment of the drill bit assembly is prevented from moving upward with respect to the telescoping drill pipe and its retaining shoe during the drilling operation but is permitted to be withdrawn readily by a wire line cable provided with novel means at its lower tip for automatic attachment to and easy detachment from the removable portion of the drill bit assembly at the lower tip of the drill pipe, beneath which it is securely held by multiple scotching lugs or dogs pivotally mounted on the main body section of the removable portion of the said assembly and having their upper tips respectively swung outward to positions directly beneath the lower tip of the drill pipe by novel alternative means to be described later herein.

Still another purpose of the invention is to provide a novel means, capable of withstanding great torque and vertical weight, of attaching to the aforesaid main body segment of the removable portion of the drill bit assembly a suitable means of drilling a pilot hole almost as large as the interior diameter of the retaining shoe screwed on the lower tip of the drill pipe, said means of attachment also serving as a means of swinging the aforesaid drilling segments of the underreaming portion of the drill outward into the notches through the lower margin of the cylindrical retaining shoe under some circumstances to be described later herein.

A special purpose of the invention is to provide means of attaching to the lower tip of the said main body portion of the bit assembly, that is retrievable through said retaining shoe by means of a cable automatically attachable to the upper portion of said main body portion thereof, a combination pilot hole drilling and core-retaining device whereby the person operating the drill can recover at intervals, ahead of the underreaming mechanism, a continuous core of suitable segment lengths of the formations being penetrated by means of said cable without need for removing the drill pipe (conventionally jointed, but possibly welded as a continuous string) from the hole being drilled.

Another special purpose is to provide a novel coring device employing multiple rolling cutters as means of chipping the rock from around the core to be recovered instead of having to employ an annular steel bit in which suitable industrial diamonds have been set, by means known to the art, in order to cut the rock from around the core in a process that requires very great weight on the bit and resultant great torque in the drilling process, which will cause great heat that will tend to metamorphose the core to be recovered even with maximum circulation of the drilling fluid adjacent the core, which, on the other hand, may be washed away under the same drill construction in rocks only slightly consolidated.

Another purpose is to provide a modified industrial diamond mounting underreaming mechanism for the recurrent installations in the above described tubular shoe on the lower end of the jointed drill pipe, below which is mounted an annular core drilling mechanism of more than one alternative design, which drills the pilot hole and which is connected by novel means to said diamond mounting underreaming mechanism.

Another purpose is to provide a means of recovering on the end of a cable, lifted by a conventional reel at the head of the well, the core barrel containing a core segment from a pilot hole without need for removing from the hole the jointed drill pipe on which an annular diamond mounting drill bit is screwed before its insertion in said pilot hole.

Another purpose is to provide a novel mechanism for attachment to the lower portion of the underreaming segment of the drill bit to serve as a means of making as straight as possible the underreamed hole with respect to a previous pilot hole.

Other purposes will be made manifest by a reading of the following description of suitable ways to make and use the invention in conjunction with the attached drawings in which numerical designations of the various parts are the same.

FIG. 1 is a fragmentary side view of the easily upwardly removable generally cylindrical main body segment of the invention showing one of three underreaming rolling cutters 2, each one of which is mounted rotatably on a heavy cylindrical pin 3 inserted in an arm 4 hingeably mounted in a slot 5 in said main body segment 1, so that the lower tip of said arm 4 can swing outwardly through the corresponding one of the three vertical-walled notches in the lower margin of cylindrical retaining shoe 6, which has been cut away in this figure to its vertical rotational axis to reveal the side view of the main body segment of the drill bit assembly and therefore does not show any of the three said notches in the lower margin thereof.

FIG. 2 is a fragmentary vertical cross section through the axis of said removable central body segment 1 at right angles to FIG. 1 and along the rotational axis of said body segment and of the lower half of the generally cylindrical tubular

retaining shoe 6 having a novel radically serrated cylindrical retaining sleeve 6.1 integrally mounted in the lower half of said retaining shoe 6 to be described in detail.

FIG. 3 is a horizontal cross section at line 3–3' of FIG. 2 through the hinge pivot pin 4.1 mounted in removable main body segment 1 as indicated in FIGS. 1 and 2.

FIG. 4 is a horizontal lateral cross section through the smaller diameter segment 1.1 of generally cylindrical main body member 1 at line 4–4' shown in FIG. 2 prior to boring of three holes 7 for slidably mounting respective diagonally disposed cylindrical plungers 7', one of which is shown in FIG. 2, and all three of which are located respectively midway between the widely spaced pair of holes 8 shown in FIG. 4 and by broken lines in FIG. 3 for slidably mounting therethrough each of the three pairs of vertically disposed adjusting rods 8', one of which has its upper conical tip shown in FIG. 2.

FIG. 5 is a fragmentary vertical cross section through the vertical axis of the lower cylindrical segment 1.1 of removable main body member 1 immediately below line 4–4' of FIG. 2 and shows the novel strong means of slidably but nonrotatably attaching to that tubular cylindrical lower segment 1.1 of body member 1 the upper generally cylindrical tubular segment 9 of the simple but strong means whereby is attached thereto by tool-joint threads my means for boring a preceding pilot hole having a diameter only slightly less than the inside diameter of the cylindrical sleeve 6.1 integrally mounted in the cylindrical retaining shoe 6 screwed on the lower tip 11 of the drill pipe, one such said drilling means being shown in FIGS. 8, 9, and 10 as being screwed on the lower tip of cylindrical tubular member 10 shown in FIG. 5.

FIG. 6 is a fragmentary horizontal cross section at line 6–6' of FIG. 5.

FIG. 7 is a horizontal cross section at line 7–7' of FIG. 5.

FIG. 8 is a vertical cross section through the rotational axis of a coring mechanism having four rolling cutter members and being attached to the lower tip of tubular cylindrical member 10 in FIG. 5 for boring a pilot hole in the earth ahead of the underreaming segment of the combination integrated drill mechanism.

FIG. 9 is a horizontal cross section through half of the pilot hole drilling mechanism shown in FIG. 8 at line 9–9', the other half of the mechanism at that plane being an exactly inverse duplication of that half shown in FIG. 9.

FIG. 10 is a vertical cross section at right angles to the plane of the pilot hole drilling mechanism shown in FIGS. 8 and 9 through the rotational axis of said core recovering pilot hole drilling mechanism.

FIG. 11 is a vertical cross section section through the upper portion of the removable main body member portion of the drilling and underreaming bit at the same plane shown in FIG. 2 but immediately above that FIG. 2 to show a suitable hydraulic means actuating pivotally mounted restraining dogs beneath the lower tip of the cylindrical drill pipe to keep the optionally removable drill bit mechanism from moving upward in that drill pipe during drilling operations.

FIG. 12 is a horizontal cross section through the axes of the three pivotally mounted restraining dogs at line 12–12' of FIG. 11, in which one of those three restraining dogs can be seen.

FIG. 13 is a vertical cross section through the removable drill bit mechanism immediately above FIG. 11 and inside a joint of the drill pipe string to show two alternative means limiting flow of the drilling fluid inside that drill string around the drilling mechanism and to show in part the mechanism whereby that mechanism can be lifted quickly from the drill string in the hole at any time.

FIG. 14 is a side view of one segment of one of the alternative means shown in FIG. 13 for restraining flow of drilling fluid around the drill bit mechanism inside the drill pipe.

FIG. 15 is a vertical cross section through the axis of the lower tip of the cable for lifting the drill bit mechanism from the drill pipe string and through the upper tip of a suitable mechanism attached to the lower tip of that cable for catching hold of the upper portion of the drill bit mechanism as shown in FIG. 13.

FIG. 15—16 is a top view of the apparatus shown in FIG. 15.

FIG. 16 is a horizontal cross section at line 16–16' of FIG. 15 through the lifting cable and the grappling mechanism attached to the lower tip thereof and also shows the upper tip of a cylindrical mechanism spliced around the cable for sliding said cylindrical mechanism down the cable to release the grasping mechanism from the drill bit mechanism under very improbable special circumstances.

FIG. 17 shows the lower tip of the spliced cylindrical mechanism shown in FIGS. 15 and 16 showing the means attached to the grappling mechanism whereby the spliced cylindrical mechanism contracts the lower tips of the four segments of that grappling mechanism to free them from the means whereby they have been automatically attached to the removable drill bit mechanism as shown in FIG. 13.

FIG. 18 is a vertical cross section through the rotational axis of the removable drilling mechanism immediately above FIG. 2 and shows, in lieu of the hydraulic means actuating the three movement-restraining dogs beneath the lower tip of the drill string illustrated in FIG. 11, an alternative means retracting two diametrically opposed restraining dogs pivotally mounted in the main body member beneath the same lower tip of the drill string by simply lifting the retrieving cable.

FIG. 19 is a horizontal cross section through the upwardly removable drill bit mechanism shown in FIG. 18 at line 19–19' but shows four duplicate diametrically opposed dogs instead of just two as illustrated in FIG. 18.

FIG. 20 is a horizontal cross section through the removable drilling mechanism shown in FIG. 18 at line 20–20' to illustrate suitable spider framework means mounting a conical-upward projection to break a restraining cord around the lower tips of the four segments of the grasping mechanism whereby the drill bit mechanism may be lifted from the drill string on the cable within it as illustrated in FIGS. 13, 15, 16, 17, and 18.

FIG. 21 is a horizontal cross section through the removable drill bit mechanism shown in FIG. 18 at line 21–21' to show the upper tips of four lifting bolts whereby the restraining dogs beneath the lower end of the drill pipe are released after the cord around the lifting mechanism is broken to permit expansion of the four segments of the grasping clasp mechanism attached to the lower tip of the cable pulled upward thereafter.

FIG. 22 is a fragmentary vertical cross section through an alternatively formed restraining dog in lieu of the restraining dog shown at the left-hand side of FIG. 18 and illustrates one of four such alternative dogs to be disposed at 90 degree intervals as illustrated in FIG. 19.

FIG. 23 is a fragmentary vertical cross section through the restraining dog shown in FIG. 22 at line 23–23' to illustrate how each of the alternative restraining dogs is surrounded by gaps in the two tubular cylindrical mechanisms for adjusting posture of the four such restraining dogs that hold the drill bit mechanism down in the drill pipe during drilling operations.

FIG. 24 is a vertical cross section through the rotational axis of a central body member 1 generally corresponding to the central body member 1 shown in FIG. 2 but with industrial diamonds being mounted on the lower tips of two (of four) arms 4 underreaming the drill pipe shoe in lieu of the steel alloy rolling cutters mounted on the lower tip of one of three such arms 4 illustrated in FIG. 2.

FIG. 25 is a horizontal cross section through the axes of two of four pivot pins respectively mounting arms for at line 25–25' in FIG. 24.

FIG. 26 is a side view of the body member 1 shown in FIGS. 24 and 25 to show means attached to said body member limiting its downward movement into the tubular shoe screwed onto the lower tip of the cylindrical tubular drill pipe.

FIG. 27 is an interior view looking outward from the rotational axis toward one of four downward projections of the drill pipe shoe members to show the means attached to the inner arcuate surface of said downward projections of the drill pipe shoe between the gaps therein to limit downward movement of the main body member 1 (shown in FIGS. 24 and 25)

in joint cooperative conjunction with the features illustrated by one quadrant of the cylindrical outer surface of that body member 1 in FIG. 26.

FIG. 28 is a vertical cross section through the rotational axis of a novel connecting member connecting the body member 1 shown in FIGS. 24 and 25 to a pilot hole drilling mechanism, which is vertically movable within short limits but is not rotatable with respect to said main body member, whose arms mounting the cutting diamonds are alternatively adjusted hingeably by vertical movement of said body member with respect to the pilot hole drilling mechanism not shown in fragmentary FIG. 28.

FIG. 29 is a core-recovering pilot hole drilling mechanism attached to the lower tip of the connecting member shown in FIG. 28.

FIG. 30 is a horizontal cross section through FIG. 29 at line 30–30'.

FIG. 31 is a vertical cross section through the rotational axis of the cylindrical lower segment of the main central body member 1 shown in FIGS. 1, 2 and 24, 25, said lower cylindrical segment of the main body member having coarse tool-joint threads on its conical lower tip, on which is screwed a novel adapter bushing mounting on its lower tip a tubular cylindrical mechanism with a closed slightly conical lower end whereby the underreaming mechanism of said body member mounted in the larger drill pipe shoe is kept drilling a hole as straight as possible around a previously drilled pilot hole in which that cylindrical mechanism travels downward as nearly as possible in the center of the pilot hole.

FIG. 32 is a vertical cross section through the rotational axis of a core barrel of a different construction, the core barrel in FIG. 32 being upwardly removable by cable attached to the means illustrated through its inclosing conventional drill pipe, on the lower tip of which is screwed a suitable core drilling bit for drilling the pilot hole into which the tubular cylindrical member shown in FIG. 31 later is inserted, there being no requirement in either instance for unjointing the drill pipe of the pilot hole drilling mechanism or later of the larger drill pipe mounting on its lower tip the shoe substantially containing the main body member of the underreaming mechanism.

FIG. 33 is a vertical cross section through the lower tip of the cable whereby the inner core-barrel grappling mechanism shown in FIG. 32 alternatively can be hoisted to to the head of the well through the relatively smaller conventional jointed drill pipe, in the lower joint of which it is locked during the drilling operation by the means illustrated in FIG. 32.

FIG. 34 is a cross section at line 34–34' of FIG. 33 showing means whereby the cable is attached to the grappling mechanism on the lower tip thereof, the grappling mechanism generally resembling that shown in FIGS. 15, 16, and 15—16 except that it has to be much smaller for passage down the smaller drill pipe for the pilot hole drilling operation in lieu of direct attachment of a relatively short drill pipe joint to the body member 1 mounted in the larger drill pipe on which the shoe is screwed.

FIG. 35 is a slightly fragmentary horizontal cross section through FIG. 32 at line 35–35'.

FIG. 36 is a vertical cross section at the rotational axis through the core barrel and surrounding drill pipe segment directly below the same members shown in FIG. 32, as well as in horizontal cross-sectional FIG. 35 directly above it on the same sheet.

FIG. 37 is a vertical cross section through the rotational axis of the lower tubular segments of the same core barrel and drill pipe segments shown in FIGS. 32, 35, and 36 and mounting on the lower tip an alternative novel annular drill bit for drilling the pilot hole and recovering the core therefrom, whether that core be alternatively recovered on the cable attachment shown in FIGS. 33 and 34 or be recovered with the main body member 1 by means of the cable and grappling device shown earlier herein in FIGS. 15, 16, 15—16, and 17.

FIG. 38 is a view from below of half of the annular drill bit shown in vertical cross section in FIG. 37.

FIG. 39 is a vertical cross section through the rotational axis of the upper tip of the core barrel shown in the same drill pipe of the pilot hole shown in FIGS. 32, 35, and 36 and shows means whereby the upper tip of that core barrel is automatically attached to the cable by an "overshot" mechanism.

FIG. 40 is a horizontal cross section of FIG. 39 at line 40–40'.

FIG. 41 is a vertical cross section of the core barrel shown in FIG. 39 but with an alternative means (in addition to special weights) whereby the core barrel is scotched above its upper tip in a pilot hole drill pipe provided with an unconventional shoulder in one joint thereof, means being shown whereby the scotching lugs are released to permit upward travel in the pilot hole drill pipe, when the cable is drawn upward after attachment of the "overshot" device.

FIG. 42 is a horizontal cross section of FIG. 41 at line 42–42'.

FIG. 43 is a fragmentary view from above of the hinge tip of a device necessary for detaching the grappling "overshot" mechanism shown in FIG. 39 from the "spear" shown attached to the upper tip of the core barrel shown in FIGS. 39 and 41, when such a core barrel is raised by means of the cable to the head of the well.

FIG. 44 is a vertical cross section through the device illustrated in FIG. 43 at the central line 44–44'.

FIG. 45 is a vertical cross section through the rotational axis of an alternative annular core drill differing from that illustrated in FIG. 37 and mounted in a different kind of smaller diameter tool-joint screwed onto the lower tip of a suitable thread-tipped drill pipe joint inclosing a novel lighter core barrel having a novel alternative core-catching device attached to the lower tip of the core barrel by an alternative means not employing threads.

FIG. 46 is a horizontal cross section of FIG. 45 at the line 46–46' thereof.

FIG. 47 is a vertical cross section through the rotational axis of the upper tip of the pilot hole drilling drill pipe joint shown in FIG. 45 and shows a novel coiled compression spring means of holding down said core barrel in the rotational center of a modified tool-joint screwed onto the upper tip of the joint of drillpipe shown in FIG. 45.

FIG. 48 is a quadrant of the drill pipe and core barrel shown in FIG. 47 at the line 48–48' thereof.

FIG. 49 is a vertical cross section through the rotational axis of the tool-joint screwed onto the pilot hole drill pipe shown in FIG. 48.

FIG. 50 is a vertical cross section through the rotational axis of the tool-joint screwed onto the pilot hole drill pipe shown in FIG. 47 and shows the means of attaching the upper tip of the tool-joint shown therein to the lower tip of an alternatively constructed connecting member such as that shown in FIGS. 28 and 47.

FIG. 51 is a cross section horizontally of FIG. 50 at line 51–51'.

FIG. 52 is a horizontal cross section of FIG. 50 at line 52–52'.

FIG. 53 is a vertical cross section through the rotational axis of the tool-joint shown at the upper tip of FIGS. 47 and 50 but shows means mounting in the said tool-joint (and the drill pipe screwed into the lower tip thereof and in turn screwed into another tool-joint mounting a novel annular core-drill) of a novel flexible core barrel formed of a single sheet of thermoplastic polyethylene employed alternatively in said pilot-hole drilling mechanism connected to the underreaming body member shown in FIGS. 24 and 25.

FIG. 54 is a horizontal cross section of FIG. 53 at line 54–54'.

FIG. 55 is a horizontal cross section of FIG. 53 at line 55–55'.

From further study of the foregoing drawings in connection with the following description thereof, it can be seen that one of the primary purposes of the present invention is to cut manufacturing costs for all the various parts of my invention

(with the exception of the actual drilling parts coming in direct contact with the rock formations being drilled by my drilling mechanisms) by making those parts insofar as possible out of cylindrical tubes and threaded couplings and tool-joints now on sale to the oil industry, all of which parts are modified by machining and welding as will be described presently herein in connection with the attached drawings, in which corresponding numerals indicate the various parts of the invention.

FIG. 1 shows a fragmentary side view of the easily removable generally cylindrical main body segment 1 of my invention showing one of three underreaming rolling cutters 2, each of which is mounted rotatably on a heavy pin axle 3 inserted fixedly in an arm 4 hingeably mounted in a vertically disposed slot 5 in said main body segment 1 so that the lower tip of said arm 4 can swing outwardly on its respective pivot pin (See 4.1, 4.2, and 4.3 in FIG. 2) through the corresponding one of the three vertical-walled notches 6.0 through the lower margin of the cylindrical retaining shoe 6, which has been cut away in this FIG. 1 to its vertical axis to reveal the main body segment 1 of the drill bit assembly and therefore does not show any of the drill pipe 11, whose lower externally threaded tip is shown in FIG. 11 as being screwed into the upper tip of the upper segment 6 of the drill pipe shoe.

The present invention may be made in various sizes to bore holes of greatly differing diameters to great practical depths. But, since it has been designed particularly to use in the construction thereof various sizes of tubular steel pipes now readily available for use in the oil fields of the United States and elsewhere, it is much easier to construct an embodiment thereof for boring holes of larger diameter. The attached drawings (prior to reduction of about one-third in size by the U.S. Pat. Office) therefore show an embodiment of the invention mounted on the lower tip of a widely used steel casing joint having an outside diameter of 6⅝ inches, because that size casing is the one used almost exclusively in oil and gas wells of considerable depth. Such tubular casing (now to be used also as drill pipe) is readily available on the market in this country in various weights per foot (according to the depth of the well in which the pipe is to be suspended from the well head), which obviously determine the respective inside diameters of such casings from 6.049 to 5.675.

The present drawings show my invention mounted on the lower tip of a casing joint weighing 19.49 pounds per foot (approximately 20 pounds per foot including internally threaded couplings 7¼ inches in length and either 7 inches or 7.39 inches in diameter between joints of about 20 feet in length, depending on kind of threads employed in the couplings) with a wall thickness of .288 inch. But it will be appreciated that casing joints of much greater weight and wall thickness would be required in a hole 10,000 feet in depth, since the greatest strain usually is the weight of the casing on the threads of the upper joints in a casing string. The diameter of my drill bit mechanism to be installed and removed through such casing pipe in the hole therefore would have to be small enough to pass through the upper joints of the casing, which with my invention is employed in lieu of another expensive string of drill pipe employing special tool-joints (to be removed from the hole being drilled and disconnected at frequent intervals for a very expensive and time consuming change of the worn bit on the lower tip of the drill pipe or to drill around and recover a few feet of core of the rock formations penetrated with a special coring mechanism mounting industrial diamonds as long known to the mining art), and which can be left in the hole with a single "makeup" of the threads of the casing joints in their much less expensive threaded couplings, if the casing is to be left in the hole as an oil, gas, or water producer.

It will be appreciated, however, that the relatively light casing-drill pipe shown in my drawings is quite adequate for drilling holes several thousand feet deep, since my invention presently to be described and employing a pilot mechanism to drill a pilot hole less than 6 inches in diameter ahead of the underreaming bit mechanisms (to enlarge that pilot hole to more than accommodate the casing couplings having an outside diameter of at least 7¼ inches) will cause the present invention to bore an unusually straight hole, thereby removing strain on the drill pipe casing ordinarily caused by the crooked holes drilled in the earth with large bits mounted on conventional drill strings of approximately the same weight but much smaller in diameter, at least between the tool-joints.

At least one manufacturer of steel pipe for the oil industry now sells drill pipe having an outside diameter of 6⅝inches, but that drill pipe of such large diameter is not suitable for mounting the presently to be described drill bit mechanism to be removed and installed through the drill pipe in the hole being drilled, since that large size drill pipe has internal as well as external "upsets" at the ends of the pipe joints (attached by flash welding) for accommodation of the special very large tool-joint couplings. It is necessary that such internal and external "upset" tips not be welded to their respective joints of drill pipe, since it is contemplated with the present invention that the internal diameter of the cylindrical drill pipe will be substantially uniform with the exception that the ends of the pipe joints usually have an interval of almost an inch between them in each conventional casing coupling. A reading of the following description should convince anyone sufficiently skilled in the art of drilling oil wells that the large drill pipe casing of 6⅝ inches in diameter will tend to remain virtually straight in the hole being drilled and will not subject the drill string to vibrational fatigue at the threaded joints, because the hole will remain straight, as indicated above and for reasons that will be manifest later from the following description of my invention of a novel drill bit mechanism, which may be used with or without a coring mechanism at any time without need to unjoint the drill string in removing it from the hole. By way of contrast it may b may be noted that the conventional 6⅝ inch outside diameter drill pipe having "internal upset" at its tips attached to the tool-joint has a coupling of 7.75 inches outside diameter, while no such coupling is made for the same size pipe having an "external upset," which obviously would require a much larger coupling.

Although it is possible to employ industrial diamonds (both natural and synthetic) as rock cutting means mounted on my drilling mechanism, as will be explained later herein in connection with FIGS. 24, 25, 26, 27, and 28, it is illustrated in FIGS. 1, 2, and 3 that rolling cutters 2 are mounted pivotally on the basic generally cylindrical central body member 1, which is installed through the cylindrical tubular drill pipe string 11 having its internal diameter only slightly larger than the outside diameter of central member 1 of my drill bit mechanism to be fitted in the lower tip of that tubular drill string, from which most of the drill bit mechanism to be described may be removed at the election of the driller by means of a cable without need of pulling from the hole being drilled the drill pipe string in a time consuming and therefore very expensive as well as rather dangerous process at times.

It is much less expensive to manufacture my invention out of tubular steel members at present available for the oil well drilling industry insofar as possible. For drilling deep holes the steel companies now will provide a drill pipe having outside diameter of 6⅝ inches with the threaded tips of the joints (having a wall thickness of .33 inch and therefore inside diameter of 5.965 inches) being joined by couplings 9 inches long and 7.750 inches outside diameter; but the "internal upset" of 5 inches at each tip of the joint has an internal diameter of only 5 inches. Such drill pipe, which at least ordinarily is made of better quality steel than the ordinary "well casing" available to the oil industry, therefore is not satisfactory for use with the present invention, unless such drill pipe is modified, as may be done by some manufacturers contemplating very great business to be derived therefrom to justify the very considerable increased cost. But for drilling holes only a few thousand feet in depth the best quality ordinary "casing" is entirely satisfactory as a "drill string," since my invention tends to drill very straight holes without unusual strain (in removing from the hole or otherwise) on casing of 6⅝ inches

outside diameter employed by me as drill pipe. Some such casing may have a wall thickness of only .288 inch with an inside diameter of 6.049 and weight of 20 pounds per foot (with the threaded coupling thereon); but other such casing has a wall thickness of as much as .475 inch. Obviously it is possible within limits to make the diameter of my invention correspond to the internal diameter of the tubular drill pipe (whether ordinary casing or otherwise) as well as to make my drill bit mechanism larger to fit in drill pipe of larger diameter for boring holes of greater diameter, whether such holes be made for producing oil or gas or water or sulfur or for any other purpose.

Since casing having an outside diameter of 6⅝ inches is usually considered satisfactory in size for completion of an oil, gas, or water well, and since it is contemplated that my drill pipe may be left in the hole as casing in event of a satisfactory discovery of oil or water or sulfur etc., let it be presumed that the drill pipe **11** shown in FIGS. **11, 12, 13, 18, 19, 22,** and **25** has internal diameter slightly less than 6 inches and that my drill mechanism is small enough to slip readily down that drill pipe **11** quite easily, even if the drill pipe **11** be slightly "out-of-round" at places for any reason. The lower tip of drill pipe **11** is threaded externally and screws into the upper half of an ordinary casing coupling **6**, which is modified as shown in the present drawings to form a cylindrical tubular "shoe" segment of my drill bit mechanism, that remains attached to said drill pipe **11** as long as that pipe remains in the hole being drilled. Such casing couplings, which are slightly conically threaded internally from each end, come in lengths of 7¼, 8¾, and 9⅝ inches (depending on whether the internal conical threads are *RTB*, short, *RTB* long, or Buttress) with outside diameters of 7.39 except for special clearance 7 inch outside diameter for *RTB* or Buttress. But, simply for ease of construction by employing such a coupling already available in the market under mass production, it may be noted from FIGS. **1** and **2** that there is screwed into the lower half of said coupling **6** an externally threaded pipe **6'** of suitable short length, around which is fixedly attached a short cylindrical sleeve **6''** (having the threads bored out of another such coupling cut into suitable lengths), which serves as reinforcement of pipe segment **6'** and may be welded conveniently to the lower tip of coupling **6** as well as to pipe segment **6'** of the cylindrical shoe.

Within the sleeve member **6'** is fixedly mounted another cylindrical tubular sleeve **6.1**, whose upper face is perpendicular to the cylindrical inner wall of sleeve **6'** and is very radically serrated as a means of rotatably oscillating the removable body member **1**, when an inversely serrated cylindrical sleeve **1'** (rigidly attached around that cylindrical body member **1**) comes down to rest against serrated tubular sleeve **6.1** in the drilling posture. In FIG. **1** it is shown that two of the three serrating lower points of sleeve **1'** are disposed at angles of 120° from each other around the vertical axis of cylindrical central body member **1**. And in FIG. **2**, showing a vertical cross section through the rotational axis at right angles to FIG. **1**, can be seen the other lower point of sleeve **1'**, which is at angles of 120° from the other two such lower points respectively; and the lower three points of the symmetrical serrations of sleeves **6.1** and **1'** respectively are diagonally opposed to the axis of the rolling cutter axle pin **3**, whose inner tip is screwed into the lower tip of arm **4**, whose upper tip is pivotally mounted on the cylindrical pin **4.1** extending across the generally rectangular vertically disposed slot cavity **5** in body member **1**, as indicated by broken lines in FIG. **1** also.

In FIG. **3** the horizontal cross section of the three vertical cavity slots **5**, symmetrically disposed at angles of 120° from each other and equally spaced from a cylindrical canal **1.0** through body member **1** around its vertical axis for the purpose of conveying drilling fluid, shows that those somewhat rectangular vertical slots **5** are exact duplicates at the plane of line **3–3'** of FIG. **2**, which plane includes the axis of pin **4.1** mounting arm **4** shown in both cross-sectional FIGS. **2** and **3** at right angles to each other. But, in order not to weaken body member **1** by boring therein all three of the horizontal holes **4.1'**, **4.2'**, and **4.3'** for mounting hinge pivot pins **4.1**, **4.2**, and **4.3** respectively at the same plane of line **3–3'** of FIGS. **2** and **3**, in which two of the arms **4** have not been shown in slots **5** for simplification and clarity, I bore the horizontal hole **4.2'** for mounting pin **4.2** one inch above the hole for that pin **4.2**. The elevations of these other two holes for pins **4.2** and **4.3** are indicated by broken lines in FIG. **2**, but actually the holes for those pins **4.2** and **4.3** at their respective elevations are disposed symmetrically in body member **1** around the cylindrical canal **1.0** at equal distances from the vertical axis thereof, just as indicated by broken lines in FIG. **3**. This arrangement of course requires that the three vertical slots **5** mounting therein the respective arms **4** on pins **4.1**, **4.2**, and **4.3** respectively differ in length vertically by corresponding amounts of approximately 1 inch. But, regardless of whether the axes of pins **4.3** and **4.2** may be a little more or a little less than 2 and 1 inch respectively above the axis of pin **4.1** shown in FIG. **2**, it is essential that the respective rolling cutters **2** mounted on pins **3** in arms **4** (pivotally mounted on hinge pins **4.2** and **4.3** respectively) be almost on the same level in the drilling operation, although it is contemplated that the shortest arm **4** shown in FIG. **2** will be mounted at the highest level to provide for its rolling cutter **2** acting to cut the extreme outer portion of the enlarged hole, while the other two cutters **2** will be mounted at slightly lower levels respectively to carve out beneath the drill pipe shoe (composed of fixedly attached segments **6**, **6'**, **6''**, and **6.1**) three overlapping circular terraces, as indicated diagrammatically in FIG. **2**, although the surfaces thereof will merge almost imperceptively.

Regardless of whether the three underreaming rolling cutters **2** are mounted on arms **4** of different lengths to carve (by substantial impact of the teeth thereof on the rock surfaces) three terraces differing slightly in elevation or are mounted alternatively to carve substantially a single terrace in the rock being pulverized thereby, it is to be noted particularly that these differences in elevation of the three rolling cutters are to be accomplished within the portion of the drill bit assembly that is removable from the hole through the drill string, for all of the serrations in cylindrical sleeve **6.1** of the drill pipe shoe (fixedly attached to the lower tip of said drill pipe **11**) are exactly symmetrical with respect to each other, as are the inverse serrations in guiding sleeve **1'** rigidly attached to body member **1**, not only to keep it from ever passing entirely through the shoe members **6**, **6'**, **6''**, and **6.1**, but simultaneously to rotatably oscillate it into proper position, with respect to the vertical walled gaps **6.0** of that drill pipe shoe, for swinging arms **4** outward hingeably in slotted cavities **5** of the body member **1** into those gaps **6.0** through the lower margin of said shoe fixedly attached to the drill pipe **11**. Since those gaps **6.0** in the lower margin of the drill pipe shoe are exact duplicates and are disposed symmetrically at intervals of 120° around the vertical rotational axis of that shoe to correspond in the drilling posture with the rotational spacing of arms **4** in slotted cavities **5** of the removable portion of the drill bit mechanism, it makes no difference in what rotatable posture the body member **1** goes downward into the shoe, because the inverse serrations in sleeve **1'** rigidly attached to body member **1** cooperate with the serrations in sleeve **6.1** rigidly attached to the drill pipe shoe **6**,**6'**, **6''** to rotatably oscillate body member **1** by the required number of degrees in that shoe to permit the arms **4** mounting their respective rolling cutters **2** into the respective gaps **6.0** in said drill pipe shoe to act as underreamers thereof in expanding the smaller pilot hole (presently to be explained) to a suitable diameter in excess of the outside diameters of the collars of the drill pipe (of the same size as the shoe members **6** and **6''**) for circulating upwardly the drilling fluid, which is pumped downward through the drill pipe **11** (in a way well known to the art) and also through the canal **1.0** in the center of body member **1** of my drill bit mechanism, the size of canal **1.0** depending on various factors to be explained later in connection with the pilot hole drilling mechanism for recovering a "rock core" therefrom.

It obviously would be possible (even if somewhat more expensive in most circumstances) to make shoe members **6**, **6'**, and **6''** as a single integral unit; but it would be almost impossible as well as impractical to fabricate the serrations of sleeve **6.1** in the same integral unit, because it is necessary that the upper faces of those serrations be substantially perpendicular to the inner wall of shoe member **6'**, in order to avoid any possibility that the body member **1**, having inverse serrations in its external cylindrical sleeve **1'**, would become wedged in the drill pipe shoe before settling downward to the required position for the outward expansion of arms **4** mounting rolling cutters **2**. However, it is quite practical to cut such serrations having such perpendicular upper faces (as indicated in FIG. **2**) in the sleeve **6.1** prior to its placement in the cylindrical tubular shoe member **6'**, to which it then conveniently can be welded fixedly in order to rotatably oscillate sleeve **1'** of body member **1** to its proper position (as just explained) and ultimately to keep that sleeve **1'** mounted on body member **1** from passing on through the drill pipe shoe, before it is lowered into drilling position at the bottom of the hole being enlarged.

While I have spoken above of the sleeve **6.1** as being a single cylindrical member, it will be appreciated that sleeve **6.1** can be installed in shoe member **6'** as multiple segments, each of which would be welded to that tubular cylindrical shoe member **6'**. FIG. **1** illustrates that flathead bolts **6.1'** may be inserted through corresponding holes in tubular shoe member **6'** for pulling such alternative segments tightly against the inner wall of tubular shoe member **6'** for welding thereto, after which the nuts (not shown) would be sawed off with the tips of the bolts **6.1'**, which then would be welded into said holes in shoe member **6'** as shown. The aforesaid alternative segments of sleeve **6.1** conveniently may be made of tubular material having greater thickness than required; but the at least substantially combined sleeve **6.1** welded into internal shoe member **6'** then can be placed in a lathe for increasing internal diameter of sleeve **6.1** to make a suitable cylindrical internal face thereof, since the upper serrated faces of sleeve **6.1** need be only about one-eighth inch wide, in order for it to guide and check downward movement of sleeve **1'** rigidly attached to body member **1**. It is not even necessary, however, for such segments of sleeve **6.1** to come completely together in order to form a suitable guide for the serrations of sleeve **1'** of body member **1**, for it actually is desirable, at least in almost all circumstances, that some of the drilling fluid escape downward between the drill pipe shoe and the removable portion of the drill bit mechanism, so that additional such drilling fluid (beyond that passing through canal **1.0** of body member **1**) may pass downward inside the drill pipe shoe toward the drilling faces cut by rolling cutters **2** for circulation upward around the drill pipe **11** to carry out all the small rock segments disintegrated in the drilling process by the multiple cutters, as is well understood in the art of well drilling with rotary tools employing suitable drilling fluid to carry such rock segments upward in suspension as well as in solution in said drilling fluid, sometimes called "drilling mud," if it is liquid as is usually the case.

As is indicated in FIG. **2**, it is not necessary that the three lower tips of sleeve **1'** attached rigidly to body member **1** come down entirely against the sleeve **6.1** of the drill pipe shoe; but it is essential that the three upper tips of sleeve **6.1** of that drill pipe shoe be exactly 120° from each other in order to cooperate perfectly with the lower tips of sleeve **1'** of body member **1**, when that body member **1** is lowered into the drill pipe shoe, for otherwise the body member **1** might hang in the drill pipe shoe, if the points of the two sleeves came into contact at intervals other than 120°. To insure that there will be no such hanging of sleeve **1'** in the drill pipe shoe above the position necessary for outward hinging of arms **4** in cavities **5** into gaps **6.0** in the lower margin of the drill pipe shoe, it is convenient to blunt very slightly the upper points of serrated sleeve **1'** (as indicated at the upper center of FIG. **1**) as well as the lower points of sleeve **1'**, so that the body member **1** may be shifted from any such blocking position by a simple sudden rotation of the drill pipe very slightly before the drill bit mechanism ever is lowered completely into the hole on the end of drill pipe **11**.

Note particularly in FIG. **1**, however, that the cooperating serrations of sleeves **6.1** and **1'** need not be exactly symmetrical. In FIG. **1** it can be seen that, in order to make the sleeve **6.1** somewhat stronger adjacent the gaps **6.0** in the shoe adjacent the cavity slots **5** in body member **1** for arms **4** mounting rolling cutters **2** (without need for lengthening the serrations of sleeves **6.1** and **1'**), the visible one of the three serrations in sleeve **1'** (generally corresponding to serrations in sleeve **6.1** not visible in that figure) have been widened slightly adjacent the upper corners of cavity **5** in body member **1**. Note particularly that, after the radical serrations of guiding sleeve **1'** of removable body member **1** have settled down completely into the substantially inversely corresponding radical serrations of guiding sleeve **6.1** screwed tightly onto the drill pipe **11** FIGS. **11**, **18**, **22**), there is no conflict between the outward hinging arms **4** on their respective pivot pins **4.1**, **4.2**, and **4.3** and the radical serrations of guiding sleeves **1'** and **6.1**, for the gaps **6.0** in the lower margins of shoe members **6.1**, **6'**, and **6''** are substantially in alignment vertically with the slotted cavities **5** in body member **1**, in which those arms **4** are hingeably mounted midway between the respective lower points of guiding sleeve **1'**.

While the radical serrations in guiding sleeves **6.1** and **1'** would tend to some extent to make the removable body member **1** rotate with the rotating drill pipe **11** in the drilling process (because means presently to be explained prevents the body member **1** from moving upward with respect to the drill pipe), it is most significant that the primary means for rotating the three arms **4** mounting rolling cutters **2** consists of the vertical sidewalls of the gaps **6.0** in shoe members **6''**, **6'**, and **6.1**, all of which are screwed onto the lower tip of drill pipe **11** by means of upper member **6**. This torque of the drill pipe exerted directly on arms **4** by said sidewalls of gaps **6.0** in shoe members **6.1**, **6'**, and **6''** of the drill pipe shoe has to be very quite considerable in order to rotate arms **4** and thereby the rolling cutters **2** mounted on pins **3** thereof, for in drilling hard rocks it is necessary to put very great downward pressure on the rolling cutters **2** to make them disintegrate the surfaces of the rocks being penetrated by the drill into very small segments, which will then be carried upward to the well head around the drill pipe in the circulating drill fluid, as has been known in the art for other kinds of rolling cutters employed in drilling well holes with rotary tools for more than half a century. It is significant, however, that the torque of the drill pipe **11** on arms **4** mounting rolling cutters **2** directly beneath the drill pipe as indicated in FIG. **2** is in no way comparable to the much greater torque necessary to rotate such underreaming arms **4** carrying industrial diamonds (to be described later herein) to actually "cut" hard rocks, for it is much easier to "chip" the surface of such a rock formation in very small pieces by rotating the hardened steel alloy rolling cutters **2** under great downward pressure than to "cut" the hard rock by relatively much harder industrial diamonds mounted in the lower tips of the rotating hingeably mounted arms **4**, as will be explained later herein.

To carry the great weight exerted downward on the three rolling cutters **2** by the drill pipe **11**, some of whose weight at great depths would be supported in a derrick or mast pole by means of a "swivel" well known in the art of boring wells by means of a rotary drill pipe circulating drilling fluid through the "swivel," there is mounted in each of the rolling cutters **2** the outer race of an antifriction tapered roller bearing, whose inner race is mounted around the axle pin **3** against a suitable annular spacing washer as shown in FIG. **2**, in which it can be seen that a suitable cavity **4.0** has been cut out of the lower half of arm **4** to accommodate the rolling cutter **2** mounted on said cylindrical axle pin **3**, whose inner threaded tip is shown screwed into the correspondingly threaded cylindrical cavity in the remaining approximate half of the lower portion of arm

4 mounting that cutter 2, just as do the other arms 4. That cylindrical cavity in arm 4 into which the tip of pin 3 is screwed does not reach entirely through that arm 4, but the lower inner tip of that cavity reaches the diagonal exterior lower tip of the arm 4, so that it is conveniently possible to secure the tip of pin 3 in arm 4 by spot welding the inner tip of pin 3 to arm 4 through a small hole therein at that lower point of said cavity (as is indicated by the dot in FIG. 2), after the pin 3 has been screwed into arm 4 against an annular shoulder on said pin 3, whose outer circular face of its conical outer tip is flush with the outer annular extremity of the rolling cutter 2.

Around the spacing washer mentioned above is mounted an annular flexible washer of material suitable for keeping dirt out of the antifriction bearing assembly, which may be lubricated by means of grease conveniently inserted through a suitable connection (well known in the art of lubrication) screwed into a small threaded cylindrical cavity in pin 3 at the interior of a hexagon cavity in the outer tip of that pin 3 for insertion of a tool with which to screw pin 3 into its hole in arm 4. A small hole in pin 3 perpendicular to its axis connects the aforementioned small threaded cylindrical cavity in pin 3 with the space around pin 3 in which the tapered roller bearings are carried by their inner and outer races. Additional grease thus may be provided for each of the bearings of rolling cutter 2 at any of the frequent times the drill bit mechanism is removed quite readily from the hole through the drill pipe by means to be explained later herein. It is to be understood, however, that antifriction ball bearings may be substituted just as easily in lieu of the tapered roller bearings shown in the drawings; and similar such alternative bearings provided with suitable seals, so that no subsequent lubrication ever is required, now are readily available on the market to fit the 1 inch diameter pins 3 on which rolling cutters 2 are mounted.

Because of the horizontal torque exerted on arms 4 directly by the vertical walls of respective gaps 6.0 in the lower margin of the drill pipe shoe members 6.1, 6', 6'' around the rotational axis of drill pipe 11 screwed into shoe member 6, as well as because of the very considerable necessary downward pressure on the arms 4 mounting rolling cutters 2, it is necessary that those arms 4 be made as strong as possible, even though the size of those arms 4 is limited by the space in body member 1 (having an outside diameter easily slidable through drill pipe 11, that may not be exactly round in some places), which simultaneously has to have a cylindrical canal 1.0 of suitable diameter therethrough (to carry drilling fluid downward to a lower pilot hole drilling and core recovering mechanism to be explained later herein), which in turn has to have a wall of that body member 1 between said canal 1.0 and the adjacent slots 5 in which are hingeably mounted arms 4 of sufficient strength to enable the slotted body member 1 to rotate the said lower pilot hole drilling mechanism by means of the arms 4 rotated by the sides of bottom margin gaps 6.0 of drill pipe shoe members 6.1, 6', 6'', 6.

Note in FIGS. 1 and 2 that the cavity 4.0 provided in the outer half of arm 4 (of which the other two arms 4 are duplicates except in overall length for mounting on pivots 4.2 and 4.3 at different heights in body member 1 from that of hinge pin 4.1) is arcuate and only large enough to accommodate the outer tips of the teeth of rolling cutter 2, so that the sides of the respective arm 4 come into quite adequate contact with the rotating vertical wall of gap 6.0 in the lower margin of shoe members 6.1 and 6', although rotational contact is made with the side of the gap not shown in FIG. 2, since the shoe member 6 (made of an ordinary pipe coupling readily available on the market in oil fields) is threaded clockwise to accommodate conventional oil field pipe whose threads screw up clockwise. But also note in FIG. 1 that both the vertical sides of arm 4 are drawn inward very slightly toward the outsides thereof, in order that the arms 4 may hinge outward quite readily into the gaps 6.0 of the drill pipe shoe and yet on their ultimate outward swinging on their respective mounting pivots 4.1, 4.2, and 4.3 will fit quite snugly into those gaps 6.0, each of which in turn has its vertical sidewalls drawn in slightly toward the outside of the drill pipe shoe as well as toward the top thereof.

It will be noted in horizontal cross-sectional FIG. 3, however, that the outer wall of the inwardly retracted arm 4 (shown in a somewhat outwardly extended posture in vertical cross section in FIG. 2) is arcuate with a radius only very slightly less than the radius of the guiding and movement checking serrated sleeve 6.1 of the drill pipe shoe, through the gaps 6.0 in which those retracted arms 4 have to slip quite easily during installation and removal of body member 1 from the drill pipe 11. And it is to be understood that the roofs of gaps 6.0 in shoe members 6.1, 6', and 6'' are similarly arcuate to fit substantially the respective outwardly hinged arcuate outer walls of arms 4. Although each of the gaps 6.0 in the lower margin of my drill pipe shoe may be substantially an exact duplicate of the other two such gaps 6.0, it will be noted in FIGS. 1 and 2 that there is mounted in the outer wall of the arm 4 a spacing plate 4', whose thickness along the vertical center line thereof will determine (on that plate's coming in contact with the arcuate roof of the gap 6.0) the ultimate angle from vertical at which that arm 4 will swing outward beneath the drill pipe shoe to make its cutter 2 carve a suitable disintegrated annular segment out of the rock being penetrated by the underreaming drill mechanism, since that arm 4 pivotally mounted on pin 4.1 (mounted in body member 1 intermediate the cutting path of rolling cutter 2 and the vertical rotational axis of body member 1) will tend to swing outward just as far as possible by virtue of other forces (to be explained presently) besides the upward vector force of cutter 2 on its arm 4 disposed at a suitable angle (shown conveniently in FIG. 2 as 15° from vertical, although the angles from vertical of the three arms 4 may be increased correspondingly) with respect to the rotational axis of the drill pipe 11 and its shoe mounted on the lower tip thereof. A corresponding spacing plate is mounted on each of the other two arms 4 beneath a shoulder in the outer wall thereof just as indicated by the spacing plate 4' shown in FIGS. 1 and 2; and each such plate 4' is held in place otherwise on its respective arm 4 by its corresponding setscrew 4'' as shown. However, each of the spacing plates 4' differs in thickness from the other two plates by just enough to make the three cutters 2 mounted on their respective arms 4 travel in an annular path overlapping that of the cutter 2 adjacent to it as illustrated by the exaggerated terraces in FIG. 2, so that the three cutters 2 operating in conjunction serve to ream out completely the pilot hole beneath the drill pipe shoe to a larger hole of adequate diameter for passage of the drilling fluid upward (as indicated by the arrow F in FIG. 2) around the multiple couplings of the drill pipe 11, even though those couplings rotating in the drilling fluid tend to keep the hole straight and in alignment with the pilot hole, to be explained later herein.

FIG. 2 also shows a threaded setscrew pin screwed into a cylindrical threaded hole in the arm 4 immediately below the pivot pin 4.1 as a convenient means holding that hinge pin 4.1 locked in the arm 4 and thus in the body member 1 provided with vertical slots 5 for each of the three arms 4 similarly secured therein. Obviously such locking pins 4.1' are not needed, when the pivot pins alternatively are provided with threads for screwing into their respective horizontal holes 4.1', 4.2', and 4.3' in body member 1 through their slots 5 therein, as illustrated by the pivot pin 4.1 in FIG. 3, in which that threaded pivot pin 4.1 also is locked in place by a small cylindrical securing pin in a perpendicularly disposed small hole in body member 1. It is essential only that none of the parts be permitted to come loose from the drilling mechanism during the drilling process, for recovery from the hole is quite expensive. Other means of course may be employed alternatively to retain hinge pivot pins 4.1, 4.2, and 4.3 in their respective horizontal cylindrical holes at different levels in body member 1. For instance, in FIGS. 1 and 2 it is indicated that one of the lower tips of serrated guiding sleeve 1' alternatively is made as a removable small arcuate plate of suitable configuration held in position on body member 1 by a retain-

ing flathead bolt inserted through a hole in that removable arcuate plate and screwed into a horizontal hole in the body member 1, after the pivot pin 4.1 of suitable length is inserted in its mounting hole in that body member 1. Such an alternative arrangement for retaining the pivot hinge pins of arms 4 by bolted plates 1'' is quite convenient for removing those arms 4 from body member 1 to replace worn parts of the cutters 2 rotatably mounted on the three arms 4, but that alternative construction is not as strong as the construction shown in FIG. 3 (and explained previously), in which all three of the lower tips of serrated sleeve 1' are welded to body member 1.

One of the primary requisites of the present invention is that it must employ as much of the space within the drill pipe 11 as possible to give ultimate strength to body member 1 for rotation of the drilling mechanism (to be explained later herein) for the pilot hole (almost as large as the internal diameter of drill pipe 11) below the underreaming mechanism inside the drill pipe shoe as illustrated in FIGS. 1, 2, and 3. As mentioned previously herein, the three horizontal cylindrical holes mounting the three symmetrically disposed hinge pivot pins 4.1, 4.2, and 4.3 shown in FIG. 3 (but at different levels as indicated in FIG. 2) are drilled in body member 1 (and its serrated partially inclosing guiding and retaining sleeve 1' welded thereto) at different levels therein, so that such horizontal holes in body member 1 will not weaken it too much at any one level, and simultaneously so that the three arms 4 in their extreme outwardly hinged postures (whatever the suitable disposition from vertical may be chosen ultimately for particular circumstances of drilling etc.) will be disposed at slightly different angles from the vertical axis of the drill, thereby making them describe different annular drilling paths, which in combination are of sufficient width to enlarge the pilot hole sufficiently to carry the drilling fluid and all its small disintegrated rock segments held in suspension therein upward past the multiple drill pipe collars or couplings of whatever nature employed in the oil fields, for which such pipe is manufactured at various places in the world. It can be seen in FIG. 3 that at the level of the lowest hinge pivot pin 4.1 at line 3–3' in FIG. 2 the body member 1 (with the exceptions of the central canal 1.0, the slotted cavities 5 for mounting arms 4 therein, and the single horizontal hole 4.1' for mounting the lowest hinge pin 4.1 bored also through one of the lower points of serrated sleeve 1' welded thereto) that body member 1 almost fills the retaining sleeve 6.1 of the drill pipe shoe in a configuration (around the central canal 1.0 of adequate diameter) that gives very great strength to that cylindrical body member 1, which has even greater strength above that line 3–3', because at higher levels the three lower tips of serrated guiding sleeve 1' welded thereto make that body member combination 1 and 1' almost completely fill the cylindrical tubular drill pipe shoe member 6' having the same inside diameter as the drill pipe 11 screwed into the upper half of the coupling shoe member 6.

Although FIGS. 2 and 3 show at the center of cylindrical body member 1 a cylindrical vertical canal having a diameter of 2 inches, which is more than adequate to carry drilling fluid under considerable pressure (from the pump well-known to the art for that purpose at the head of the well) to the core-drilling mechanism in the pilot hole PH below, as will be explained later herein, and although I have shown cylindrical pivot pins 4.1, 4.2, and 4.3 in those FIGS. as having diameters of five-eighths inch each, it is appropriate to mention here that those three hinge pivot pins do not have to be that large, since the only appreciable strain on them is in pulling arms 4 mounting cutters 2 from the hole into the drill pipe shoe, and since preceding such pulling upward of the body member 1 through the drill pipe 11 (by means of a cable, as will be explained later herein) the driller can raise the drill pipe 11 a few inches from its previous drilling position in the hole to make the arms 4 swing back quite freely into their respective vertical slots 5.

Until acted on by other forces to be explained presently, the arms 4 mounting rolling cutters 2 on the lower tips thereof remain entirely retracted in their respective exterior vertical slots 5 of generally cylindrical body member 1, within which they each tend to be kept in their retracted positions by means of a pair of rather small U-shaped springs 414 mounted around the respective pivot pin in corresponding cavities 414' at each side of the upper tip of each arm 4, as indicated by broken lines in FIG. 2 in conjunction with FIGS. 1 and 3. Although restrained to some extent in its downward fall by drilling fluid in the hole, the retrievable drill bit mechanism therefore will settle downward in the cylindrical drill pipe 11 quite rapidly, until the serrated sleeve 1' of body member 1 comes in contact completely with obstructing serrated sleeve 6.1 of the tubular cylindrical shoe screwed on the lower tip of that drill pipe 11. Circulation of the drilling fluid under pressure of the pump adjacent the well head may be employed to speed up downward travel of the drill bit mechanism through drill pipe 11 and to make the serrated sleeve 1' of that drill bit mechanism finally come to rest against the sleeve 6.1 of the drill pipe shoe in the extreme lower position shown in FIG. 2 with the respective serrations in members 1' and 6.1 completely intermeshed.

At that time, even before the drill pipe 11 may have been lowered to a position at which the lower tip of its shoe will be substantially adjacent the bottom of the enlarged hole, I have provided multiple means to make the lower tips of arms 4 mounting rolling cutters 2 swing outwardly from their recessed positions in slotted cavities 5 of body member 1 into the gaps 5 in the lower margins of shoe members 6.1, 6', and 6'' by virtue of means provided for utilizing pressure of the pump at the head of the well on the drilling fluid inside the drill pipe and inside the canal 1.0 in body member 1. Note in horizontal cross-sectional FIG. 3 (at the floor of each of the two slotted cavities 5 from which the two respective arms 4 have been removed in that drawing) that in each of the three such vertical cavities 5 there is bored a cylindrical hole 7 in the body member 1. And in vertical cross-sectional FIG. 2 it is illustrated that each of these three cylindrical vent holes 7 is bored at an angle of 45° from vertical in the body member 1 to emerge well below the floors of the three slotted cavities 5 into the vertical central canal 1.0 immediately below the horizontal plane at which that cylindrical central canal 1.0 begins increasing in diameter gradually to a diameter of 2⅝ inches in diameter about nine-sixteenths of an inch below the cylindrical section of that canal 1.0 having a diameter of only about 2 inches at the level of horizontal cross-sectional FIG. 3. In each of the three diagonally disposed vent holes 7 slightly more than one-half inch in diameter is inserted a cylindrical prod rod about one-half inch in diameter and somewhat longer than the respective hole 7, in which it is quite easily slidable, and having a small annular shoulder on its upper blunt and somewhat conical tip to check downward slippage of the prod rod 7', as soon as it slips down into an annular cavity in the diagonally disposed floor of the notch 5 of body member 1, into which the prod rod 7' will recede completely, whenever the arm 4 has receded to its vertical posture in slotted cavity 5 for passing through the drill pipe 11. But, as soon as the driller increases greatly the pressure of the drilling fluid in canal 1.0 in body member 1 by means of the hydraulic pump at the head of the well (presuming that the drilling fluid is liquid rather than air or natural gas, as sometimes might be used), when that body member 1 has descended all the way into the shoe at the bottom of the drill pipe, the prod rods 7' in their three respective holes 7 will be forced by hydraulic action upwardly and outwardly against the lower tips of the respective arms 4, thereby making those arms 4 swing outwardly on their respective hinge pivots, until the adjusting plates 4' of each is brought into contact with the arcuate roof of its respective gap 6.0 in the drill pipe shoe, thereby bringing the three rolling cutters 2 mounted on those three arms 4 into their respective positions for drilling beneath said shoe of the drill pipe 11.

Excessive pressure outward on the lower halves of arms 4 is not required in the drilling process, after the three cutters 2 have reached their proper positions as a result of arms 4 being hinged outward from their vertical postures on their respective pivots 4.1, 4.2, and 4.3 in slotted cavities 5 until their ad-

justing plates 4' (of suitable different thicknesses to make the cutters 2 describe proper annular paths around the rotational axis of the drill pipe shoe to disintegrate the rock formation being penetrated in a combined swath wide enough to enlarge the pilot hole to a suitable larger diameter, as described previously) protrude against the respective arcuate roofs of the three gaps 6.0 in the lower margins of cylindrical tubular shoe elements 6.1, 6', and 6''.

Note in FIG. 3 as well as in FIG. 2 that 4.30 diameter of rolling cutter 2 is greater adjacent the outer face of the lower half of the arm 4, on which it is mounted rotatably by means of axle pin 3, than is the diameter of that rolling cutter 2 at the outer points of the cutting faces of that rolling cutter 2. The foregoing variations of diameter of the cutting faces (in each of the three cutters 2, which may be substantially the same, even though they describe different annular paths around the rotational axis of the drill pipe shoe as a result of variations in thickness of the three adjusting plates 4' limiting their hinging movement and as a result of variations in the length of the three arms 4 and of the respective elevations of pivot pins 4.1, 4.2, and 4.3) is for two entirely different reasons. It can be seen that the aforesaid variations in diameter of the cutting faces of the rolling cutter 2 shown in FIG. 3 make it possible to cut a wider swath with the said rolling cutter 2, which is substantially the same as the other two such rolling cutters 2 not shown in their respective slots 5 in that FIG., because those three rolling cutters 2 have to have outer faces that will travel downward freely through the tubular cylindrical drill pipe 11; and the construction shown, together with the fact that each of the rolling cutters 2 is somewhat thicker adjacent its respective axle pin 3 than at the outer cutting surfaces of said cutters, makes it possible to employ the maximum space within the drill pipe 11 for mounting cutters 2 on axle pins 3 mounted in arms 4, while using rolling cutters 2 having suitable outer diameters to afford sufficiently large cutting surfaces to endure very considerable wear, and also to afford sufficient space inside the cutters 2 for mounting suitable antifriction bearings on axle pins 3 suitably attached to the lower tips of arms 4.

In addition to the foregoing reasons for making the cutting surfaces of rolling cutters 2 somewhat conical as shown (with the smaller diameter of the truncated cone disposed outwardly), note in FIG. 2 that the foregoing somewhat conical shape of those rolling cutters 2 tends to relieve them to some extent of their tendency to push outward unduly from the rotational axis of the drill bit as a result of the fact that their mounting arms 4 are disposed (during the drilling process) on their respective pivot pins 4.1, 4.2, and 4.3 at considerable angles from the said rotational axis of body member 1. Note in FIG. 2 that, if the cutting surface of rolling cutter 2 had been made perfectly cylindrical (with corrugations or teeth therein as indicated in FIG. 1) instead of conical in general conformation (as would be possible, if the diameter of the inner section of each cutter 2 were made the same as that of the outer diameter of that rolling cutter 2, which is approximately as large as is possible for insertion of the entire mechanism through the drill pipe), not only would the cutting surface of cutter 2 in FIG. 2 be reduced somewhat, but at the same time the rolling cutter 2 (disposed on an arm 4 at the angle of 15° from the vertical rotational axis as shown) might have a tendency to pull outwardly from said axis in drilling a hard rock, so that the cutter 2, instead of remaining pressed tightly against the tapered roller bearing mounted therein, could tend to pull outward against the tapered outer tip of axle pin 3, on which it is mounted rotatably but snugly in order to keep drilling fluid from entering the antifriction bearing space. And in connection with the foregoing slightly tapered general configuration of the rolling cutters 2 (with the "point" of the truncated conical configuration disposed outwardly toward the wall of the hole being cut by this novel disposition of the generally conical cutter, exactly opposite to that ordinarily employed in mounting conical rolling cutters), it will be noted, not only that is it essential that the antifriction bearings mounted in cutters 2 be kept pressed snugly against the inner races thereof mounted on axle pins 3, in order to insure that the rolling cutters 2 will disintegrate the surfaces of the hard rocks with which their own cutting surfaces (teeth) come in contact beneath those rolling cutters 2, but that my underreaming rolling cutters 2 have their rotational axes disposed differently from the rotational axes of conical rolling cutters previously designed to drill cylindrical holes in rocks in exploring for oil and gas. Whereas the ordinary conical rolling cutters previously used to drill hard rocks in oil wells have been mounted inwardly with their free ends toward the center of the vertical hole being drilled, it will be noted in FIG. 2 as well as in FIG. 1 that the free ends of axle pins 3 mounting my reaming rolling cutters 2 are adjacent the outer wall of the cylindrical hole being drilled and that the rotational axes of the 3 rolling cutters 2 (having a generally slightly conical configuration) actually tilt upwardly from the horizon to some extent toward the outer free ends of the very strong axle pins 3, whose respective inner tips are mounted fixedly (and substantially rigidly) in the respective centers of the lower tips of the hingeable equally strong arms 4, which have to sustain enough weight of the drilling bit mechanism and the drill pipe attached thereto (by means presently to be explained) to make the lower cutting surfaces of rolling cutters 2 continually and almost continuously disintegrate the surfaces of the hard rocks into small bits less than one-eighth inch in diameter, as is well recognized in the art employing conical rolling cutters mounted rotatably on the lower end of a rotatable drill pipe.

In connection with the foregoing statements as to the general slightly conical configuration of the many cutting surfaces of the rolling cutters 2, it may be noted from FIG. 2 that a line drawn perpendicular to the lower cutting face of the rolling cutter 2 from the midpoint thereof would pass almost but not quite through the axis of hinge pivot pin 4.1 of arm 4, thereby indicating that a reactionary force exerted along such an imaginary line would keep the antifriction bearing in rolling cutter 2 pressed firmly against the inner race of that antifriction bearing held firmly against the outer face of the arm 4 in which axle pin 3 is fixedly mounted, but indicating that simultaneously the pressure of the rock formation being disintegrated in the rotary drilling process against that lower cutting rough face of rolling cutter 2 would press upwardly on arm 4 slightly outside the axis of pivotal mounting pin 4.1, so that the adjusting plate 4' mounted on the upper outside of arm 4 would be kept pressed firmly against the arcuate roof of gap 6.0 in the lower margins of shoe members 6.1, 6', and 6'', thereby forcing the rolling cutter 2 outwardly the maximum amount to make it cut an underreaming larger hole of the suitable diameter at least large enough to permit drilling fluid in suitable quantity to flow upward to carry away from the drill bit mechanism the disintegrated segments of the rock being penetrated.

Only a minimum amount of reactionary upward pressure need be exerted on pivotal hinge pins 4.1, 4.2, and 4.3, because the upper surfaces of arms 4 are made arcuate as previously indicated and of proper thickness from the respective hinge pins to fit quite snugly against the correspondingly formed roofs of slotted cavities 5, thereby absorbing the reactionary pressure of the rock formation on the respective rolling cutters 2. In FIG. 2 the upper surface of arm 4 is illustrated as conforming exactly to the roof of vertically slotted cavity 5 in central body member 1, and the other two arms 4 may be made conveniently to conform exactly to their respective cavities 5 or vice versa. But such exact correspondence is not necessary, since the final disposition (while drilling is going on) of the several arms 4 (at their desired differing angles with respect to the rotational axis of the drilling mechanism for disintegrating their overlapping annular sections of rock in the underreaming process) is determined in the last analysis by the limitations of the respective arcuate roofs of the exactly duplicate gaps 6.0 on the respective adjusting plates 4' and not by the roofs of the slots 5, in which arms 4 are pivotally mounted. Thus there is no great strain on

my pivot pins 4.1, 4.2, and 4.3. And in this same connection it will be noted particularly that the substantially vertical sides of the gaps 6.0 in drill pipe shoe members 6.1, 6', and 6'' (rather than the vertical slots 5 in the central body member 1) are the means of rotating the three arms 4, on which rolling cutters 2 are mounted on axle pins 3. The above mentioned rotation of arms 4 by means of the substantially vertical sides of exactly duplicating gaps 6.0 (provided with very slight angles of the sidewalls thereof to permit easy entrance of arms 4 therethrough) in the drill pipe shoe members 6.1, 6', and 6'' affords a very strong means of mounting the three arms 4 and their respective rolling cutters 2 (which together have to disintegrate rock of approximately the same quantity as that of the pilot hole PH previously drilled by the coring mechanism, to be described later herein) very largely (and even almost completely) in those strong drill pipe shoe members themselves in the drilling process. Note this particularly in FIG. 2, in which it can be seen that the substantially vertical walls of those gaps 6.0 in the drill pipe shoe members extend down even below the lower tips of the arms 4; and in FIG. 1 it is indicated schematically by the perspective side view that the vertical sides of all three of those arms 4, in whose lower cavities rolling cutters 2 are rotatably mounted on pivot pins 3 on which the cutters 2 are rotatably mounted, extend down approximately as far as the axes of their respective mounting pins 3 of the respective cutters 2, although that fact is not so evident in cross-sectional FIG. 2 showing the same arm 4 shown in FIGS. 1 and 3 with its pin 3 mounting rolling cutter 2 in its outwardly hinged posture (with the adjusting plate 4' at least almost in contact with the arcuate roof of the gap 6.0 in the drill pipe shoe and with the rolling cutter 2, swinging outwardly on a greater radius from pivot pin 4.1 of arm 4, only a short distance from the outer cylindrical wall of the hole being enlarged beneath the drill pipe shoe members, when the three arms 4 are fully hinged outward.

Again note particularly in FIG. 2 that the bottom face of the enlarged section of the hole being drilled in the earth by the rolling cutter 2 (operating in conjunction with the other two such rolling cutters 2 mounted respectively on arms 4 pivotally hinged on pins 4.2 and 4.3 and describing overlapping annular paths for disintegration of the rock formation beneath all three of said cutters 2) slopes upward toward the outside wall of that enlarged hole (in which the drilling mechanism is illustrated as being reinserted), which said upward sloping of said bottom face of the enlarged hole is a result of the conical cutting faces of the three cutters 2 mounted on arms 4 of different lengths in corresponding slots 5 on hinge pins 4.1, 4.2, and 4.3 at suitable differing elevations in the body member 1. And in this connection it will be noted also that, in drilling in soft unconsolidated rock materials such as sedimentary shales, all three of the rolling cutters 2 (having somewhat conical outer cutting faces as indicated schematically in FIGS. 1, 2, and 3) will tend to simply pack such soft shales outwardly to some extent, so that the resultant packing of the disintegrated soft shale rock material will tend to reinforce the vertical sidewalls of the enlarged hole being drilled in the earth. Such soft or unconsolidated rock formations are easily penetrated by my drill mechanism, however, for the underreaming rolling cutters 2 tend simply to bury themselves quite readily into said rock formations, in the process of which the drilling fluid coming down through the drill pipe 11 (under considerable pressure by the conventional pump at the head of the well, as is well known in the art) and through canal 1.0 in the center of body member 1 to travel on downward through the coring mechanism (to be described later herein), after which said drilling fluid (together with any such fluid emerging around prod pins 7' in holes 7 in body member 1 and around said body member 1 within the drill pipe shoe) rises upward around the lower cylindrical section 1.1 of central body member 1 (FIGS. 2 and 4) in the pilot hole PH and then outwardly (somewhat radially) between the rolling cutters 2 to carry upward the disintegrated rock materials, whether they be soft or hard and depending on the nature of the rock layers being penetrated. While the lower edges of the once cylindrical tubular members 6.1, 6', and 6'' of the drill pipe shoe (in which gaps 6.0 have been formed in the lower margin thereof) obviously might be otherwise serrated alternatively in any way desired to make them serve as an auxiliary agitating means for moving the unconsolidated rock materials into which said rolling cutters 2 had penetrated, this is not necessary. In FIG. 2 it is indicated that the lower edges of all three of the drill pipe shoe members 6.1, 6', and 6'' are made to extend down (except for the gaps 6.0 in the lower margins thereof) substantially to the respective levels of the cutting faces of the three rolling cutters 2, so that one of the vertical sides of each of those gaps 6.0 will serve as a rotating means of agitating the rock materials into which the teeth of the respective rolling cutters 2 have penetrated. And the lower tip of that vertical side of each of the gaps 6.0, into which the arms 4 mountir.g rolling cutters 2 are hingeable, conveniently may be hardened by application with an oxygen-acetylene torch of tungsten carbide as is well-known in the art under the names of studite and stellite or ferrotungsten carbide), so that the downward protrusions of the drill pipe shoe between gaps 6.0 therein will withstand such continued agitation of the disintegrated rock materials, which will be carried away anyway primarily by the drilling fluid flowing outward radially from the lower smaller cylindrical section 1.1 (of body member 1) in the pilot hole PH being drilled as will be described later.

Note, however, in FIG. 2 that the body member 1 fits not too tightly in the serrated cylindrical guiding member 6.1 for easy installation repeatedly in the drill pipe shoe, which the driller can leave substantially at the bottom of the enlarged hole shown as being drilled by the underreaming mechanism. Some of the drilling fluid being forced downward under pressure through the drill pipe 11 can be forced on downward alternatively between the generally cylindrical body member 1 and shoe member 6.1 immediately adjacent the floor of the enlarged hole being underreamed to act almost like a circular jet. But it will be appreciated that some such drilling fluid being expelled downward between body member 1 and the shoe member 6.1, having three gaps 6.0 in the lower margin thereof, will tend to escape around the arms 4 disposed in those gaps of the drilling shoe and then to sweep any disintegrated rock cuttings away from the rolling cutters 2 hingeably mounted in those gaps 6.0, from which all said cuttings will be carried upwardly by the combined streams of drilling fluid around the drill pipe shoe as indicated by the arrow F in FIG. 2. In this same connection, it is illustrated in FIG. 2 that the cylindrical rods 7', which force the lower tips of all three arms 4 out into the gaps 6.0 in the lower margins of shoe members 6.1, 6', and 6'', fit loosely and slidably in their respective cylindrical holes 7' in body member 1, so that some drilling fluid flowing downward through drill pipe 11 and thence through canal 1.0 of body member 1, under pressure of the pump at the well head, will escape around those cylindrical prod rods 7' to merge with the other drilling fluid sweeping across the generally conical floor of the enlarged hole and around the three rolling cutters 2 to sweep all the disintegrated rock segments upward around the drill pipe shoe as indicated immediately above. But note in FIG. 2 that, when the drill pipe shoe members are lowered with drill pipe 11, until the lower cutting face of rolling cutter 2 reaches the bottom of the enlarged hole, the lower protrusions of the drill pipe shoe between its gaps 6.0 will be almost in contact with the said bottom of the enlarged hole, thereby forcing the drilling fluid to travel outward on said hole bottom at a suitably high rate of speed to sweep the rock cuttings outward radially between the teeth of the rolling cutters 2.

Obviously suitable variations as to length and angle of deviation of arms 4 from the vertical rotational axis of central body member 1 may be made in order to vary the diameter of the enlarged hole within limits; and some changes may be made suitably in the mountings of rolling cutters 2 on arms 4 without departing from the principles of my invention. In FIG. 2 it is indicated that, in order to lubricate the antifriction bear-

ing mounted in rolling cutter 2 around the cylindrical midsection of axle pin 3, there is formed in the outer tip of that axle pin 3 a polygon shaped cavity, in which can be inserted a correspondingly formed wrench tool for screwing the male threads on the inner tip of that pin 3 into the correspondingly threaded female cylindrical hole in the lower tip of arm 4, whose lower inner surface is formed at a suitable angle with respect to the remaining inner surface of that arm 4 for slidable accommodation thereon of the upper tip of adjusting prod pin 7. And in that polygon shaped cavity in the outer tip of axle pin 3 is installed a grease inserting tip (such as is well known in the art, as previously explained) for pressure insertion of grease through a suitable very small canal in said axle pin 3 leading to the antifriction bearing cavity for lubrication of that bearing. But the only requirement of that bearing is that it be of a nature on which to impose the weight of the drill pipe (except in so far as that weight is carried in part by the swivel sustained by the derrick or mast pole at the head of the well) directly on the three rolling cutters 2, in order that their cutting faces of "teeth" on rotation of the drill pipe at moderate speed will cause them to "dig" into the hard rock formations very slightly for disintegration of the surfaces of those rocks into small segments, in much the same way that the bit of a percussion pneumatic core drill can be made to disintegrate a rock in a hole of reasonable depth by many small strokes of its air-actuated reciprocating hammer on one end of the drill rod having somewhat similar "teeth" on the other tip thereof. Many variations of such "teeth" on rolling cutters of various kinds have been employed effectively in the oil fields for many years to disintegrate hard rock formations at the bottoms of the holes being drilled in those fields.

Therefore, in order to emphasize diagrammatically the conical configuration of the rolling cutters 2 disposed exactly opposite to the conventional disposition of such conical rolling cutters in general not resembling my relatively narrow such rolling cutters 2 in other respects, I have illustrated in FIG. 1 that the "teeth" of the rolling cutter 2 are simply "chisels," which vary somewhat in shape from each other conveniently and in disposition with respect to the axis of rotation on axle pin 3. In this connection, as has been indicated previously above, it is particularly notable that rolling cutters 2 are made smaller in diameter at their outside faces than at their inner faces thereof adjacent the respective arm 4. This disposition of my rolling cutters 2 (primarily to increase the size of rolling cutters 2 that will slip downward into my drill pipe 11 remaining in the hole is exactly opposite to the previous dispositions of conical rolling cutters by others in the drilling of holes in hard rocks, as explained previously above for their rolling cutters (operating on the bottom of the hole being drilled) have been designed by their manufacturers to minimize abrasive wear of the rocks on the cutting surfaces of their conical rolling cutters, which have had to be removed from the hole for renewal thereof by unscrewing the many joints of the drill pipe from the hole. But my disposition of my rolling cutters 2 (with their smaller diameters adjacent the outer wall of the cylindrical hole being drilled, as indicated in FIGS. 1, 2, and 3) actually causes the chisel teeth shown in FIG. 1 to drill more rapidly into the rock formation, which is disintegrated by the very slightly "twisting" chisels of the rolling cutters 2, on which wear is not too excessive, however, because it will be noted that the cutting faces or "chisels" of the rolling cutters 2 shown in FIG. 2 are only about five-eighths of an inch long. And, if it were necessary for me to underream an annular swath of more than 1½inch width by each of those cutters 2, it probably would be entirely impractical because of the excessive wear on the "chisels" of that width disposed as indicated in FIGS. 1, 2, and 3, even though it is comparatively easy to crumble off the wall of the pilot hole PH immediately adjacent the upper end thereof. But again it should be noted that disposition of my hinge pins 4.1, 4.2, and 4.3 in body member 1 at different levels makes the rolling cutters 2 mounted on the lower tips of arms 4 hinged on those pins respectively cut an annular swath only about one-third as much, because those three rolling cutters 2 screwed. in series to underream the drill pipe shoe and enlarge the hole required therefor instead of having each of the three rolling cutters traverse the same annular path at the bottom of the enlarged hole surrounding the pilot hole PH.

While those cutting faces of my rolling cutters 2 may be in the configuration of multiple continuous chisels (as illustrated schematically in the conical rolling cutter shown in FIG. 1 for ease of illustration), it obviously is possible alternatively to serrate each of those chisels as indicated in FIG. 2 (showing irregular serrations of two such "chisels") in order to reduce the area on which downward pressure is exerted by the rolling cutter at any moment for pulverizing the rock formation, whose surface is disintegrated very slightly by the increased number of smaller "teeth," which of course can be machined prior to heat treatment to make them become staggered as illustrated in FIG. 2.

The rolling cutters 2 may be made of any of the steel alloys known to the art for drilling hard rocks. And their worn teeth may be replaced by use of an oxygen-acetylene torch to install tungsten carbide (stellite or studite) on the surfaces thereof, which do not have to be maintained with the sharp contact lines shown in FIG. 1, but which drill more rapidly with less vertical pressure when they have rather sharp surfaces, whose moderately sharp configurations can be maintained readily on my drilling mechanism because of the ease with which my drilling mechanisms can be removed from the hole at frequent intervals (in the simultaneous process of recovering rock cores of the formations penetrated by the means to be described later herein) by means of a wire line cable without necessity for unjointing the drill pipe for its removal from the hole for any purpose whatsoever.

While in FIG. 2 there is illustrated an antifriction bearing of a variety having tapered rollers, whose axes of rotation between their inner and outer races are quite obvious, and which can withstand great pressure from above on the rolling cutter 2, I alternatively of course can employ ball bearings mounted between corresponding races just as well-known to the art; and such ball bearing assemblies, having seals that preclude any necessity for added lubrications and that prevent any infiltration of grit into the cavities therein, have been readily available on the markets for years. It will be noted in FIG. 2, however, that I have illustrated an annular leather seal around the spacing washer installed between the inner race of the tapered roller bearing and the arm 4 into which the axle pin 3 has been screwed. Likewise I have illustrated a small felt washer installed between the outer race of that tapered roller bearing and the axle pin 3, on which the rolling cutter 2 carrying that bearing's outer race is mounted. Such seals are well known to the art and therefore are only illustrative. For replacement of said seals, the antifriction bearings themselves (whether of the tapered roller, spherical ball, or simple cylindrical roller variety well-known to the art) or the rolling cutters 2, it is necessary only to grind out a spot weld at the lower inner tip of the axle pin 3, whereby said threaded tip of that pin 3 is held securely screwed into the arm 4 in which it is mounted, unscrew the pin 3 from the arm 4 and then make any necessary replacements in the bearing or its rolling cutter 2, after which the axle pin 3 can be rescrewed into the arm 4, to which it again can be joined securely by means of another spot weld at the same place, although it of course would be possible alternatively to simply weld into arm 4 a snugly fitting cylindrical inner tip of an axle pin 3 without the threads illustrated diagrammatically in FIG. 2.

One of the extreme handicaps of other underreaming devices now employed (for reaming out an inadequate hole to make it large enough to install casing in holes drilled for producing oil) is that such previous underreamers tend to bore out crooked (usually corkscrewlike) holes in the strata of sedimentary rocks of different hardness at different depths, said underreamed holes often being so crooked that it is sometimes impossible to install a continuous string of casing without causing impossible stresses therein, if indeed such casing can

be installed at all. This handicap is overcome by the nature of my invention for the following reasons. In FIG. 2 it can be seen that only the lower face of the rolling cutter 2 will come in contact with the rock formation being penetrated by it, for it may be noted that the lower outer face of that rolling cutter is at a slight angle with respect to the vertical wall of the cylindrical hole that already has been bored above the pilot hole PH, even before the adjusting plate 4' of the arm 4 hinging on pivot pin 4.1 has been hinged out completely against the arcuate roof of the gap 6.0 in the drill pipe shoe members 6.1, 6', and 6'', all of which are rigidly attached to the internally threaded shoe member 6 screwed onto the lower tip of the drill pipe 11, as explained previously. But the actual configuration of the somewhat conical outer face of all three of those rolling cutters 2 is determined primarily by the necessity of making those cutters 2 slip freely downward through the serrated inner cylindrical tubular member 6.1 of the drill pipe shoe, as indicated in FIG. 3 by broken lines to show the retracted position of rolling cutter 2 below the upper approximate half of arm 4 (FIG. 2) shown in FIG. 3 as having a curved cylindrical outer surface, that will just freely slip through said cylindrical tubular serrated guiding member 6.1, which is shown in FIG. 3 as having three gaps 6.0 therein, into each of which the respective arm 4 will be hinged outwardly as shown in FIG. 2, when the serrated guiding member 1' attached to central body member 1 travels downward through the tubular cylindrical member 6' the maximum distance to bring that serrated guiding member 1' into complete cooperation with the inversely serrated guiding shoe member 6.1 (finally blocking passage of guiding member 1' fixedly attached to body member 1 from further downward passage of the body member 1 through the drill pipe shoe), thereby simultaneously permitting all three of the arms 4 to hinge out into their respective gaps 6.0 of the drill pipe shoe members 6.1, 6', and 6'', although the shortest arm 4 shown in FIG. 2 swings outward into its respective gap 6.0 (an exact duplicate of the other two gaps 6.0, however) to a slightly greater angle from vertical than does the arm 4 mounted on pivot pin 4.2, which in turn swings outward slightly more into its respective gap 6.0 than does the still longer arm 4 mounted on pivot pin 4.3 (both of which are indicated by broken lines in FIG. 3). But any one of the three arms 4 can swing outwardly into any one of the duplicate gaps 6.0 in the drill pipe shoe members 6.1, 6', and 6'', when the serrations of guiding members 1' and 6.1 are brought into complete cooperative contact limited by maximum downward movement of the body member 1, on which cylindrical guide member 1' is rigidly mounted. And, regardless of the outward angles of disposition of the three arms 4 with respect to the rotational axis of the drill mechanism (as determined by the respective adjusting plates 4' of different thickness in contact with the arcuate roof of their particular gap 6.0 at that installation), the three rolling cutters 2 will be kept extended outward at just the proper angles to drill a perfectly enlarged straight hole, because the position of body member 1 will be kept in perfect alignment with the lower pilot hole previously drilled by the lower core drilling mechanism, to be explained later herein.

Since, as indicated previously, the only appreciable strain on the three pivot pins 4.1, 4.2, and 4.3, mounted horizontally in central body member 1 (at different heights therein) and extending through arms 4 hingeable in vertical slots 5 thereof (as illustrated in FIGS. 3, 2, and 1 by broken lines) is in pulling those arms 4 upward into the drill pipe shoe for removal of the entire drilling mechanism (except the shoe attached to the lower tip of the drill pipe 11) through the drill pipe (by means of a cable, as will be explained later herein), those three pivot pins mounting hingeable arms 4 respectively may be made even less than one-half inch in diameter, in order to give increased strength to central body member 1 for its rotation of the coring mechanism below FIGS. 1 and 2 by means of its lower cylindrical segment 1.1 shown in FIG. 2, as will be explained presently. Pulling the drilling mechanism upward through drill pipe 11 tends to keep arms 4 retracted into slots 5 in body member 1. But note again that, in order to keep the arms 4 and their rolling cutters 2 retracted into their respective vertical slots 5 in body member 1, when the drilling mechanism is being reinserted through the drill pipe 11 for installation of arms 4 in the gaps 6.0 of drill pipe shoe members 6.1, 6', and 6'', there are provided narrow recessions at each side of the upper tip of each of the arms 4 in which are mounted horizontally disposed U-shaped small resilient springs 414 (FIGS. 1, 2, and 3) inserted around the respective hinge pivot pins 4.1, 4.2, and 4.3 to keep those arms 4 always vertically retracted into the respective vertical slots 5 in body member 1, until those arms 4 are acted upon by other forces (such as the hydraulically actuated prod pins 7' in cylindrical holes 7 illustrated in FIGS. 2 and 3), after body member 1 has reached its extreme lower position in the drill pipe shoe, that is screwed on the lower threaded tip of drill pipe 11 and finally limits downward movement of body member 1 in that drill pipe. Note particularly that it is not necessary to lower my drilling mechanism through the drill pipe 11 by means of attaching it to a restraining cable, since the drilling fluid in that drill pipe will tend to limit undue downward speed of said drilling mechanism almost filling said cylindrical drill pipe without need for restraint in falling by means of a cable.

Drill pipe 11 may be kept suspended in the hole being drilled from the top thereof to keep its shoe members 6.1, 6', and 6'' as well as my drilling mechanism installed therein continuously from descending all the way to the bottom of the enlarged hole, in which event increase of the pressure of the drilling fluid in said drill pipe (through a swivel well-known in the art of drilling such wells), by means of the conventional pump adjacent the well head, will cause the adjusting prod rods 7' slidable in cylindrical vents 7) of body member 1 (FIGS. 2 and 3) to cause arms 4 to be extended outward hingeably into gaps 6.0, even before the rolling cutters 2 reach the annular shoulder of the rock formation to be drilled out by them. But, even without necessity for turning on pressure of said pump into the drill pipe 11 as a means for extending arms 4 outward by means of their respective tilt adjusting rods 7' in vents 7, I have provided another alternative means for forcing outwardly the lower tips of arms 4 mounting cutters 2 into gaps 6.0 of the drill pipe shoe. Note particularly in FIG. 2 that, alternatively, continued upward pressure of the vertically disposed conical-tipped cylindrical pushrod 8.1 (mounted slidably between the inner wall of arm 4 and the adjacent central wall of the vertical slot 5 of central body member 1) also will cause the lower portion of pivotally mounted arm 4 to hinge outward on its pivot pin 4.1 in vertical slot 5 of the body member 1 and into the gap 6.0 of said drill pipe shoe, until the adjusting plate 4' of that arm 4 is forced against the movement limiting arcuate roof of said gap 6.0 in shoe members 6.1, 6', and 6''. The cylindrical pushrod 8.1 shown in FIG. 2 is one of a pair of duplicate such pushrods 8.1 mounted in the inner corners of that vertical slot 5; and similar such pairs of vertical pushrods 8.1 are mounted in the other two vertical slots 5 of central body member 1, as is illustrated in FIG. 3 by the broken line circles 8 indicating the vertical cylindrical holes 8 in said body member 1 beneath those respective slots 5 therein, and as indicated in horizontal cross-sectional FIG. 4 at line 4–4' of FIG. 2. While each of the two pushrods 8.1 beneath one of the arms 4 is of the same length as the other one of that pair, each of the pairs of pushrods 8.1 would be of slightly different length in order to accommodate the arms 4 mounted on hinge pivot pins 4.1, 4.2, and 4.3 at three different heights for reasons previously explained above, for it is indicated in FIG. 5 by broken lines for two of those rods 8.1 that all of the six such vertical pushrods 8.1 have their lower ends mounted at the same level in arcuate hemicylindrical slots 9.1 in the outer wall of an inner cylindrical tubular member 9 of smaller outside diameter (See FIGS. 5, 6, and 7), which is vertically slidable with respect to its larger telescoping segment 1.1 of body member 1 within limits and is one tubular part of a novel means connecting the lower tubular cylindrical segment 1.1 of body member 1 with the upper part

of the lower pilot hole drilling mechanism to be described presently. Pushrods 8.1 are held down against the lower ends of arcuate slots 9.1 of generally cylindrical tubular connecting member 9 by cylindrical keys 8.2 inserted quite snugly through horizontal holes in the respective cylindrical vertical pushrods 8.1 and into corresponding horizontal holes in the generally cylindrical tubular connecting member 9, in order that, when the shoe 6 on drill pipe 11 is raised slightly from the bottom of the hole (preparatory to pulling the entire drilling mechanism upward through that drill pipe 11), the weight of the pilot hole drilling mechanism attached to the lower tip of connecting member 9 mounting the lower tips of pushrods 8.1 will pull all those rods 8.1 downward simultaneously in their respective holes 8 in body member 1 and its lower cylindrical segment 1.1 by means of horizontally disposed keys 8.2, until the upper tips of those six vertical pushrods 8.1 disappear entirely from the three vertical slots 5 in that body member 1, thereby enabling the lower tips of arms 4 mounting rolling cutters 2 on axle pins 3 to hinge inwardly into said slots 5 on their respective pivot pins 4.1, 4.2, and 4.3 as a result of the inwardly restraining actuation of the small U-shaped resilient springs 414 augmented by upward pulling of a reel on a cable attached to the drilling mechanism by means to be described later herein.

When vertical pushrods 8.1 are drawn down entirely out of vertical slots 5 in body member 1, the three arms 4 (mounting rolling cutters 2 on the respective lower parts thereof) can recede entirely into those slots 5 to permit free passage of the drilling mechanism through the drill pipe 11. But, when the drilling mechanism is reinserted in the drill pipe shoe through that drill pipe 11, and when that drill pipe 11 is lowered until the pilot drill reaches the bottom of the pilot hole PH drilled by it previously, the conical upper faces of all the vertical pushrods 8.1 (indicated by the one such vertically disposed pushrod 8.1 shown in FIG. 2) immediately come into contact with the diagonally disposed bottom faces of the lower tips of the three arms 4, so that the lower portions of those three arms 4 and their respective rolling cutters 2 mounted rotatably thereon are held fixedly by the upper tips of the vertically disposed cylindrical pushrods 8.1 (immediately below the conical upper tips of those pushrods) inserted between the inner walls of their respective cavities 5 and the inner walls of arms 4. Because the upraised tips of vertically disposed pushrods 8.1 (immediately below the conical segments thereof) are inserted between the rigid vertical inner walls of the three cavities 5 and the diagonally disposed inner walls of the respective arms 4, it is not necessary that the pair of such pushrods 8.1 holding each arm 4 and its adjusting plate 4' rigidly against the arcuate roof of the respective gap 6.0 be as large in diameter as the five-eighths inch diameter rod 8.1 shown in FIG. 2; and obviously making the six vertical holes 8 in lower segment 1.1 of central body member 1 slightly smaller than shown would add strength to that body member 1.1 shown in FIGS. 4 and 5. It has been indicated above that the six such vertical pushrods 8.1 (inserted in holes 8 in body member 1 and its lower cylindrical segment 1.1 having an outside diameter of 5 inches) are a means of holding arms 4 outward rigidly in gaps 6.0 of the drill pipe shoe as an independent means alternative to hydraulic actuation by the drilling fluid of the three diagonally disposed adjusting rods 7' inserted slidably in their respective cylindrical holes 7 in body member 1 immediately below the midpoints of vertical slots 5 as illustrated in FIG. 2.

But in FIG. 4 it is further indicated that the vertically disposed pushrods 8.1 inserted in holes 8 of body member 1 may operate entirely independent of hydraulically actuated diagonally disposed adjusting rods 7' in their respective cylindrical holes 7 in body member 1, for in that FIG. 4, which is a horizontal cross section of FIG. 2 at its line 4–4', the three holes 7 have not been shown midway between the widely spaced pairs of holes 8 for accommodation of vertically disposed rods 8.1 slidable therein. When the three hydraulically actuated hinge adjusting rods 7' are employed in the diagonally disposed holes 7 in body member 1 as illustrated in FIGS. 2 and 3, it is particularly notable in FIG. 5 that another means is available to keep arms 4 locked in their outward postures in respective gaps 6.0 of the drill pipe shoe members 6.1, 6', and 6''. From horizontal cross-sectional FIGS. 6 and 7 in conjunction with FIG. 5 it can be seen that the generally cylindrical tubular member 9, serving to connect lower cylindrical segment 1.1 of body member 1 to the upper member 10' of the lower pilot hole drilling members to be explained later herein, has an upper cylindrical tip 9.2 of smaller diameter than its central body section. And this upper cylindrical tip 9.2 of connecting member 9, which has a central vertical canal 9.0 (of about the same diameter as vertical cylindrical canal 1.0 through body member 1) extending entirely therethrough, has the upper end of that upper tip 9.2 rounded hemispherically, so that drilling fluid may flow most readily into canal 9.0 of connecting member 9 at all times from canal 1.0 through body member 1, and so that, when the three pins 7' are forced outwardly by hydraulic pressure in canals 7 on the drilling fluid to the maximum extent, and when the pilot drill reaches any sediment in the bottom of its pilot hole (on reinsertion therein) and thereby forces connecting member 9 upwardly into the larger cylindrical cavity in lower cylindrical segment 1.1 of body member 1 (locked by means to be explained later herein in the show of the drill pipe 11 being lowered into the hole just a little above its previous lowest level) by the maximum distance (as illustrated in FIG. 5), the inner ends of diagonally disposed hinge adjusting rods 7' will be locked outwardly in their diagonally disposed cylindrical holes 7 (shown in FIG. 2 as being halfway between vertical and horizontal) by virtue of the fact that the adjacent inner ends of rods 7' will be tangential to the outer halves of the hemispherically rounded upper end of the cylindrical tubular upper segment 9.2 of generally cylindrical tubular connecting member 9. Thus even moderate pressure of body member 1.1 downward on cylindrical member 9 (rigidly connected to the pilot hole drilling mechanism at the bottom of its pilot hole) will keep the rolling cutters 2 mounted on arms 4 disposed at suitable distances from the rotational axis of the drill pipe shoe to ream the pilot hole out to substantially constant proper size, even if the angle of deviation of arms 4 and their respective rolling cutters 2 from said rotational axis were not completely sufficient to accomplish that purpose, for any inward pressure on one of the adjusting rods 7' is opposed by the other two rods 7' acting on the hemispherically rounded upper end of cylindrical tubular upper segment 9.2 of connecting member 9.

It will be noted in FIG. 5 that I have shown two adjusting rods 7' diametrically opposed, in order to illustrate that the same general arrangement can be employed alternatively in forcing outward corresponding hingeably mounted arms 4 mounting industrial diamond cutting means employed in lieu of the rolling cutters 2 illustrated in FIGS. 1, 2, and 3, as will be explained later in connection with FIGS. 24 and 25.

But, even without the opposing forces on strong cylindrical tubular upper segment 9.2 of connecting member 9 by the several adjusting prod rods 7' holding the lower tips of arms 4 and their respective cutters mounted thereon (whether industrial diamonds as illustrated schematically in FIG. 24 or rolling cutters as indicated in FIG. 2), it is indicated in FIGS. 5, 6, and 7 that, while the strong tubular connecting member 9 and its integrally attached upper segment 9.2 of smaller outside diameter are quite easily slidable vertically with respect to the strong telescoping tubular lower segment 1.1 of body member 1, the spacings between the several integral segments of generally cylindrical tubular connecting member 9 (having differing outside diameters) are meant to be close enough in actual construction that the strong tubular connecting member 9 (and the lower pilot hole drilling mechanism rigidly attached by means of bushing 10' to the lower conical tip 9.3 thereof by suitable large tapered tool joint threads, several types of which are well-known to the art and are indicated only diagrammatically in FIG. 5) is kept always in perfect alignment with the tubular cylindrical lower segment 1.1 in-

tegrally attached to its body member 1, which in turn is kept in perfect alignment with drill pipe 11, as will be more fully explained later herein in connection with upper features of that tubular body member 1 substantially filling drill pipe 11 and its shoe members rigidly attached by suitable threads to the lower tip thereof.

It can be seen in FIGS. 6 and 7, however, that (in addition to their service in holding arms 4 hinged outwardly in gaps 6.0) the vertical pushrods 8.1 (mounted fixedly by means of horizontal pins 8.2 on the largest outside diameter midsection 9.4 of tubular cylindrical connecting member 9 in its six corresponding hemicylindrical keyways 9.1) simultaneously serve as means keeping tubular connecting member 9 from rotating with respect to lower cylindrical tubular segment 1.1 of body member 1, for in FIG. 7 it can be seen that the telescoping outer tubular body segment 1.1 has in its interior generally cylindrical wall six inversely corresponding hemicylindrical keyways, which are only downward extensions of the cylindrical keyways 8 shown in FIGS. 6 and 4, and which extend on upward into the three vertical slots 5 as indicated in FIGS. 2 and 3. In fabrication of the generally cylindrical tubular central body member 1 having a lower cylindrical tubular segment 1.1 it appears necessary to bore first the six vertical keyway holes 8 (from what later will become the lower end of tubular lower cylindrical segment 1.1) in a cylindrical block of steel having an outside diameter of approximately 6 inches, which later (after the boring of holes 8) in an engine lathe for reaming out the central canal 1.0 (bored through the center thereof) to make that expanded canal fit suitably the tubular connecting member 9 having outside diameters as indicated in FIGS. 6 and 7 at lines 6–6′ and 7–7′ of FIG. 5, thereby leaving the vertical hemicylindrical keyways in lower segment 1.1 of body member 1 as indicated in FIG. 7. Likewise the convenient (but not necessarily only) way to fabricate keyways 9.1 in the outer wall of tubular cylindrical connecting member 9 is simply to bore vertical holes (disposed just as are the six exactly corresponding vertical holes 8 shown in FIG. 6) from above into a tubular cylindrical block of steel having an outside diameter at least 4¾ inches, which then (after the holes for keyways 9.1 have been bored) can be turned down in a lathe to a diameter of 3⅞ inches to leave the hemicylindrical keyways 9.1 shown in FIG. 7. (The six keyways 9.1 do not have to be perfectly cylindrical, however; and they can be formed with any suitable cross section on a milling machine.) But, since there is a tendency for a long bit boring the holes 8 to deviate from a straight hole, it is necessary that the holes 8 be made slightly oversize with respect to the diameters of vertical pushrods 8′ to be inserted slidably therein later to serve as a vertically disposed paired adjusting rods for hingeable arms 4 and to serve simultaneously as means whereby cylindrical body member 1 (fixedly mounted during the drilling process in the show of drill pipe 11) employs the connecting member 9 to rotate the pilot hole drilling mechanism to be described later herein.

After strong tubular connecting member 9 (together with the multiple vertically disposed pushrods 8.1 fixedly attached thereto by means of horizontal keys 8.2 in its hemicylindrical keyways 9.1) is inserted in the telescoping tubular body member 1 having the tubular cylindrical lower segment 1.1, whose lower tip of slightly less outside diameter than the remainder thereof is externally threaded, there is screwed onto that threaded lower tip an internally threaded collar 1.2 (FIG. 5), which keeps connecting member 9 from slipping out of lower tubular segment 1.1 of body member 1, because the lower half of collar 1.2 below the lower tip of said segment 1.1 has an internal diameter only very slightly in excess of the outside diameter of the lower half of said generally cylindrical tubular connecting member 9, which is about a quarter of an inch less in diameter than the midsection 9.4 thereof shown in FIGS. 5 and 7.

Thus it can be seen from FIG. 5, in which quite strong tubular connecting member 9 is shoved substantially all the way upward into segment 1.1 of body member 1 with its upper horizontal annular shoulder almost against the inversely corresponding horizontal annular shoulder in said tubular cylindrical segment 1.1, that, while connecting member 9 never can clip completely out of said lower segment 1.1 having the reduced collar 1.2 screwed on the lower tip thereof (thereby enabling the lower pilot hole drilling mechanism to be pulled from the hole being drilled by means of body member 1, as will be explained more fully later herein), at the same time connecting tubular member 9 (having an outer annular shoulder of midsection 9.4 thereon about 2½inches from the inner annular shoulder of reduced diameter collar 1.2 screwed on the lower tip of cylindrical lower segment 1.1 of body member 1) can be drawn downward by the weight of the lower pilot hole drilling mechanism sufficiently to make conical tipped vertical adjusting rods 8.1 (held fixed with respect to cylindrical tubular connecting member 9 by the respective small horizontal pins 8.2 inserted through those rods 8.1 and into corresponding holes in the respective keyways 9.1 in the largest outside diameter midsection 9.4 of connecting member 9) disappear entirely from the three vertical slots 5 in body member 1, one of which can be seen in FIG. 2.

It is to be understood particularly, however, that the hemicylindrical keyways 9.1 in the outer wall of midsection 9.4 of connecting tubular member 9 extend downward therein only to the lower ends of vertical adjusting rods 8.1 (See two such rods 8.1 in FIG. 5), which adjusting rods 8.1 therefore can be pressed upward with great force by the connecting member 9 (fixedly attached to the lower pilot hole drilling mechanism by means of tool-joint threads on the lower conical tip 9.3 of body member 9 screwed into adapter bushing 10′) as a result of vertical pressure by drill pipe 11 and body member 1 (held locked therein during the drilling process by means to be explained later herein), whose combined weight of course can be sustained in part, as desired by the driller, at the top of the hole by methods well-known in the art of drilling oil and water wells to great depths. Thus, while other alternative more complicated and less strong means may be employed to make connecting tubular member 9 vertically slidable within desired limits but nonrotatable with respect to the lower cylindrical tubular segment 1.1 of body member 1, the paired cylindrical pushrods 8.1 are a novel simple means of accomplishing those objectives, as described, while simultaneously being slidably mounted in the corresponding six vertical cylindrical holes 8 in that central body member 1 at a uniform suitable distance from the rotational axis thereof to serve simultaneously as a means of keeping the lower tips of underreaming arms 4 in vertical slots 5 shoved outwardly beneath their mounting hinge pivots into the respective duplicate gaps 6.0 of the drill pipe shoe serving as the ultimate limitation on such outward movements of the three arms 4 of the underreaming mechanism.

Immediately above the inner annular horizontal shoulder of internally threaded collar 1.2 shown in FIG. 5 may be seen the two round cross sections of an annular rubber ring (undesignated), which draws snugly against the cylindrical outer face of the midsection of the connecting tubular cylindrical member 9, thereby preventing the drilling fluid (under hydraulic pressure from the pump at the well head) from escaping outwardly between that collar 1.2 and the cylindrical section of connecting member 9 inserted therethrough, although some slight leakage of the drilling fluid at that point would only augment the drilling fluid passing downward through the central canal 9.0 into the lower drilling mechanism and thence upward around that mechanism to carry its cuttings upward around the drill pipe 11. Obviously other somewhat similar means may be employed under some circumstances to seal the spaces between the tubular cylindrical connecting member 9 and its telescoping tubular cylindrical segment 1.1 of central body member 1. For instance, in FIG. 5 a similar annular rubber ring of larger diameter is shown mounted around the upper shoulder of the cylindrical midsection 9.4 of generally cylindrical tubular member 9; and almost inside that larger diameter rubber ring (undesignated)

is a flat annular flexible washer (undesignated) shown above that shoulder intermediate said annular rubber ring and the rounded perimeter of the base of the smaller outside diameter upper section 9.2 of that tubular connecting member 9. But it must be observed that these two annular seals, at the upper end of the section 9.4 having the largest diameter at the mid-section of connecting member 9, cannot be employed, when pushrods 8.1 are installed in the holes 8 as a means of adjusting angles of arms 4 hinged in body member 1, for obviously those upper seals indicated in FIG. 5 would be in conflict with any of the six such pushrods 8.1 (as indicated by broken lines in FIG. 5). Those two upper seals shown in FIG. 5 therefore must be understood as being operable only when the prod rods 7' in diagonally disposed cylindrical holes 7 (See FIG. 2 as well as at the upper tip of FIG. 5) are utilized to adjust the respective arms 4 by hydraulic pressure.

In FIG. 5 immediately adjacent to the annular cylindrical collar 1.2, when the connecting tubular member 9 is in its upper position with respect to the lower cylindrical segment 1.1 of body member 1, is the horizontal annular upper face of a generally cylindrical tubular bushing 10' having external threads on its reduced lower tip, which threads are screwed into the internally threaded upper tip of a cylindrical tube (also having a 5 inch outside diameter), which is an outer drill pipe (sometimes called an "outer core barrel" in the oil field industries) of the pilot hole drilling mechanism shown in FIGS. 8, 9, and 10, which has means of recovering a small core of the formations penetrated from the center of that pilot hole. Since tubular connecting member 9, having suitable conventional tool-joint threads on the lower conical tip thereof, is always nonrotatable with respect to telescoping lower cylindrical segment 1.1 of central body member 1, it is possible to place one chain pipe tong (such as is well-known in the art) around segment 1.1 and another such chain pipe tong around bushing 10', onto which cylindrical steel tube 10 is screwed, in order to tighten and loosen said bushing 10' quite quickly on the tool-joint threaded conical lower tip of tubular connecting member 9. Thus the lower pilot hole drilling mechanism presently to be described may be attached to and detached from that tool-joint threaded conical lower tip of that connecting member 9 with great ease and speed.

The conventional steel pipe tubular cylinder 10, which is readily available on the market for other purposes, and which has an outside diameter of 5 inches for the present mechanism (to be inserted through a drill pipe having an outside diameter of 6⅝ inches), may be of any suitable length according to the practical length of the "rock core" that is to be recovered therewith at one insertion and removal of my drilling mechanism through said drill pipe 11. And it of course is possible alternatively to employ the upper portion of my drilling mechanism (consisting of the underreamer section thereof mounted on central body member 1 in the shoe that is screwed on the lower tip of drill pipe 11, to drill a hole in the earth continually (without recovering any core) to a desired total depth, for there can be installed quite quickly on the tool-joint-threaded conical lower tip 9.3 of connecting member 9 a female tool-joint attached by conventional means to a conventional rotary drill bit (long known to the art) of a suitable size to drill the pilot hole PH shown in the present drawings as being 5¼ inches in diameter, since that is approximately the largest size pilot drill that can be inserted readily through the serrated inner cylindrical tubular member 6.1 of the shoe mounted on the lower tip of drill pipe 11. Such a conventional rotary drill bit, having canals through the lower tip thereof for carrying to the rock cutting members the usual drilling fluid coming down through vertical canal 9.0 of connecting member 9, may mount on the lower tip thereof either conical rolling cutters (well-known to the art of well drilling for more than 50 years) or industrial diamonds (either natural or synthetic at slightly higher cost), which have been known in the mining industry for many years as a means of drilling much larger and deeper holes for the production of oil as a result in part of improved means of employing the drilling fluid under pressure in conjunction with improved canal designs for carrying it across the lower faces of the drill heads mounting such diamonds employed to "cut" rather than to disintegrate otherwise the rock being penetrated, either to recover a "core" of the sedimentary rocks in the manner long known for mining igneous rocks or alternatively to drill a full hole. But employment of a coring mechanism, operating in perfectly aligned conjunction with an underreaming mechanism such as that mounted in my central body member 1 retrievably installed in the gap 6.0 of the shoe screwed on the lower tip of drill pipe 11, is entirely new, whether the annular coring drill boring the smaller pilot hole be equipped with rolling cutters 2 as indicated generally in FIGS. 1, 2, and 3 or be equipped with industrial diamond mounting cutters such as the diamonds 100 in the lower tips of arms 4 illustrated in FIGS. 24, 25.

In either instance (and particularly in connection with a coring drill head mounting diamonds 100 on its lower tip 91.1 as shown in FIGS. 29, 30) it is necessary that the means connecting the lower pilot hole drilling mechanism to the lower tip of the drill pipe 11 be able to withstand very great amount of vertical pressure and resultant great torque around the rotational axis on said means connecting said lower pilot hole drilling mechanism to the lower tip of the drill pipe 11. And in this connection it may be noted from FIG. 5 that my steel alloy generally cylindrical tubular connecting member 9, having a maximum diameter only very slightly less than 4⅞ inches (for a drill of the size illustrated in my drawings for insertion through a drill pipe 11 having an outside diameter of 6⅝ inches) with its vertical cylindrical canal 9.0 for transmitting drilling fluid to the lower pilot hole drilling mechanism, is able to withstand tremendous vertical pressure of the drill pipe 11 on said lower pilot hole drilling mechanism. And in FIGS. 6 and 7 (together with FIG. 5) it can be seen that the six vertically disposed rods 8.1 (even if they had been only one-half inch in diameter instead of the nine-sixteenths of an inch shown in those drawings) inserted in the hemicylindrical keyways 9.1 of that connecting member 9 and in the corresponding keyways and holes 8 of the telescoping cylindrical lower segment 1.1 of body member 1 (also designed to withstand great torque for rotating the lower pilot hole drilling mechanism, although a major part of the underreamed larger hole is drilled by the cutters mounted on arms 4, which are rotated directly by the vertical sides of gaps 6.0 of the shoe members 6.1, 6', and 6'' of drill pipe 11) are quite adequate to withstand the very considerable torque on cylindrical tubular connecting member 9 operating in telescoped conjunction with the telescoping cylindrical tubular lower segment 1.1 of body member 1, which will be in the very closely associated position with respect to the connecting member 9 as shown in FIG. 5 during the process that requires such great strength for the telescoping tube 1.1 as well as the telescoped member 9.

A pilot hole drill bit having a coring mechanism employing rolling cutters therein, for recovering "cores" of suitable length of the rock formation remaining in the center of the hole being drilled, may require less torque on the member 9 connecting it to the lower tip of the lower drill pipe 11 than would a coring mechanism equipped with diamond cutters; but no one previously ever conceived a practical means of recovering a "core" from a hole drilled with rolling cutters for reasons that will be apparent from the following description of FIGS. 8, 9, and 10. From FIGS. 8 and 10, which show cross-sectional views at right angles to each other of the lower pilot hole drilling mechanism and the core recovering mechanism operating in conjunction therewith, it can be seen that the internally threaded lower tip of strong cylindrical tubular pipe member 10 (having an outside diameter of 5 inches and a wall thickness as required for necessary torque and compression strength, depending on its length and the nature of the steel alloy of which it is made) is screwed onto the upper threaded tip of the generally cylindrical tubular body member 12 of the lower pilot hole drilling mechanism (generally designated PCD for Pilot Core Drill), whereby the annular pilot hole PH is to be drilled around the core of rock R to be recovered by

means attached to the lower tip of a cable under circumstances to be explained later herein.

The upper face of body member **12** slopes down conically toward its vertical rotational axis, in order to facilitate frequent installation in the center of that body member **12** of a strong outer cylindrical core barrel **13**, whose lower externally threaded tip is screwed into a cylindrical cavity **12.0** at the center of that body member **12** having left-hand or counterclockwise threads that tend to tighten as a result of friction of the rock core R inside the core barrel **13**, when the pilot core drill assembly PCD is rotated in the hole clockwise from above by means of cylindrical pipe member **10** on rotation of drill pipe **11** above in the universal manner. The rock core R does not tend to impede rotation of the outer core barrel **13** directly, however, for there is loosely fitted inside said outer core barrel **13** a smaller telescoped inner cylindrical core barrel **14** made of rolled sheet metal and having a vertical slit at one side thereof to permit that frail inner core barrel **14** to expand slightly around the remaining rock core R, when the body member **12** settles downward around said core R by virtue of the annular disintegration of the rock around that core on rotation of the cutting members of the pilot core drill PCD. The inner core barrel **14** extends on downward almost to the bottom of body member **12** inside a vertical cylindrical hole therethrough, which is aligned with the core barrel **13** and has a diameter at its midsection **12.0'** equal to the inside diameter of said core barrel **13** to within a fraction of an inch of the bottom of body member **12**. Within a fraction of an inch of the bottom of body member **12**, the lowest section **12.0''** of that central cylindrical hole through body member **12** is reduced to a diameter only very slightly larger than the core R remaining after the annular section of the rock being penetrated by the pilot drill has been removed from the hole PH. At the plane of the last reduction of the diameter of the cylindrical hole **12.0'** through the midsection of body member **12** there remains a horizontal annular shoulder **12.1**, on which rests a suitable core-catching mechanism **15** shown in FIGS. **8** and **10** as being a short cylindrical ring made of strong spring steel and having approximately the same inside diameter as the lowest section **12.0''** of vertical cylindrical hole through body member **12**. Core-catching ring **15** has projecting upward from its upper face multiple strong resilient prongs **16** equally spaced from each other and having their upper tips drawn inwardly toward the rotational axis of the coring mechanism. But, on entrance of the core R into the core barrel **14**, the resilient spring prongs **16** can recede into corresponding notches in the lower margin of that core barrel **14** resting on the ring **15**, which conveniently may have a vertical slit in one side thereof to permit slight increase in its diameter to slip over the core R, just as does the inner core barrel **14**, which, however, does not have so much strength and resiliency as the cylindrical core-catching ring **15** of spring steel. Obviously, for recovering cores in rather soft rock formations, it would be possible to combine the ring **15** with its prongs **16**; but such prongs **16** made of ordinary metal such as the galvanized steel plate of core barrel **14** would not be sufficiently strong to break loose even a very small core about one inch in diameter (such as is indicated in FIGS. **8**, **9**, and **10**), when the core R is composed of a well consolidated rock like dolomite, limestone, or sandstone. Various kinds of core-catching devices have been known to the art for many years; and in FIG. **29** there is illustrated another kind of core-catching collar **95.1** (mounted in the conically swaged lower tip **93.1** of the lower segment **93** of core barrel **94**) for recovery of a core R of twice as great diameter in conjunction with an annular drill bit **91** mounting diamonds **100**, as will be explained later. Such conical collet core-catching devices have been known to the art for a half century and are quite successful in recovering cores of hard rock formations; but such a device is not necessary for recovering small cores in sedimentary rocks, and the required conical seat for such a collet core-catching device at the base of body member **12** shown in FIGS. **8**, **9**, and **10** tends to weaken slightly the lower tip of that central body member **12** mounting on axle pin **17** a rolling cutter **18** (FIG. **8**), which disintegrates the rock formation in an annular path immediately around the small core R.

Axle pin **17** mounting rolling cutter **18** is shown in FIG. **8** as being five-eighths inch in diameter at the central cylindrical section of said pin, around which is installed the inner race of a tapered roller antifriction bearing (generally corresponding to the antifriction bearings, spacing washers, lubricant seals, etc. in the mountings of the three rolling cutters **2** on larger axle pins **3** mounted in arms **4** of the underreaming section of my invention illustrated by FIGS. **1**, **2**, and **3**) having its rotational axis in axle pin **17** disposed at an angle of 30° from the horizon, so that the rolling cutter **18** actually tends somewhat to pack any soft material into the core R being recovered, if the rock formation being penetrated is unconsolidated and the core R therefore would be likely otherwise to disintegrate. The thread tapped hole in body member **12** in which the externally threaded inner tip of axle pin **17** is screwed very tightly extends inward just enough that there is a small connecting hole at its lower edge into the vertical hole **12.0'** of the body member **12**, so that a spot weld can be inserted through said small connecting hole onto the tip of axle pin **17**, which thereby is secured in body member **12**, until such time as it may be necessary to grind out the spot weld to remove axle pin **17** for any necessary repair of the bearings or renewal of the rolling cutter **18**, which of course might have its cutting faces rebuilt by installation of studite or stellite (tungsten carbide with an oxygen-acetylene (calcium carbide) torch. On the other hand, it can be seen in FIG. **8** that the cross- hatched pointed tip of the body member **12** adjacent the core R extends downward almost as far as the lower inner corner of the rolling cutter **18**; and in FIG. **10** the two corresponding tips **12.2** are not cross hatched to indicate that the lower tip of body member **12** is serrated to trim away any excess rock material from the core R, after any hard rock material has been disintegrated around that remaining core by rotation of rolling cutter **18**.

Note particularly, however, that the axle pin **17** mounting rolling cutter **18** in FIG. **8** is the only one of the four axle pins, mounting the four rolling cutters in FIGS. **8** and **10**, that is screwed into the body member **12**, which below the line **9–9'** in FIG. **8** (about 2 inches from the top, in the midsection thereof) is only about 3 inches in diameter, as is indicated in FIG. **9**. The other three axle pins **19**, **20**, and **21** are screwed into suitable faces in a lower annular generally cylindrical body member **12'**, which is held fixed with respect to upper cylindrical body member **12** by multiple means, so that, after the several parts of the drilling mechanism illustrated in FIGS. **8**, **9**, and **10** are assembled for installation in the lower tip of cylindrical tubular pipe **10**, body members **12** and **12'** become essentially one element, even though it is necessary to make them separate in order to install the quite strong means of recovering core R. Above the line **9–9'** the upper surface of annular body member **12'** is conical to fit the corresponding lower face of body member **12**, so that those two body members **12** and **12'** cannot move laterally with respect to each other, although they would be prevented from doing so also by the fact that the lower cylindrical section of body member **12** fits snugly into body member **12'**. In FIG. **10** are shown by broken lines multiple "half moon" keys **12''**, which serve to keep body member **12** from rotating with respect to body member **12'**; and in FIG. **8** alternative straight broken lines **12''** indicate that any suitable overlapping corrugations in the two adjacent conical faces of body members **12** and **12'** likewise may prevent any such rotary movement of one of those body members with respect to the other, just as straight flat keys in corresponding keyways might accomplish the same purpose alternatively. Both vertical and rotary movement of body member **12** with respect to body member **12'** is prevented by four bolts **12.3**, two of which are indicated by broken lines in FIG. **9** as passing through horizontal holes in annular body member **12'** and into correspondingly thread tapped holes in the outer wall of the lower inner cylindrical

body member 12. Obviously such horizontal holes for the four bolts 12.3 may be staggered as desired to miss multiple vertical holes 22, which extend downward through body member 12 for carrying drilling fluid under pressure to the bottom of the hole being drilled, and to miss likewise the vertical holes 23, which extend downward in alignment through both body members 12 and 12' for the same purpose. One such horizontally disposed bolt 12.3 has been shown in FIG. 8 by broken lines as extending through the annular lower body member 12' and into the adjacent vertical wall of inner cylindrical body member 12 at a suitable height in the midsection of that body member 12. That is a suitable position for said bolt 12.3 joining those two body members to have been shown in solid lines; but that bolt 12.3 has been shown in broken lines in order to indicate more clearly with a minimum number of drawings that the canal hole 23 is to pass all the way through body members 12 and 12'. In actual construction, however, the holes 23 are to be moved in position around the rotational axis of body members 12 and 12' just enough that holes 23 miss bolts 12.3 completely and almost at least do not come in contact with the cavities in the lower margins of body members 12 and 12', in which the four rolling cutters are mounted on their respective axle pins 17, 19, 20, and 21.

Likewise, while it of course is possible to make the vertical holes 22 pass through body member 12 immediately above at least some of the three rolling cutters other than rolling cutter 18, it is actually contemplated that these vertical canal holes 22 carrying fluid downward through body member 12 under considerable pressure will not eject that fluid directly onto those three rolling cutters, but will carry the drilling fluid downward farther to make it emerge as jets onto the bottom of the hole being drilled, since such jet action of the drilling fluid under pressure is very effective in aiding the drilling process, particularly in drilling unconsolidated rock materials, as is well-known in the art of drilling oil wells in such areas of recent geologic age.

In addition to the multiple horizontally disposed bolts 12.3 holding body members 12 and 12' rigidly together, tip threaded stud bolts 12.4 conveniently may be inserted diagonally from vertical through corresponding holes in the upper one third of body member 12 and into thread tapped holes in lower body member 12' as indicated by broken lines in FIG. 8 at places not in conflict with the canal holes 22 and 23 therein. It will be noted, however, that the horizontally disposed tip threaded stud bolt 12.3 illustrated in that FIG. 8 by broken lines as well as in FIG. 9 has a square hole in its head (for screwing its inner tip into the threaded hole in body member 12) and that this head of bolt 12.3 leaves a cavity in the outer wall of body member 12', which is one of several such shallow bolt cavities that may be employed conveniently in conjunction with a special wrench well known in the art to turn the combined body members 12 and 12' for screwing the upper tip of body member 12 into and out of the internally threaded lower tip of tubular cylindrical drill pipe 10.

In FIG. 10 it can be seen that the two substantially duplicate rolling cutters 24 are rotatably mounted on their respective diagonally opposed axle pins 20 and 21 by means of suitable antifriction ball bearings in those rolling cutters 24; and it is contemplated that these antifriction ball bearings will be of the kind now on the market that are so sealed that no further lubrication of the bearings is required, although it will be appreciated that plugs alternatively can be inserted in the free ends of those axle pins 20 and 21 to provide for easy and frequent lubrication of the bearings in rolling cutters 24 just like the plug shown in axle pin 17 for lubricating the tapered roller bearing shown in rolling cutter 18 in FIG. 8. The two rolling cutters 24 are mounted in cavities milled in the lower margin of outer annular substantially cylindrical body member 12' just large enough to accommodate those rolling cutters 24 mounted on tip-threaded axle pins 20 and 21 screwed into that annular body member 12' to rotate on axes at suitable angles from the horizon shown as 30° in FIG. 10, just as the axis of rolling cutter 18 around its axle pin 17 screwed into the lower tip of body member 12 in FIG. 8 is at a suitable angle of 30° from the horizon. But the process of disintegrating a hard rock formation at the bottom of the pilot hole PH is entirely different for the two rolling cutters 24 shown in FIG. 10 as mounted in outer body member 12' from the process of rolling cutter 18 mounted on axle pin 17 screwed into the lower tip of generally cylindrical body member 12 at the same angle of 30° from the horizon in FIG. 8. The two rolling cutters 24 shown in FIG. 10, which rotate around the same path with respect to the rotational axis of the drill mechanism and the core R in the center thereof, have to disintegrate a major portion of the rock in the bottom of the pilot hole PH, because that path almost an inch in width at the perimeter of the hole covers a major portion of the annular hole (slightly more than 5¼ inches in maximum diameter) that has to be drilled out by the four rolling cutters around the cylindrical remaining core R. But there is not undue wear on the cutting faces of the two rolling cutters 24, because the general configuration of those cutting faces is conical, so that those two rolling cutters 24, which have to travel greater distance around the bottom of the hole than the other two rolling cutters, simply roll around the axis of the central core R to disintegrate the rock formation in their common path by means of the multiple staggered teeth thereon. By way of contrast, the general configuration of the rolling cutter 18 mounted on pin 17 attached rigidly to the lower tip of body member 12 in FIG. 8 is almost cylindrical, although the many teeth of those cutting faces may give a slightly different impression; but it will be noted that the path traveled by generally cylindrical rolling cutter 18 (less than one inch in width in FIG. 8) is only a fraction as long around the immediately adjacent core R as the path of the two rolling cutters 24, whose axle pins 20 and 21 are mounted in outer annular body member 12' at angles of 30° from the horizon (just as is the axle pin 17 mounted in body member 12 in FIG. 8) but exactly opposite with respect to the wall of core R and the outer wall of the pilot hole PH disintegrated by those rolling cutters.

Yet all of those cutters have to have their free ends disposed away from the remaining core R or from the remaining outside wall of the pilot hole PH so that those free ends of the axle pins 17, 20, and 21 can travel in the annular groove carved out of the rock formation by the several rolling cutters in the pilot hole drilling mechanism. And it will be noted in FIG. 8 that still another axle pin 19 mounted fixedly in lower annular body member 12' (midway between the two pins 20 and 21 shown in FIG. 10) rotatably mounts a fourth rolling cutter 25, whose cutting faces have a generally somewhat conical configuration but at not such a radical angle of inclination with respect to the base thereof as do the rolling cutters 24 with respect to their respective bases shown in FIG. 10. Rolling cutter 25, which disintegrates an annular groove in the rock slightly below the other three rolling cutters to more than clear the path that otherwise would be left remaining between the path of inner rolling cutter 18 and the path of the two outer rolling cutters 24, has to have its rotational axis around its mounting axle pin 19 disposed at a considerably less angle with respect to the horizon than the other three pins 17, 20, and 21, in order that the rolling cutter 25 of suitable size and having its axle pin 19 mounted in the lower margin of body member 12' will not intrude too far into the telescoped body member 12 and thus leave insufficient material remaining around the central vertical hole therethrough to mount the core barrel and to sustain the inner tip of axle pin 17 mounting rolling cutter 18. In FIG. 8 the longitudinal axis of axle pin 19 has been drawn at the convenient angle of 15 degrees from the horizon, and the conical configuration of rolling cutter 25 has been made to correspond therewith, so that the rolling cutter 25 in its rotation around the axis of the drill mechanism around the core R will permit that rolling cutter 25 to accomplish a major portion of the necessary rock disintegration without undue wear on its cutting faces, which actually tend to crush the surface of the rock repeatedly and very effectively into small pieces less than one-eighth of an inch in diameter

instead of actually "cutting" the hard rocks in the same manner as do diamonds mounted on core drilling mechanisms, one of which will be explained later herein. Needless to say, such a coring mechanism employing rolling cutters **18**, **24**, and **25** to disintegrate the annular rock surface (in the continual process of rolling thereon) requires much less torque on the pipe **10** than would continuous "cutting" of a hard rock by a drill bit equipped with a head mounting many quite expensive diamonds, which are rather expensive to mount in the matrix of an oil well drilling bit, whether they be natural or synthetic stones. At present it costs about $500 just to mount the diamonds in such a matrix; and in the past it has been estimated that the cost of such a diamond mounted drill bit is about 20 times that of a corresponding steel bit, although there have been no "core drills" of the latter variety. It thus has been necessary that the diamond mounted drill bit make "hole" faster without such frequent removals of the drill pipe from the hole to replace the shorter-life steel bits with their "-conical" rolling cutters, to the initial cost of which had to be added the cost of loss of time for an expensive drilling rig, for which the cost of recovering many "core" segments was prohibitive, when the "drill string" had to be removed from the hole each time a core was recovered.

It is to be noted from FIGS. **8**, **9**, and **10** that in the lower half of the lower body member **12'** there is an outward protrusion **26** of said body member **12'** adjacent each of the four rolling cutters, whose axes are in planes at right angles to each other. And the drilling fluid carrying away the cuttings from the bottom of the pilot hole PH passes upward between these protrusions, into which extend the outer threaded tips of the axle pins **19**, **20**, and **21** just far enough that the outer tips of those pins can be spot welded through those outward protrusions **26**, which extend outward almost to the vertical cylindrical wall of the pilot hole PH and thus serve also as guides for the pilot hole drilling mechanism PCD (as well as the upper underreaming segment of my drilling mechanism having its hingeable arms **4** and rolling cutters **2** thereof mounted in central body member **1** snugly fitting in the drill pipe shoe and held in substantially perfect alignment therewith by means of the very strong generally cylindrical tubular connecting member **9** telescoped with suitable snugness by lower cylindrical tubular segment **1.1** of that central body member) in addition to affording some strengthening of the lower margin of central body member **12'**, which otherwise has an outside diameter of 5 inches for the present embodiment of my invention.

In addition to the fact that it has been necessary to mill out an arcuate notch in one side of the lower margin of outer annular body member **12'** for rotative accommodation thereunder of rolling cutter **18**, whose axle pin **17** is screwed into the face (diagonally disposed with respect to the horizon) machined at one side of the lower tip of the inner cylindrical segment of body member **12**, my FIGS. **8** and **10** indicate that it is necessary to mill three additional arcuate notches (disposed at suitable angles between the horizontal and vertical) in the lower margin of the other annular generally cylindrical body member **12'**. But, even after all four of those arcuate notches are milled in the lower margin of body member **12'**, more of that annular body member **12'** remains than might appear from FIGS. **8** and **10**, which are cross sections at the vertical planes passing through the respective axes of those arcuate cavities above the four rolling cutters mounted therein. And the remaining segments of the lower half of annular body member **12'** are reinforced by the originally cylindrical annular lower tip of body member **12**, which is very snugly inserted therein from above with almost a permanent "-pressed fit," after the three rolling cutters **24** and **25** have been installed on their respective axle pins **20**, **21**, and **19** suitably installed in said annular lower body member **12'**.

Body member **12** is removable, however, from its telescoping lower body member **12'**; and it is notable from FIGS. **8** and **10** that somewhat arcuate notches also have to be cut in the lower margin of that central body member **12** for accommodation therein of the free tips of axle pins **19**, **20**, and **21** as well as rotative accommodation therein also of the upper halves of rolling cutters **25** and **24** mounted thereon respectively. Cross-sectional FIGS. **8** and **10** indicate that, at those right angle vertical planes, only about enough of central body member **12** remains in the lower tip thereof (except around the inner tip of axle pin **17** mounted securely therein) for removing upwardly the core R that will remain caught therein, when the pilot hole PH is drilled; but it will be appreciated that the remaining lower marginal segments of body member **12** shown in those drawings also serve to connect the much stronger remaining segments of that lower margin of body member **12** midway between the vertical planes indicated in FIGS. **8** and **10**. And, in spite of the fact that body member **12** is weakened somewhat by the three canals **22** disposed as shown in FIG. **9** (but alternatively to be moved from the plane of FIG. **8**, as explained above, for directing jets of the drilling fluid away from direct contact with the respective rolling cutters to be disposed at right angles necessarily as shown) and extending somewhat vertically therethrough to carry drilling fluid (under pressure from the conventional pump at the head of the well) to be extruded as jets against the bottom of the pilot hole PH, the two body members **12** and **12'** so closely joined together have quite adequate strength for supporting on the four rolling cutters **18**, **24**, and **25**, rotatably mounted therein, the thousands of pounds of weight necessary to disintegrate hard and even igneous rocks around the core R at the bottom of the pilot hole PH, from which cores of suitable length can be recovered in the light core barrel **14** of corresponding length inside core barrel **13**. As indicated previously, however, it is to be understood that any kind of core barrel and core-catching device known to the art may be employed inside the vertical cylindrical hole through the center of my body member **12** shown in FIGS. **8**, **9**, and **10** and in conjunction with my core drilling mechanisms, one of which is illustrated in those drawings.

But, if my core drilling mechanism illustrated in those figures **8**, **9**, and **10** penetrates relatively unconsolidated rock material, in which the rolling cutters **18**, **24**, and **25** tend to bury themselves quite easily, note particularly at the lower left hand corner of FIG. **8** that the outer lower tip **12.4** of body member **12'** (immediately adjacent the lower tip of rolling cutter **25** in FIG. **8**) is so serrated that it tends to plow such unconsolidated material away from the outer cylindrical wall of the hole being drilled. And the drilling fluid carried downward toward the bottom of the pilot hole PH under pressure through the multiple canals **22** and **23** (disposed as indicated generally in FIG. **9**) not only will tend to disintegrate such relatively unconsolidated materials in the bottom of that pilot hole PH, but also will carry upward (in suspension and solution) the loosened material plowed inwardly away from the outer wall by those multiple serrations in the lower outer tip **12.4** of body member **12'** as well as such loose material plowed outward by the serrated lower tip **12.2** of body member **12** immediately adjacent to core R. It is to be noted, however, that any such serrations in the lower tip **12.2** of body member **12** are not to be high enough to permit injury by the drilling fluid jets under pressure to the core R, into which any such soft material might tend to be pressed to some slight extent by the compressive action of rolling cutter **18**, whose lower face is disposed at a slight angle from the horizon as indicated in FIG. **8**. Milling of the arcuate cavities in the lower tip of outer annular body member **12'**, for mounting the three rolling cutters **24**, **25** therein, simultaneously tends to make serrations in the lower outer wall of that body member; but such remaining segments in the lower tip **12.4** thereof obviously may be even further serrated to facilitate inward plowing of soft material from the outer wall of pilot hole PH. Any suitable number of such additional serrations may be made in the lower tip **12.2** of body member **12** adjacent the cylindrical hole **12.0''** therethrough for accommodation of core R.

In order to facilitate installation of the threaded lower tip of core barrel **13** in the center hole **12.0** of body member **12**

(particularly when the rather long tubular pipe member **10**, in which that body member **12** is mounted, is lying horizontally on the ground), and in order to keep outer core barrel **13** in the center of that pipe member at all times, there is installed on the midsection of that outer core barrel **13** a spider attachment **13.1** (not shown). Various means are known to the art for mounting an "inner core barrel" (such as my core barrel **13**) in an "outer core barrel" (such as my drill pipe **10** shown in FIGS. **8**, **9**, and **10**); but a novel arrangement for mounting such an "inner" core barrel in an "outer" core barrel will be explained later herein in connection with FIGS. **29** and **30**, in which a diamond mounting core drilling mechanism is illustrated schematically, but which figures also illustrate a suitable means for attachment of the rolling cutter mechanism shown in FIGS. **8**, **9**, and **10** to my connecting member **9**, which may be employed in either instance.

During the drilling process, the entire drilling mechanism can be locked in the internally threaded shoe **6** screwed on the externally threaded tip of drill pipe **11** by the means illustrated in FIG. **11**, in which body member **1** having a central cylindrical canal **1.0** therein is an upward extension of the generally cylindrical central body member **1** shown in FIGS. **1**, **2**, and **3**, in connection with which it was explained that body member **1** is inclosed in part by a tubular cylindrical sheath **1'**, whose outside diameter is almost as great as the inside diameter of drill pipe **11**, and whose lower margin is radically serrated to guide that sheathing cylindrical member **1'** (and the central body member **1**, on which it is rigidly attached, whether said attachment be in one or more segments of the sheath **1'**) into proper oscillatory rotational engagement with the corresponding serrations in the upper margin of internal cylindrical tubular member **6.1** of the shoe screwed on the lower tip of drill pipe **11**. In FIG. **11** it can be seen that, when the lower tip of drill pipe **11** is screwed into the upper coupling member **6** of said shoe by the maximum amount, there still remains a distance of about 1 inch between the lower tip of drill pipe **11** (illustrated as having an outside diameter of 6⅝) and the upper horizontal shoulder tip of cylindrical tubular shoe member **6'** (of substantially the same internal diameter as drill pipe **11**), which is illustrated in FIG. **11** as well as in FIGS. **1** and **2** as being screwed into the lower internally threaded half of the ordinary coupling **6** employed with a pipe of that size having an internal diameter of slightly less than 6 inches, depending on the wall thickness and weight of the pipe and coupling used in the art of well drilling for specific purposes, according to depth of the wells and other factors dictating casing requirements. Slightly above the level of the lower tip of drill pipe **11**, when the serrated segments of cylindrical oscillatory guiding sleeve **1'** rigidly attached to central body member **1** are in complete engagement with the inversely serrated upper shoulder (horizontally disposed) of internal tubular cylindrical member **6.1** of said shoe mounted on the lower tip of that drill pipe **11** as illustrated in FIGS. **1**, **2**, and **11**, the vertical cylindrical central canal **1.0** through central body member **1** becomes conical and increases in diameter by successive stages, until it is almost 5 inches in diameter at the top of that body member **1** a little over three inches above the lower tip of drill pipe **11**.

And immediately adjacent the approximately 1 inch vertical annular space, inside tubular coupling member **6** of said shoe and between the lower end of drill pipe **11** and the upper end of tubular cylindrical shoe member **6'** (rigidly installed in that coupling shoe member **6**), three vertically disposed slots **32** FIGS. **11** and **12**) are milled in the exterior wall of body member **1** at angles of 120° from each other. Through each of the slots **32** extends a cylindrical hinge pivot pin **33**, whose tips are mounted in horizontally and perpendicularly disposed hole **34** bored in body member **1**. On the midsection of each of the pins **33** in the respective slot **32** is pivotally mounted the lower arcuate tip of a scotching dog **35**, one of which is shown in FIG. **11** to illustrate that each of said pivotally mounted dogs **35** during the drilling process will have its outer upper corner shoved outward beneath the lower horizontally disposed annular end of drill pipe **11** into the above mentioned annular space inside coupling shoe member **6** above the upper annular tip of shoe member **6'** rigidly mounted therein (by threads and otherwise), so that body member **1** cannot possibly be moved upward with respect to drill pipe **11**, as long as the upper tips of scotching dogs **35** remain in that outwardly disposed posture with respect to pivot pins **33** and the resultant arcuate lower tips of dogs **35** pressing against the lower arcuate faces of slots **32** suitably corresponding respectively, for any upward movement of central body member **1** (in which those three vertically disposed slots **32** of suitable width are milled as shown in FIG. **12**) with respect to drill pipe **11** shown in FIG. **11** would only shove the outer upper corners of scotching dogs **35** out farther into said annular space below the lower tip of drill pipe **11** and eventually substantially against the cylindrical tubular coupling shoe member **6**, into which that drill pipe tip is screwed, before it ever enters the hole to be drilled. Note particularly that it is not necessary for me to cut any annular horizontal groove in my shoe attached to the drill pipe **11**, for I take advantage of the annular groove about 1 inch high below the lower end of that drill pipe **11** to which said shoe is attached by the conventional threads on the lower tip of the lower joint of said drill pipe, although I will explain later how I may take advantage alternatively of a similar annular space between two joints of the drill pipe at a higher level. But in FIG. **11** it can be seen that the scotching dog **35** visible in that figure (in which the mounting slot **32** thereof is located at a position diametrically opposite to the vertical slot **5** in body member **1** hingeably mounting arm **4** at a lower level in FIG. **2**, just as are the other two mounting slots **32** shown in FIG. **12**) is completely beneath the annular (normally very slightly rounded) horizontal lower face of drill pipe **11**, which can be an entirely different (or new) joint of drill pipe **11** (with such lower face of drill pipe **11** thereby completely restored and none the worse for any wear by the dogs **35**) for each well drilled without need for any repair repair of any part of my drilling mechanism under such circumstances. And note again in this same connection that the cylindrical tubular oscillatory guiding sheath **1'** rigidly mounted around central body member **1**, to which it is integrally attached as a whole or by segments alternatively, substantially fills the drill pipe **11** (in FIGS. **11** and **12** as well as in FIGS. **1**, **2**, and **3**) and the shoe member **6'**, so that substantially all the space within shoe members **6**, **6'**, **6''**, and **6.1** is utilized to give maximum strength to my drilling mechanism, although there is no great strain on body member **1** within drill pipe **11** itself, because vertical pressure as well as horizontal torque on the hingeable arms **4** is exerted directly on those arms **4** by the roof and wall of each of the gaps **6.0** of said shoe members.

In FIGS. **11** and **12** it is illustrated that the scotching dogs **35** are extended outward through their respective slots **36** in arcuate (segmented cylindrical tubular) plates **37**, which extend considerably more than just over those slots **32** in body member **1**, and which are rigidly attached to that body member **1** by multiple flathead stud bolts inserted through holes in each of said arcuate plates **37** and screwed into corresponding thread-tapped holes in body member **1** on each side of said slots **32**. Between the three arcuate plates **37** thus bolted to body member **1** are three other arcuate plates **39** having multiple holes therein, whereby those plates **39** are fixedly attached to body member **1**. Inside each of the slots **32** there is integrally attached to its covering arcuate plate **37** a small shoulder **41**, on which rests the shorter tip of a U-shaped steel spring **42**, which cannot escape from the suitably restricted upper tip of slot **32**, and whose much longer inside tip reaches down inside that slot **32** about to the upper tip of slot **36** in plate **37**, so that said longer inside tip of spring **42** presses against an upper projection **35.1** of scotching dog **35**, which thus is kept from protruding through slot **36** in arcuate plate **37** into any of the spaces between the joints of drill pipe **11**, until another force is brought to bear upon said scotching dogs **35**. Obviously the hingeably mounted dogs **35** do not materially check downward travel of body member **1** in drill pipe **11**, no matter what other circumstances may exist.

After body member 1 falls (in the drilling fluid) all the way through drill pipe 11 to a position even very slightly below the position shown in FIG. 11, pressure is applied by the pump at the head of the well at the election of the driller to the drilling fluid inside drill pipe 11 and thereby to the drilling fluid in canal 1.0 extending through central body member 1. Since vertical cylindrical canal 1.0 is a slight restriction on flow of that drilling fluid downward in drill pipe 11, some of that fluid under pressure in the conical section of canal 1.0 immediately above the lower cylindrical segment of said canal in FIG. 11 presses outward through three diagonally disposed cylindrical smaller canals 43 (two of which are indicated in FIG. 11) connected with that conical section of the upright canal passing entirely through body member 1. Each of those three cylindrical canals 43 has a diameter of about 1 inch extending outwardly less than an inch outward and slightly downward, and beyond that distance there is a small cylindrical aligned hole 44 about three-eighths of an inch in diameter extending through the remainder of body member 1 at the center of said canal 43 to connect with the respective vertical slot 32 in the exterior wall of body member 1. In each of the cylindrical canals 43 is a cylindrical piston 45, which fits slidably therein, and which has attached to the center thereof a piston pin 45', which likewise is slidable through the smaller cylindrical hole 44 in body member 1. Intermediate the approximate 1 inch diameter section of piston 45 and the circular wall of body member 1 at the end of canal 43 there is mounted around piston pin 45' a coiled compression spring 46, which holds piston 45 adjacent the inner end of canal 43, until the pressure of drilling fluid F inside the inner canal of body member 1 is sufficient to overcome resistance of that weak coiled compression spring 46. A small knob spot welded in the upper inner tip of canal 43 is a convenient means of keeping piston 45 from ever slipping out of that canal 43 into the conical central canal from which it originally is installed. When pressure of the drilling fluid F in the upper conical section of the central vertical canal of body member 1 is increased sufficiently, after that body member has traveled downward in shoe member 6' by the maximum amount permitted by shoe member 6.1 restraining further downward movement of serrated guiding member 1' mounted around cylindrical body member 1, as previously explained, the piston 45 in canal 43 forces its smaller piston pin 45', which has a hemispherical outer tip, against the upper tip 35.1 of scotching dog 35 (held inward to some extent by small spring 42), which thus is forced outward through the slot 36 in arcuate plate 37 to the position shown in FIG. 11, in which the pressure of the outer upper tip of said scotching dog 35 against the lower somewhat horizontal face of drill pipe 11 screwed into shoe member 6 keeps said body member 1 from moving upward with respect to said drill pipe 11, which thus is ready for rotation with at least part of the weight of the drill pipe string being exerted downward on the several rolling cutters 2, 18, 24, and 25 previously described.

But, when it is desired to remove the drilling mechanism upwardly through drill pipe 11 (by means of a cable, as will be explained presently), the pressure in drill pipe 11 is cut off by the driller thereby permitting the scotching dogs 35 to recede (under the continual actuation of spring 42, with coiled compression spring 46 around piston pin 45' tending to move piston 45 inwardly in canal 43) into their respective slots 32 in body member 1, which then will fall a fraction of an inch in drill pipe 11 to remove the dogs 35 pivotally mounted on horizontal pins 33 in their respective slots 32 in body member 1 from any restraining contact with the lower tip of drill pipe 11 that would tend to prevent retreat into those slots 32 by the upper tips of scotching dogs 35 by virtue of the pressure of the respective springs 42 thereon, after the outer tips of cylindrical piston pins 45' have been pulled inwardly from those slots 32 by expansion of coiled compression springs 46 acting on respective pistons 45, from which the pressure differential of drilling fluid F in the central canal through body member 1 has been decreased by cessation of the flow of such fluid into drill pipe 11 from the aforementioned conventional pump at the head of the well. Raising the drill pipe 11 at least a fraction of an inch in the hole to permit body member 1 and scotching dogs 35 to be moved slightly with respect to the lower tip of that drill pipe 11 obviously is even more necessary, if the outer upper corner of the scotching dogs 35 alternatively are made with their upper faces completely horizontal to match the lower somewhat horizontal face of drill pipe 11, as obviously is possible, it being intended that scotching dogs 35 will be made with their upper tips so shaped as to make most efficient use of drill pipe casing joints available on the market without any added costs of modification, in so far as possible.

The three inverted somewhat U-shaped springs 43 are made the same width as scotching dogs 35, which fit rather snugly but movably in slots 32 in body member 1, just as indicated in FIGS. 11 and 12, so that any drilling fluid escaping under pressure from the central canal in body member 1 through canals 43 and around the pistons 45 and their cylindrical small tips 45' into slots 32 will tend to force the lower tips of those resilient springs 42 and the adjacent upper tips of the scotching dogs 35 outward through slots 36 in arcuate plates 37. As will be explained presently in connection with FIGS. 13 and 14, most of the drilling fluid under pressure is to be restricted to the central canal passing vertically through body member 1. In FIG. 11 in the annular space 11.0 inside coupling shoe member 6, between the lower end of drill pipe 11 and the upper face of tubular cylindrical shoe member 6' of the same diameter, is shown an annular somewhat flexible guiding member 11.1 of hard rubber, whose upper inner annular corner is diagonally disposed from vertical to correspond substantially with the lower faces of scotching dogs 35, when the upper outer tips of those three dogs 35 are pressed out against the tubular cylindrical coupling member 6 of the drill pipe shoe. While the slightly elastic hard rubber annular guiding member 11.1 might tend to restrict downward flow of drilling fluid around the body member 1 and its partially inclosing arcuate plates 37 and 39 to some extent, because the inner diameter of that guiding member 11.1 of suitable slightly flexible material is slightly less than the diameter of cylindrical members 11 and 6', that annular guiding member 11.1 is intended primarily as a centering device to guide body member 1 and the various parts attached thereto into the drill pipe shoe and to keep the central body member 1 centered in that drill pipe shoe thereafter. Accordingly it may be noted from FIG. 11 that below the top of cylindrical drill pipe shoe member 6', on which that annular guiding and centering device 11.1 rests, there are multiple holes 47 through each of the three arcuate plates 37, so that any of the drilling fluid escaping through canals 43 and 44 past the rather loosely fitting pistons 45 and piston pins 45' may travel on outward around dogs 35 in slots 32 and thence through holes 47 into the small annular spaces between the drilling mechanism and the drill pipe shoe members to emerge as a kind of circular jet adjacent the annular surface of the hole being underreamed above the pilot hole PH below.

However, in FIG. 13, whose parts may be spaced suitably in drill pipe 11 as many feet as desired above central body member 1 according to the length of tubular cylindrical pipe 48 having an outside diameter of 5½inches (just as the same pipe 48 in FIG. 11), whose internally threaded lower tip is screwed onto the externally threaded upper tip of body member 1 (FIG. 11), there are shown multiple alternative means whereby the drilling fluid coming down through drill pipe 11 is substantially restricted to the interior of that pipe 48 and thereby to the central 1.0 through body member 1, in which that vertical conduit is progressively restricted as shown in FIG. 11 and as previously described. In FIG. 13 it can be seen that the internally threaded upper tip of heavy cylindrical tubular pipe 48 is screwed into the externally threaded lower tip of a sustaining cylindrical pipe 50, which is slightly over 6 inches long and has an outside diameter of 5 inches. The upper annular horizontal face of splicing pipe 48 is widened somewhat by welding around its upper tip a cylindrical sleeve 48.1, whose outside diameter is only slightly less than the inside diameter of drill pipe 11, in which the sustaining pipe 50

thus is kept substantially centered. Around sustaining pipe **50** and above the horizontal upper faces of splicing pipe **48** and its augmenting cylindrical sleeve **48.1** is installed a flexible annular fluid-catching washer-cup **51**, which conveniently may be made of leather moulded into the shape illustrated in cross sectional FIG. **13**, in which it can be seen that the lower face of that flexible washer-cup **51** is disposed horizontally on the upper tips of said cylindrical tubular members **48**, **48'**, while the midsection is vertically disposed with an outside diameter only slightly less than the inside diameter of drill pipe **11**, and the upper approximately one-third margin is disposed at an angle from vertical. Inside the "cup" thus formed by flexible washer **51** are two annular metal washers **52**, which tend to keep that washer **51** resting on the tops of annular members **48** and **48'**, which thus serve as a seat for this flexible washer fluid valve arrangement **51**. Resting on the external margin of the upper diagonally disposed upper annular segment of flexible cup-washer **51** is the correspondingly diagonally faced lower tip of the annular guiding sleeve member **53**, which can be seen more completely in side perspective in FIG. **14** than in cross sectional FIG. **13**. Multiple slots **53.0** are cut out of the upper half of sleeve member **53**, and the remaining strips **53.1** of the upper margin of that sleeve member (having holes in each of their respective upper tips) are first swaged inwardly toward the surrounded cylindrical pipe **50** and then bent up vertically around it to be held fixedly in that vertical posture by means of suitable brads **53'** inserted horizontally through said holes in said strips **53.1** and through corresponding brad holes in a surrounding annular sleeve **54** around the upper tips of those strips **53'** as illustrated in FIGS. **13** and **14**. Obviously the upwardly cupped flexible washer **51** within drill pipe **11** as illustrated in FIG. **13** would keep substantially all the drilling fluid from flowing downward with respect to cylindrical pipes **48** and **50** of the drilling mechanism resting in the shoe on the lower tip of drill pipe **11**, for any such fluid on flowing downward outside sleeve **50** would enter the slots **53.0** of guiding sleeve member **53** and then would flow downward within the cup of flexible valve member **51** to force the vertical walls of that cup valve tightly against the wall of drill pipe **11**. Yet, when the drill mechanism is falling rapidly inside drill pipe **11** to reach its drilling position in the lower shoe thereof, sleeve **48.1** around splicing cylindrical tube **48** serve to keep cylinder **50** in the center of drill pipe **11** and to keep flexible cup-washer **51** from being damaged by the ends of the externally threaded joints of that drill pipe (screwed into suitable internally threaded couplings in the conventional manner, as illustrated diagrammatically by the threaded tips of such pipe segments **11** and **6'** shown in FIG. **11**), for the natural tendency of the drilling fluid through which that cup valve **51** is falling is to compress that flexible cup **51** inwardly anyway. But, when the drill mechanism is being drawn upward through the pipe **11** containing drill fluid for removal of the core from core barrel **13** or for any other reason (by means of a latch attached to the lower tip of a cable, as presently will be explained), the sleeve member **53** likewise serves as a guide to protect said flexible cup-washer **51** from the ends of the joints of the drill pipe **11**, for that guiding sleeve member **53** (having its upper per segment strips **53.1** swaged inwardly against pipe member **50** and being vertically slidable with respect to that cylindrical pipe **50**, around which it is mounted) tends to press its diagonally faced lower annular tip end downward against the outer upper face of the cup valve **53**, which thus tends to be reduced in diameter slightly thereby and thus to be held out of the annular spaces between the ends of the joints of the drill pipe **11** at its couplings.

It is particularly notable, however, that the more complicated cup valve **51** and its protecting sleeve **53** described immediately above are only an alternative means of completely sealing the flow of drilling fluid around my drilling mechanism mounted in the shoe at the lower tip of drill pipe **11**; and such complete sealing of the downward flow of drilling fluid around body member **1** in the drill pipe shoe members is intended primarily for raising pressure of the drilling fluid in canal **1.0** of that body member, so that the pressure of the drilling fluid in the connected canals **7** (FIGS. **2** and **5**) and in larger diagonally disposed cylindrical canals **43** (FIG. **11**) will be more than adequate for actuation of prod rods **7'** to adjust arms **4** mounting cutters **2** (and alternatively diamonds **100**, as will be explained later in connection with FIG. **24**) and simultaneously to actuate pistons **45** in said canals **43** for locking body member **1** in the drill pipe shoe. But, in connection with FIGS. **2**, **5**, **6**, and **7** it has been explained that upward pressure of the core-drilling mechanism in pilot hole PH can be used alternatively to hinge arms **4** out into gaps **6.0** of the drill pipe shoe, either with or without employment of prod rods **7'** in canals **7**, which weaken body member **1** to some extent at its juncture with its lower cylindrical member **1.1**, in which key members **8.1** are mounted in vertical holes **8**. And it will be explained later herein that I can employ other alternative means actuating locking dogs **35** than the hydraulic actuating means shown in FIG. **11**, in which event leakage of the drilling fluid between sleeve **1'** of body member **1** and the surrounding drill pipe shoe members is no particular problem for increasing pressure of the drilling fluid in body member **1**, connecting member **9**, and the core-drilling mechanism to be explained in detail later herein.

However, immediately above the cylindrical ring **54** of guiding sleeve device **53** in FIG. **11** is shown another much more simple but effective means of sealing against any excessive downward flow of drilling fluid in drill pipe **11** around my drilling mechanism mounted in my novel shoe screwed on the lower tip thereof. Around sustaining vertical pipe member **50** is slipped a snugly fitting short sleeve **55**, which is held fixed with respect to that pipe member **50** by means of multiple flat head screw bolts **56** inserted in suitable holes therein and screwed into corresponding threaded holes in pipe **50**. The lower face of cylindrical sleeve **55** is sloped conically to make it slide easily downward through the tips of the joints of the drill pipe **11**; and in the upper face of sleeve **55** is cut an outer annular groove **57** just large enough to accommodate therein an inexpensive quite flexible annular round rubber ring **58**, whose outside diameter when installed is slightly larger than the outside diameter of sleeve **55** and at least almost as great as the inside diameter of drill pipe **11**. Against the upper horizontal face of sleeve member **55** and the annular rubber ring **58**, installed in annular groove **57** formed therein, is pressed the lower internally threaded tip of a second upper cylindrical sustaining pipe **59**, which has an outside diameter of 5 ½ inches, and which is screwed onto the externally threaded upper tip of the first said sustaining pipe **50**. Around the lower tip of the upper sustaining pipe **59** is welded a short sleeve **59'** (having an outside diameter only slightly less than the inside diameter of drill pipe **11**), whose upper face is conically sloped to facilitate rapid upward movement across the spaces between the ends of joints of drill pipe **11**, and whose lower horizontal face is at the same level as the lower end of upper pipe **59** screwed down on lower pipe **50** against sleeve member **55**, thereby completing the upper face of annular horizontal groove **57** in which the inexpensive quite flexible annular rubber sealing ring **58** may be installed as often as necessary to prevent downward flow of excessive amounts of drilling fluid in drill pipe **11** around my drilling mechanism when mounted in the lower drill pipe shoe thereof.

Obviously sleeves **59'** and **48'** both serve to keep my drilling mechanism centered in drill pipe **11**; but my drilling mechanism having the central body member **1** is kept aligned most effectively with the inclosing drill pipe **11** and its shoe members **6**, **6'**, **6''**, and **6.1** screwed on the lower tip thereof by the short cylindrical sleeve **59''** welded around the upper tip of sustaining pipe **59** (having an outside diameter of 5½ inches), which is of any suitable considerable length to insure such substantially perfect alignment most effectively and for other reasons. Even though drill pipe **11** may be "out-of-round" in some sections thereof, and even though the joints of that drill pipe **11** may not be suitably threaded to achieve perfect alignment with each other, even before the drill pipe

joints may have been bent slightly in the field and in the holes being drilled therein, such short cylindrical sleeves as those designated by numerals 59'', 59', and 48.1 will slip quite readily through the drill pipe 11 with their outside diameters much more closely approaching the interior diameter of the drill pipe 11 than would a single long joint of pipe having the same outside diameter as the sleeves 48.1, 59', and 59' illustrated in FIG. 13.

In the foregoing connection it is particularly notable that I have provided means whereby my drilling mechanism may be fabricated as described and shown in very large part by utilizing in its construction sections of cylindrical pipes and couplings readily available for the oil fields. Other than the necessarily very hard rolling cutters 2 (made of suitable steel alloys suitably heat treated and hardened), their mounting arms 4, etc. the only other "solid" member is the central body member 1, which may be machined from a tubular cylindrical member having the canal 1.0 extending therethrough, if possible, but which also may be machined quite easily to suitable dimensions from a solid piece of steel 6 inches in diameter and about 2 feet in length, to which the other necessary parts of body member 1 and the tubular cylindrical members attached thereto may be attached for installation within the drill pipe shoe as described previously. Referring again to FIG. 2, it may be noted that body member 1 may be made of such diameter as to fit as closely as desired into the serrated guiding sleeve 6.1 welded inside the cylindrical drill pipe shoe member 6', thereby insuring perfect alignment within drill pipe 11 of my long but strong drilling mechanism attached suitably at each end to that strong body member 1, for the conical outer face of that body member 1 immediately above the lower cylindrical segment thereof at line 4–4' serves to guide my drilling mechanism perfectly into that sleeve 6.1, whereby the drilling mechanism is retained in the drill pipe shoe members 6', 6'', and 6, which in combination give quite adequate strength to that drill pipe shoe in spite of the three gaps 6.0 in the lower margin thereof whereby the arms 4 mounting rolling cutters 2 are rotated directly by drill pipe 11 screwed tightly into shoe member 6. Such a snug fit of body member 1 into sleeve 6.1 of the drill pipe shoe is not absolutely necessary, however, for it is desirable that a certain amount of the drilling fluid flowing down through drill pipe 11 be carried (if it does not flow down through vertical central canal 1.0 of body member 1) on downward within the drill pipe shoe almost to the floor of the enlarged hole in the rock formation cut by rolling cutters 2, even though some of said drilling fluid will escape through the vertical slots 5 in the body member 1 adjacent the arms 4 pivotally mounted in those slots. Obviously other holes (besides the three canals 7) may be bored in body member 1 to permit escape of drilling fluid from the central canal 1.0 therethrough at any level desired, although such holes should not be bored in places that will weaken that strong body member 1 excessively. While it does not appear desirable to make the lower portion of body member 1 fit too tightly in the serrated cylindrical shoe member 6.1 within shoe member 6', as was indicated above is possible, since there is no danger of my drilling mechanism "whipstocking" to deviate the bored hole from vertical unintentionally, it will be appreciated that it may be desirable under some circumstances to make such a very tight fit of the lower portion of my central body member 1 in shoe member 6.1, particularly when holes (other than for mounting prod rods 7') alternatively are bored horizontally or at some angle between vertical and horizontal to connect central canal 1.0 with the slots 5 in the central body member 1.

The upper cylindrical tip of sleeve 59'' and the upper tip of the upper cylindrical sustaining pipe 59, to which it is integrally attached, have a continuous upper face that slopes downward conically toward the rotational axis thereof, so that anything falling down drill pipe 11 will tend to fall into cylindrical upper pipe 59, which therefore (when made of suitable length of several feet) is a convenient cylindrical means for attachment to said drilling mechanism of any kind of "fishing tool" known to the art of well drilling for recovery of such cylindrical pipes through drill pipe 11 by means of a cable attached to said "fishing tool."

But in FIGS. 13, 15, 16, 15—16, 17, 18, and 21 there is illustrated a novel easy and positive means of attaching the end of a wire line cable 60 (FIGS. 15 and 16) most effectively to the upper portion of my drilling mechanism for instantaneous withdrawal of it upward through drill pipe 11. In FIG. 16 the cylindrical cable 60 (one-half inch in diameter and made up of multiple wire lines assembled by means known to the art for fabricating such cables) has the lower tips of its wire lines frayed and turned upward in a cylindrical mass 61 of softer metal having a lower melting point, that conveniently can be poured in molten form around said frayed lower tip of cable 60, to which that cylindrical mass 61 then becomes integrally attached on its cooling. Around that cylindrical mass 61 and the lower tip of cable 60, to which it is integrally attached, is mounted a special clasping mechanism 62, which is bisected vertically but has the two vertically bisected segments thereof joined somewhat rigidly around said cylindrical mass 61 by multiple horizontally disposed bolts 63, extending through holes in the two segments thereof, having nuts 64 screwed on the threaded tips of each bolt respectively. Each of the clasp segments 62 is made up primarily of two long metal segments 65 having a right angle cross section with one inch faces, as indicated in FIG. 16, which is a horizontal cross section at line 16–16' of FIG. 15. On each of the two metal faces of right angle metal segments 65 is installed a metal plate 66 one-fourth inch in thickness and 1 inch wide, so that these metal plates 66 all have one side thereof in contact with the cable 60, there being cut from each of those metal plates 66 a long vertical slot 66.0 to accommodate the cylindrical mass of softer metal 61 as indicated in FIG. 15. In FIG. 16 it is indicated that four of the metal plates 66 are welded to their adjacent corresponding plates 66 as well as to the adjacent right angle cross section members 65; but it is intended that other bolts 63' will be inserted through holes in those members at right angles to the bolts 63 shown in FIGS. 15 and 16 and at intermediate levels, so that all of the vertically disposed members 65 and 66 will be very strongly bolted to each other and therefore very strongly attached to cable 60 mounting the cylindrical mass 61, which thus cannot rise with respect to the plates 66 bolted to right angle cross section members 65.

Note in FIGS. 15 and 16 that the vertically disposed right angle cross section members 65 are a half inch from each other; and, if they remain a straight, they would tend to remain spaced from each other by at least that amount to their lower tips, although it will be appreciated that they can be disposed to make their lower tips tend to be spaced somewhat more than one-half inch from each other, as desired, either by bending segments 65 or by variations of the tension of bolts 63. But, since those members 65 should have enough weight to draw cable 60 down into the well hole inside drill pipe 11 quite rapidly, from a suitable reel (known to the art of well drilling) at the head of the well, and to keep latches 67, attached to the lower tips of segments 65 respectively (FIGS. 13 and 18), sustained in the center of drill pipe 11 for ultimate insertion into the upper cylindrical sustaining sleeve 59,59'' (FIG. 13) of the retrievable drilling mechanism, those retrieving members 65 (to which latches 67 are attached at their lower tips respectively) are made a considerable several feet in length, so that they (being of equal length also) can be drawn together quite easily and can be held together by a strong cord 68 drawn and tied around those substantially vertical lifting members 65 immediately above the latches 67.

Each of the four lifting members 65 has mounted integrally in its right angle outer space three latches 67 (FIGS. 13 and 18), two of which are welded to the faces of those members 65 having right angle cross sections, and one of which is welded midway between the other two such latches 67, all of which have their outer lower faces disposed at suitable angles between vertical and horizontal, so that the four members 65 bound together adjacent their lower tips by strong cord 68 pass downward quite readily through the hole 69.0 of suitable

diameter in the center of horizontal plate 69 resting on the upper end of lower retaining cylindrical pipe 50 and held down inside upper retaining cylinder 59 by a short cylindrical sleeve 70 securely fixed in that upper cylindrical pipe 59 immediately above the outer margin of that circular horizontal plate 70 resting on the upper end of lower retaining cylindrical pipe 50. In FIG. 11 the upper inner face 70.1 of cylindrical securing sleeve 70 slopes downward conically toward the center of pipe 59 in which it is secures; but the combined latches 67 mounted on lower tips of vertical lifting members 65 held together by strong cord 68 are so wide at their upper outer tips that in falling down the pipe 59 of considerable suitable length they never would come in contact with the short cylindrical securing sleeve 70 shown in that FIG. anyway. However, it will be observed that the upper inner face 69.1 of horizontal cylindrical plate 69 in FIG. 13 slopes upwardly and outwardly from the central hole 69.0 therein to serve as a guide and to facilitate immediate downward passage of rapidly falling latches 67 (still held together by a suitable number of strands of strong cord 68 tied around vertical lifting members 65, to each of which is integrally attached three of the latches 67) through the center of that hole 69.0 whose diameter is not too much in excess of the maximum diameters of combined latches 67 rigidly mounted on the lower tips of those members 65.

Note particularly in FIGS. 13 and 18 that the lower tips of lifting members 65, which, as explained above, are conveniently made of long metal pieces of suitable thickness having 90° cross section angles, slope upwardly a fraction of an inch toward the vertical axis of that combined lifting device immediately adjacent the lower ends of those lifting members 65, which thus form a kind of four-sided pyramid 71, when the strong cord 68 holds those rather heavy and only very moderately flexible lifting members 65 close together for their passage through hole 69.0 as illustrated in FIG. 13. Immediately below the pyramided immediate lower tips of lifting members 65 in the posture shown in FIG. 13 is a cone 72, whose sharp upper tip points into the above-mentioned pyramid 71 of the lower tips of lifting members 65, and whose lower face merges integrally into the upper end of an externally threaded adjusting rod 72.1, of smaller diameter, which is screwed into an internally threaded cylindrical sleeve 73 forming the center piece of a spider arrangement supporting cone 72 in the center of cylindrical sustaining pipe 50, to whose walls internally threaded central sleeve 73 is fixedly attached by multiple arms 73.1 disposed at suitable angles therefrom. It is not necessary to illustrate diagrammatically that the multiple arms 73.1 form a very convenient means supporting in retaining cylinder 50 a round hailscreen hardware cloth (having in the center thereof a round hole for mounting it around the central spider member 73) for catching on the hailscreen any unduly large material segments that otherwise might pass through pipe 50 into the drilling mechanism below, if they were dropped into the drill pipe 11. But, as soon as the lifting members 65 fall down onto the cone 72, held fixed by nuts 73.2 and 73.3 screwed against spider member 73 around rod 72.1 to keep cone 72 fixed at suitable distance from annular plate 69 at the upper end of pipe 50, the four said lifting members 65 are forced apart thereby at their lower tips to break the strong cord 68, thereby causing the latches 67 attached to the lower tips of members 65 to spread apart (as they naturally are inclined to do by virtue of their at least almost parallel mounting on cable 60 and around cylindrical member 61 fixedly attached thereto, which obviously can be made very slightly conical as desired with a slightly greater diameter toward its lower end to make the lower tips of lifting members 65 spread apart as much as desired on release of broken cord 68) as shown in FIG. 18, so that, when those lifting members 65 are raised thereafter by means of cable 60, the outer tips of latches 67 will rise against the inner slightly conical lower face margin of horizontally disposed strong plate 69 around its center hole 69.0 and thereby will lift the entire drilling mechanism from its position in the shoe members mounted on the lower tip of drill pipe 11.

In FIG. 13 it is indicated that latches 67 are almost three-fourths of an inch below the edge of cylindrical hole 69.0 through the center of horizontally disposed plate 69, whose lower face slopes downward toward the edge of that hole 69.0 in order to make the outer tips of latches 67 (whose upper faces slope upward slightly toward those outer tips) tend to spread apart slightly beneath the inner margin of that plate 69 around said hole 69.0 thereby insuring proper secure connection between those latches 67 mounted on lifting members 65 and the horizontal plate 69 securely mounted in cylindrical pipe 59. It will be appreciated, however, that cord 68 may be broken more quickly inside retaining cylindrical pipe 50 below that plate 69 simply by the driller's loosening nut 73.3 screwed on the lower tip of adjusting rod 72.1 which then can be screwed upwardly in its central mounting spider member 73 to raise cone 72 to any desired height for suitably timed breakage of cord 68 beneath plate 69, after which the other nut 73.2 above spider member 73 can be screwed downward on adjusting rod 72.1 against that spider member 73 to lock cone 72 at the desired height in retaining cylinder 50 for most effective clasping of the margin of hole 69.0 in the center of plate 69 by the outer tips of multiple clasps 67.

When it is desired to remove clasps 67 mounted on lifting members 65 from the orifice 69.0 in the center of horizontal plate 69 outside the hole being drilled in the earth, any suitable simple means of drawing those four lifting members 65 together again at their lower tips may be employed. For instance, if the retaining cylindrical pipe 59 is not made unduly long, a pliant steel wire or short chain may be wrapped tightly around those four members 65 to force their free tips together for removal of latches 67 through orifice 69.0 and for subsequent tying of another strong cord 68 around the lower tips of those lifting members 65 as before. But, if for any reason (such as improbable breaking of one of the scotching dogs 35 or its restraining spring 42 mounted in slot 32 of body member 1) it should be desirable to remove the latches 67 attached to body members 65 from orifice 69.0 in horizontal plate 69 in the drilling mechanism still remaining in the drill pipe shoe at the bottom of the hole being reamed, so that cable 60 could be removed from drill pipe 11 to permit removal thereof from the hole by unjointing said drill pipe 11 in the conventional manner for any reason (even improbable), a simple means for accomplishing that purpose of detaching clasps 67 is illustrated in FIGS. 15, 16, 15—16, and 17. At a suitable distance from the lower tips of lifting members 65 there is welded into each of them a pair of strap restraining guide members 74 (FIG. 17) at right angles to each other and extending outward from the outer edges of those lifting members 65 by about one-half inch, the upper and lower faces of each of those eight guides 74 being disposed at sharp angles from the vertical outer edges of their respective members 65, as illustrated by two of such guides 74 in two of the lifting members 65, as in FIG. 17. And around cable 60 is mounted a generally cylindrical heavy sheath 75, having an internal diameter only slightly greater than is necessary to inclose all those eight guides 74 mounted on the four lifting members 65, when the four said lifting members 65 are pressed closely together as illustrated in FIG. 13. Sheath 75 has its upper end 77,77' closed except for a hole 75.0 in the center thereof slightly larger than cable 60, down which the closed cylindrical sheath 75 can slip quite readily. In order that it will not be necessary to pass all the cable 60 on the reel (not shown) through the generally cylindrical sheath 75, that sheath 75 is made in two sections 75.1 and 75.2, which can be installed around cable 60 from the side thereof. In FIGS. 15, 16, 17, and 15—16 it is indicated that an arcuate strip 75.1' forming a splicing member is welded to the hemicylindrical member 75.1 of substantially the same suitable length; and an arcuate strip 75.2' forming another corresponding splicing member is welded to the other hemicylindrical member 75.2. And flathead connecting stud bolts 76 are inserted through corresponding multiple holes through adjacent splicing members 75.1' and 75.2' into threaded holes in the inner hemicylindrical members 75.1 and 75.2 to join together the two half units, each of which has a closing upper

end section 77 and 77' respectively provided with corresponding holes in which other bolts 76' are screwed to complete the closure of the end section having the aligned hole 75.0 extending through those two end sections 77 around cable 60. The lower ends of hemicylindrical members 75.1 and 75.2 are sloped upwardly toward the center of the assembled cylindrical sheath 75, so that, when sheath 75 slips rapidly down cable 60 (held taut in the drill pipe) it will pass readily over the combined members 65 and 66, all of which have upper faces sloping downwardly and outwardly from the cable 60, and then will pass on downward to force strap plates 74 attached to lifting members 65 into that sheath 75, which thus will force those members 65 together to permit removal of latches 67 attached thereto to be drawn upward through orifice 69.0 in plate 69 be means of cable 60, which of course can be shaken slightly under tension to cause latches 67 to pass into hole 69.0. Such a detachment of cable 60 from my drilling mechanism appears to be a most improbable requirement, however.

It may be noted in FIG. 17 that the arcuate outer splicing strip members 75.1' and 75.2' slope upwardly and outwardly from the lower tips of hemicylindrical members 75.2 and 75.1 respectively, so that sheath 75 thus would pass quite readily into an upper cylindrical pipe 59 such as shown in FIG. 13 for pressing together the lower tips of lifting members 65, if that pipe 59 be made unusually long to keep my drilling mechanism perfectly aligned in drill pipe 11, particularly if the drilling mechanism is not made to fit very tightly in a drill pipe having an approximate 6 inch diameter, because the drilling mechanism is made enough smaller to pass through a drill pipe 11 having a 6⅝ inch outside diameter but with a greater wall thickness to drill very deep holes. It is significant, however, that under any circumstances any oscillation of my drilling mechanism around the rotational axis of drill pipe 11 and the shoe attached fixedly below it will not be excessive and will only cause my drilling mechanism to drill a slightly larger underreamed hole and recover a very slightly smaller core R from the pilot hole PH, which will tend to be kept straight by the arcuate outward extensions 26 (FIG. 9) of the lower annular body member 12' of the mechanism drilling the pilot hole around that core R.

In FIGS. 18, 19, 20, and 21 is shown another means of scotching the drilling mechanism beneath the lower tip of drill pipe 11 in the tubular shoe attached thereto, in which a similar body member 1 is mounted for easy removal through drill pipe 11 by means of cable 60 as just explained above. But in these four FIGS. no hydraulic pressure of the drilling fluid in the drill pipe and canal 1.0 of body member 1 is required to press the upper tips of scotching dogs 35 outward beneath the lower tip of drill pipe 11, as was described previously in connection with FIGS. 11 and 12. In FIG. 18 two diametrically opposed scotching dogs 35 are shown in cross section, and another dog 35 (protruding through slot 84 in cylindrical tubular member 83) is shown in the center of the page from a radial view; and all four of the scotching dogs 35 are shown in FIG. 19, which is a cross section of FIG. 18 at line 19–19' a half-inch below the bottom end of drill pipe 11 screwed into the shoe member 6. The central body member 1 (at the bottom of FIG. 18), through which there is a vertical central cylindrical canal 1.0 of suitable diameter to carry more than enough drilling fluid under pressure for the pilot hole drilling mechanism (core recovering or otherwise), corresponds generally to the central body member 1 shown in FIGS. 1 and 2 as previously described. But in FIG. 18 the central body member 1 proper does not extend above the axes of cylindrical pivot pins 33, whose lower halves are mounted in hemicylindrical cavities in the upper face of body member 1, and whose upper halves are similarly mounted in inverted corresponding hemicylindrical cavities in the plate members 78, each of which is bolted down tightly to the upper horizontal face of body member 1 by a pair of stud bolts 79, which thus with their respective lock washers provide fixed attachment of the four plate members 78 to body member 1 around its central canal 1.0. Likewise shorter hemicylindrical cavities of larger diameter are provided in the upper horizontal face of body member 1 in which are mounted pivotally the arcuate lower tips of scotching dogs 35 mounted on horizontal pivot pins 33. And slots 80 are provided in the outer wall of each of the secured plates 78 for oscillatory accommodation of the pivotally mounted scotching dogs 35, whose upper tips (as indicated in FIG. 18 by two of those dogs 35) can be tilted outwardly into the space 11.0 below the lower end of drillpipe 11 in shoe member 6 through slots 36 in a cylindrical tubular retaining member 50, whose lower internally threaded tip is screwed onto the externally threaded upper tip of body member 1 (without need for a tubular cylindrical intermediate pipe 48 of smaller diameter shown in FIGS. 11 and 13), and whose outside diameter is only slightly less than the internal diameter of drill pipe 11.

Inside the above-mentioned tubular cylindrical retaining member 50 shown in FIG. 18 the upper tip of generally cylindrical body member 1 is provided with an annular groove 82 (above the threads of retaining member 50), in which is installed the lower tip of a tubular originally cylindrical adjusting device 83, which has four suitable notches 84 mostly in the upper half thereof for tiltable oscillatory accommodation of the respective scotching dogs 35 as illustrated in FIG. 18, in which the upper tips of diametrically opposed symmetrical scotching dogs 35 (pivotally mounted on their respective parallel horizontally disposed pivot pins 33 and resting in corresponding parallel hemicylindrical cavities 35' in the upper tip of body member 1) are tilted outwardly at suitable angles from vertical immediately beneath the lower end of drill pipe 11 into the annular space 11.0 inside cylindrical shoe member 6 screwed on the lower tip of said drill pipe 11, as has been explained previously in connection with FIG. 13 and other related FIGS. Intermediate the scotching dogs 35 (whether four or only two diametrically opposed such scotching dogs 35 be employed alternatively) and above the arcuate horizontally disposed plates 78 attached to body member 1 by means of multiple stud bolts 79, four vertically disposed cylindrical dog adjusting rods 85 have the outsides of their lower tips welded to the interior wall of notched cylindrical tubular adjusting member 83 for scotching dogs 35 as shown in FIGS. 18 and 19. The threaded upper tips of those four adjusting rods 85 of suitable length (shown in FIG. 18 as 7½inches) are provided with slight annular shoulders about three-fourths of an inch from their upper ends, which are inserted through four corresponding holes in an annular horizontal lifting plate 69 (generally corresponding to the horizontal plate 69 previously described in connection with FIG. 13, but having an outside diameter that is vertically slidable in the larger tubular cylindrical retaining pipe 50 in which it is mounted in FIG. 18, in which tube 50 is screwed directly onto body member 1 a suitable distance, not all of which could be shown in FIG. 18), after which spring lock washers are installed on the upper tips of those four adjusting rods 85, and thereafter nuts 85' are screwed down on those threaded tips to hold said lock washers and the horizontal annular plate 69 tightly against said shoulders on the adjusting rods 85, as indicated in FIG. 21, which is a horizontal cross section of FIG. 18 at line 21–21'.

When it is desired to raise my drilling mechanism (either that shown in FIG. 18 or in FIG. 13) upward through the drill pipe 11, that drill pipe 11 may be drawn upward slightly in the hole (by means well known in the art of well drilling), in order to permit body member 1, to which scotching dogs 35 are pivotally attached, to have its position inside shoe members 6, 6', and 6.1 moved a very small fraction of an inch with respect to the horizontal lower end of drill pipe 11 screwed into that shoe, thereby removing the upper tips of scotching dogs 35 from restraining contact with said lower end of drill pipe 11. Thereafter, when the lifting members 65 (vertically disposed and attached to the lower tip of cable 60 as previously described in connection with FIGS. 13 and 15) fall through hole 69.0 in the center of horizontal plate 69, and when the latches 67 on the lower tips of the four outwardly distended lifting members 65 are raised upwardly (by means of cable 60)

against that plate 69, to which the four vertically disposed adjusting rods 85 are rigidly bolted, those four adjusting rods 85 (fixedly attached to plate 69 vertically slidable inside cylindrical restraining pipe 50 fixedly screwed onto body member 1) will lift slightly the cylindrical tubular adjusting member 83 to which their lower tips are securely welded. Thus the lower faces of notches 84 (cut in the upper margin of cylindrical tubular adjusting member 83, and shown in FIG. 18 as being parallel to the lower faces of scotching dogs 35 extended outward therethrough, although that most desirable angle of the notch face is not absolutely essential) will be drawn upwardly a fraction of an inch to make the upper tips of scotching dogs 35 pivot inwardly from beneath the lower horizontal end of drill pipe 11 (the lower face of which may be altered very slightly for perfect accommodation of the upper tips of slightly differing scotching dogs 35, as has been mentioned previously herein) and at least into the slots 36 respectively in retaining member 50, which thereby is permitted to slide upwardly thereafter through the drill pipe 11, to whose interior diameter the outside diameter of retaining member 50 and the body member 1 with its inclosing serrated cylindrical attachment 1' have been loosely fitted.

But horizontal plate 69 (and the scotching dog adjusting cylindrical member 83 attached thereto by means of vertical members 85) can move upward only a fraction of an inch with respect to the inclosing cylindrical pipe 50 in which it is vertically slidable, for further upward movement is limited by the fact that into the upper internally threaded tip of that cylindrical pipe 50 is screwed the externally threaded lower tip of an originally cylindrical member 86, which closes the upper tip of cylindrical pipe 50 (except for a round hole 86.0 in the center of said member 86 having a diameter in FIGS. 18 and 21 the same as hole 69.0 in circular lifting plate 69) and which also limits upward movement of plate 69 in pipe 50 to a suitable fraction of an inch. In FIG. 18 the lower face of closing member 86 is shown as being only very slightly above the upper tips of adjusting rod members 85 bolted through holes in the horizontal plate 69, because it was necessary to show all these related lifting features on a sheet of limited size. But it will be appreciated that the cylindrical rods 85, which are welded to the internal face of adjusting cylindrical member 83 as shown in FIG. 19 (for most convenient illustration), are disposed as indicated in FIG. 21 at 90° angles from each other, so that the nuts 85' screwed on the upper tips of those cylindrical rods 85 (which alternatively obviously may be made other than cylindrical in cross section below plate 69, to which they are fixedly attached as described) can pass upward within limits into the annular groove 86.01 shown in FIG. 18 and the cross section thereof at line 21–21' in FIG. 21. Obviously the position of horizontal plate 69 with respect to cylindrical adjusting member 83 attached rigidly to the lower tips of vertical rods 85 may be modified slightly by insertion of suitable spacing washers (not shown) around the upper tips of those rods 85 immediately below or above plate 69 through whose holes those tips extend. In order to install such spacing washers on rods 85 it is necessary to remove nuts 85' therefrom and to unscrew closing member 86 from the upper tip of retaining pipe 50, which normally is held fixed with respect to its end-closing member 86 by a set screw bolt 86' inserted through an internally tapped hole in that originally cylindrical member 86 until its tip is pressed tightly against the upper tip of that cylindrical pipe 50. In FIG. 18 it can be noted that the cylindrical hole 86.0 in the center of closing member 86 gradually increase in diameter toward its upper end to form an inverted conical space, from which the aforementioned internally tapped hole extends outwardly through the closing member 86 for installation therein of setscrew bolt 86', and which also serves as means whereby clasps 67 attached to the lower tips of lifting members 65 are drawn to the center of that closing member, through whose central cylindrical hole 86.0 those clasps 67 have to pass (when they are drawn together by strong cord 68) in order to pass through lower cylindrical hole 69.0 in the center of plate 69, whereby retaining pipe 50 and the drilling mechanism attached to the lower tip thereof are drawn upward through drill pipe 11 by means of cable 60, as soon as horizontally disposed plate 69 is drawn upward against the lower face of partially closing member 86 of pipe 50. Obviously it is possible alternatively to lift closing member 86 by means of the upper tips of vertical rods 85, on which nuts 85' are screwed; but the arrangement shown in FIG. 18 is more desirable, because with this arrangement the plate 69 in its lower position is a smaller fraction of an inch below the lower face of closing member 86, and because this arrangement permits slight adjustment of the distance between plate 69 and the lower cylindrical adjusting member 83 of scotching dogs 35 by means of the spacing washers indicated above as alternatively installable on the upper tips of the adjusting rods 85, which thus do not have to be made just exactly the length desired to begin with.

In order to reinstall through drill pipe 11 the drilling mechanism in shoe members 6, 6', and 6.1 of the shoe screwed on the lower tip of said drill pipe 11, it is only necessary to lift up on plate 69 sufficiently to draw the upper tips of scotching dogs 35 inwardly into their respective notches 36 in the wall of cylindrical retaining member 50, thereby permitting the entire drilling mechanism to travel down freely through drill pipe 11, for dogs 35 having their pivotal mountings at the lower tips thereof will not appreciably restrain downward travel of said drilling mechanism, which need not be lowered on a cable. But, as soon as the serrated cylindrical guiding and retaining member 1.1 (rigidly attached to the exterior of cylindrical body member 1) reaches its lowest possible position in serrated cylindrical guiding and retaining member 6.1 rigidly mounted in shoe members 6', 6, and 6'', the upper tips of scotching dogs 35 will be forced out into the annular space 11.0 beneath the lower horizontal end of drill pipe 11 screwed into the upper half of that coupling member 6 of said drill pipe shoe, for in FIG. 18 it can be seen that another cylindrical adjusting member 87 (having an outside diameter almost the same as that of cylindrical adjusting member 83 but with a slightly thinner wall in order to permit vertical movement of said adjusting member 87 with respect to adjusting rods 85 having their lower tips rigidly attached to said adjusting member 83) is mounted on the upper end of said cylindrical adjusting member 83. If the height of cylindrical adjusting member 87 alternatively were made somewhat greater than is shown in FIG. 18, it can be appreciated that its weight would be adequate to force the upper tips of scotching dogs 35 outward beneath the lower end of drill pipe 11 into the annular space 11.0, where those tips would be held against the coupling member 6 of the drill pipe shoe by the upward pressure of the drilling mechanism beneath the drill pipe, as soon as that mechanism reached the bottom of the hole being drilled, for FIG. 18 shows that the lower horizontal face of adjusting member 87 (conveniently rounded to show a hemispherical cross section, which is most advantageous but not essential) tends to force those upper tips outwardly by virtue of that weight of adjusting member 87. But (particularly if the drilling mechanism is to be employed horizontally or at other angles between vertical and horizontal) also there is shown in FIG. 18 a coiled compression spring 88, whose lower tip rests on the upper horizontal face of adjusting member 87, and whose upper tip is held down by its installation beneath the horizontal lower face of cylindrical annular sleeve 89 fixedly installed inside retaining cylindrical pipe 50. To the inner wall of sleeve 89, having an internal diameter approximating that of cylindrical sleeve 87, are attached the outer tips of multiple spider arms 73.1, whose inner tips are rigidly attached to the internally threaded cylindrical sleeve 73, into which is screwed threaded cylindrical rod 72.1 on whose upper end is integrally mounted a diffusing member 72 having a conical upper tip for breaking strong cord 68 and spreading lifting members 65 to which latches 67 are rigidly attached for lifting plate 69, as previously explained in connection with FIG. 13. But, when the arms arms 73.1 of that spider arrangement mounted inside retaining pipe 50 slope upwardly toward their

outer tips rigidly attached to sleeve **89** as shown in FIG. **18**, those spider arms **73.1** (shown as four in number in FIG. **20**) serve to keep the upper tip of coiled compression spring **88** beneath the face of sleeve **89**, although a coiled compression spring **89** of proper size would tend to remain beneath that sleeve **89** anyway by virtue of its containment in cylindrical pipe **50**. Likewise, to insure that the lower tip of coiled compression spring **88** cannot escape from the lower tip of coiled compression spring **88** cannot escape from the upper horizontal flat face of adjusting cylindrical sleeve **87**, in addition to the rods **85** within that coiled compression spring **88** in FIG. **18** I have illustrated four arcuate guiding strips **90** welded to the inner wall of cylindrical adjusting member **87** intermediate those rods **85** for positive containment of the lower tip of coiled compression spring **88**, which can move vertically with respect to those arcuate guiding strips **90**.

In FIG. **18** and in FIG. **19**, which is a horizontal cross section at line **19–19'** of FIG. **18** at the plane between the lower cylindrical adjusting member **83** and the upper cylindrical adjusting member **87**, it can be seen that gaps **84** in lower cylindrical adjusting member **83** extend only up to the horizontal upper face of that lower adjusting member **83** and that there is no gap whatever in upper cylindrical adjusting member **87**. But in FIG. **22** there is illustrated schematically an alternative arrangement for adjusting the multiple scotching dogs **35**, only one of which is shown in FIG. **22**, in which it is to be understood that all of the corresponding scotching dogs **35** (whether there be alternatively **2**, **3**, or **4** in number) would be of the more sturdy type shown in that FIG. **22**. Particularly is it to be noted in FIG. **22** that, not only is there a gap **84** in the cylindrical adjusting member **83**, but also there is a small gap **87.0** in the lower tip of the upper cylindrical adjusting member **87**, through both of which gaps the scotching dog **35** projects in order that its upper tip (projectable through slot **36** in the wall of pipe **50**) may be shoved out into and drawn back from annular space **11.0** beneath drill pipe **11** inside the coupling shoe member **6**. Gap **87.0** in upper cylindrical adjusting member **87** as well as gap **84** in lower cylindrical adjusting member **83**, through both of which gaps in adjusting members **87** and **83** the sturdy scotching dog **35** in FIG. **22** extends, is made even more obvious in FIG. **23**, which is a vertical cross section through those two cylindrical adjusting members **83** and **87** at line **23–23'** shown in FIG. **22**. It will be appreciated from FIG. **23** that the tubular cylindrical adjusting members **83** and **87** alternatively may be constructed as a single cylindrical adjusting member containing a combination of the two gaps **84** and **87.0** for a corresponding adjustment of each of the multiple dogs **35** illustrated by one such dog **35** in FIG. **22**; but such an alternative construction of tubular cylindrical adjusting members **83** and **87** as a single unit presents more difficult problems of assembly of the scotching dogs **35** through the combined slots **84**, **87.0** combined into a single polygon shaped hole (for each of the respective dogs **35**) through the alternative tubular cylindrical adjusting member **83—87**, although such a combined adjusting member **83—87** is very simple to make in the first place, to visualize which one has only to imagine that the horizontal lines at the lower face of upper adjusting member **87** and at the upper face of lower adjusting member **83** in FIG. **23** are removed from that FIG. to make one cylindrical member **83—87**, in which the holes for pivotal accommodation of the respective multiple scotching dogs **35** necessarily would have to be very slightly oversize vertically to accommodate each of the several scotching dogs **35** pivotally mounted on their respective horizontally disposed pivot pins **33** as illustrated by FIG. **22**.

Although the arcuate roof and one of the vertical sides of each of the gaps **6.0** through the lower margin of drill pipe shoe members **6.1**, **6'**, and **6''** are the primary means of pressing down on arms **4** of my underreaming mechanism and of rotating them around the axis of the rotary drill pipe **11** actuating such downward pressure and torque around the rotational axis of my drilling mechanism, whether those multiple arms **4** mount rolling cutters **2** on their lower tips, or whether those arms **4** alternatively mount diamonds **100** on their lower tips as illustrated in FIG. **24**, the body member **1** mounting such arms needs to be very strong for the purpose of rotating the drilling mechanism for the pilot hole PH, which is attached to the body member **1** by a tubular connecting member **9** as illustrated in FIGS. **5**, **6**, and **7**. But the body member **1** shown in FIG. **24** with diamonds **100** mounted on the lower tips of four arms **4** (FIG. **25**) has to have as great strength as possible for rotating the lower pilot hole core drilling mechanism such as illustrated in FIGS. **29** and **30** and mounting an annular diamond studded core drill, to be described later herein. Accordingly in horizontal cross-sectional FIG. **25** taken at line **25–25'** of FIG. **24** there are illustrated alternative somewhat different vertical slots **5** in body member **1** in which to hingeably mount four arms **4** instead of the three corresponding hingeable arms **4** previously described in connection with FIGS. **1**, **2**, and **3**. Note particularly in FIG. **25** that, at this horizontal plane containing the axes of parallel pivot pins **4.1** and **4.3** hingeably mounting two diametrically opposed arms **4** (shown in FIG. **25** as being hingeably retracted for vertical movement of the drill bit in drill pipe **11** at desired times), each of the arms **4** are milled out in their inner vertical midsections to form horizontally U-shaped members **4** within the corresponding four vertical slots **5** milled in central body member **1**. And, as indicated in FIG. **25**, the other two arms **4** mounted in the other two corresponding diametrically opposed cavities **5** at right angles to the two cavities **5** shown in FIG. **24** are similarly horizontally U-shaped at the plane containing the axes of their respective two pivot pins **4.2** and **4.4**; but the axes of these other two pivot pins **4.2** and **4.4** are mounted a fraction of an inch higher in central body member **1** than the axes of pivot pins **4.1** and **4.3**, in order that the horizontal holes in body member **1** mounting the tips of those other two pins **4.2** and **4.4** do not intersect the respective holes mounting pins **4.1** and **4.3** in that body member **1**, which thereby is made considerably stronger, just as was the case with respect to the mounting of pins **4.1**, **4.2**, and **4.3** in the body member **1** shown in FIGS. **1**, **2**, and **3**, as was explained previously in connection with those FIGS. **1**, **2**, and **3** showing rolling cutters **2** mounted on arms **4** in cylindrical body member **1**. Of course the other two arms **4** not shown in FIG. **24** have to be a corresponding fraction of an inch longer than those shown, just as do the other two vertical slots **5** in this body member **1**, in order to make the lower tips of all the four arms **4**, in which industrial diamonds are mounted in the lower tips by means well known to the art of mining, "cut" the underreamed "rock formation" in the same slightly arcuate annular overlapped path around the rotational axis of the drill and drill pipe **11**. But it will be appreciated that the four laterally extending and vertically disposed ribs **1.3** of central body member **1** at 90° intervals around the vertical axis of that body member **1**, as shown in FIG. **25** and in FIG. **24** at the axes of pivot pins **4.1** and **4.3** mounted in two such ribs **1.3**, serve to make that body member **1** quite rigid and strong in the region inclosing those four pivot pins at two levels for rotation of the core drilling mechanism (at the much lower level in the smaller pilot hole) by means usually of the lower tubular cylindrical segment **1.1** of that body member **1** telescoping a previously described connecting tubular cylindrical member **9** (See FIG. **5**) below the lower tips of slots **5** in body member **1**. However, in FIG. **24** it is illustrated at the lower tip thereof that, when arms **4** are hinged outward by pressure of the drilling fluid in canal **1.0** through body member **1**, alternatively an outer tubular cylindrical pipe **10** (often called an "outer core barrel" by the oil industry) having threads in the upper tip thereof may be screwed directly onto an alternatively threaded cylindrical lower tip **1.1** of the body member **1** hingeably mounting the arms **4** having multiple diamonds conventionally mounted in the lower tips thereof by means well-known to the art. It may be noted from the lower margin of FIG. **24** that the juncture between the central body member **1** having **4** vertical slots **5** therein is conically reduced to a diameter of 5 inches, whether the attachment of the pilot hole

drilling mechanism be directly to the body member 1 as shown alternatively in FIG. 24 or more usually to an adapter bushing 10' connected to tubular cylindrical connecting member 9, mentioned previously in connection with FIGS. 5, 6, and 7 and to be mentioned later herein in connection with FIGS. 28, 29, and 30.

In FIG. 24 it appears that the weakest region in central body member 1, which has to keep the arms 4, having their lower tips studded with diamonds 100, suitably aligned between the pilot hole drilling mechanism shown in FIGS. 29 and 30 (to be explained presently) and the long drill pipe 11 in the much larger underreamed hole above the smaller pilot hole, is in the region of that body member 1 in which the four cylindrical holes 7 are bored for insertion therein of respective adjusting prod pins 7', whereby the lower tips of the four arms 4 are swung outward hingeably into their respective gaps 6.0 through the lower margin of the drill pipe shoe members 6', 6'' on their respective pivot pins 4.1, 4.2, 4.3, and 4.4 by means of pressure (exerted at the election of the driller from the well head by means well known in the art of well drilling) on the drilling fluid in the central vertical canal 1.0, after the body member 1 reaches its lowest possible position in the drill pipe shoe attached fixedly to the lower tip of that cylindrical drill pipe 11, onto which said shoe may be screwed and unscrewed as desired outside the well. But it will be noted from FIG. 24 that those four not quite horizontal holes 7 through the wall of body member 1 (primarily for hingeable extension of the lower tips of respective arms 4 by means of prod pins 7' but also for carrying outward some excess drilling fluid around those loosely fitting adjusting pins 7') are located well above the lowest tips of shoe members 6' and 6'' between the gaps 6.0 therethrough, so that body member 1 in the region of those holes 7 is reinforced not only by those four strong arcuate downward extensions of the otherwise tubular cylindrical drill pipe shoe between its gaps 6.0 (having cylindrical members 6' and 6'' as illustrated by FIGS. 24 and 25) but by the cylindrical section of that drill pipe shoe immediately above the roofs of those gaps 6.0 in shoemembers 6' and 6''. Note particularly also that (by way of contrast with angular disposition of the cylindrical holes 7 in FIG. 2) the outer tips of the four cylindrical adjusting pins 7' aligned in their respective loosely fitting channel holes 7 in body member 1 in FIG. 24 project downwardly at suitable angles outwardly toward their points of contact with the arms 4 in the lower halves thereof, which they press outward as a result of the buildup of pressure in drill pipe 11 at the election of the driller controlling the flow of drilling fluid from a conventional well-known pump at the head of the well. In FIG. 24 the not-quite-horizontal holes 7 in body member 1 are bored through the lower midsections of laterally extending vertically disposed 1.3 but, immediately below the outer exits of those holes 7 through their respective ribs 1.3, the body member 1 (having a vertical canal 1.0 at least about 1 inch in reduced diameter therethrough) has an external diameter of about 3 inches (even between its diametrically opposed vertical clots 5, and with an outside diameter of almost 6 inches beside those slots 5), which diameter of about 3 inches (between the diametrically opposed slots 5) increases downwardly to the bottoms of vertical slots 5 in order to give greater strength to body member 1, not to mention that additional strength is given to body member 1 by the portions thereof remaining between those vertical slots 5 adjacent the outer surface of that generally cylindrical body member 1, which originally is formed with a diameter only slightly less than 6 inches, depending necessarily on the weight and wall thickness of the cylindrical drill pipe 11 determining the internal diameter of that drill pipe, when its external diameter is classified as 6⅝ inches in diameter as now listed and sold on all markets for the tubular steel goods employed in oil fields. It will be explained presently why the diameter of body member 1 in FIGS. 24 and 25 is almost 6 inches without any cylindrical guiding and retaining member 1' mounted therearound as shown in FIGS. 1, 2, and 3.

In FIG. 25 are shown eight broken line circles 8 to indicate that alternatively (either with or without employment of prod pins 7' for adjustment of the angles of disposition of hingeably mounted arms 4 by means of hydraulic pressure of the drilling fluid in canal 1.0 on pins 7') cylindrical push rods 8.1 (vertically disposed and slidable in holes 8 of suitable diameter even slightly larger than shown in FIG. 25) having conical upper tips (as illustrated by the one such push rod 8.1 of slightly greater diameter shown in FIG. 2) may be installed in eight corresponding vertically disposed cylindrical holes 8 in the body member 1 shown in FIG. 25 just as in the corresponding six holes shown in FIGS. 3, 4, 5, 6, and 7. But such vertically disposed push rods 8' are not necessary for hingeable adjustment of arms 4 in the underreaming mechanism mounting diamonds 100 in the lower tips of arms 4 as illustrated in FIG. 24, for the two arms 4 shown in FIG. 24 are disposed at angles of 30° from vertical, and the other two diametrically disposed arms 4 (because their mounting pivot pins 4.2 and 4.4 are located only a fraction of an inch higher in body member 1 than the two hinge pivot pins 4.1 and 4.3 shown in that FIG. 24 to avoid conflicts of horizontal holes for said four pivot pins, as previously explained) are disposed only a few degrees less from vertical (in order additionally to "cut" a continuous annular path in the rock formation around the pilot hole PH to overlap slightly that smaller lower hole as well as the annular path of the two arms 4 shown in FIG. 24), so that all four of the short arms 4 tend to swing outward naturally (by virtue of the "upward" pressure of the rock being "cut" by the diamonds mounted in the lower tips of arms 4 as illustrated) into their respective gaps 6.0 of the drill pipe shoe just as far as possible (during the drilling process), because the lower tips of all the four arms 4 illustrated by alternative FIGS. 24 and 25 are so far outward with respect to their respective mounting hinge pivot pins 4.1, 4.2, 4.3, and 4.4, after the respective adjusting pins 7' force the lower tips of those arms 4 outward to their maximum extent in the drill pipe shoe and before those lower tips of arms 4 mounting the diamonds 100 are brought into contact with the rock formation to be "cut" by the underreaming mechanism on lowering of drill pipe 11 by the driller at his election by means well known to the art. Accordingly in FIG. 24 it is shown that the internally threaded upper tip of tubular cylindrical pipe 10 (on the lower alternatively threaded tip of which is screwed a pilot hole drilling and core-retaining mechanism as illustrated in FIGS. 29, 30 to be explained later herein) alternatively may be screwed on the said externally threaded lower tip of the lower cylindrical integral segment 1.1 of body member 1 without need for the connecting tubular cylindrical mechanism shown in FIG. 5 and explained previously. The difference between FIG. 24 and FIG. 2 is primarily that the arms mounting diamonds 100 on their lower tips can be hinged outward so far from vertical that they always will tend to hinge out just as far as the gaps 6.0 of the drill pipe shoe will permit, while the cutters 2 rotatable on arms 4 in FIG. 2 necessary have to have during the drilling process some outward pressure on them at all times (by prod pins 7' or by vertically disposed adjusting pins 8.1 or by both) to accommodate the antifriction bearings mounted in rolling cutters 2 and on pins 3 rigidly mounted in the lower tips of the respective arms 4.

As illustrated in FIG. 24, note particularly that the four adjusting prod pins 7' fit quite loosely in their respective four not nearly horizontal cylindrical canals 7 so that there will be a considerable outward leakage of the drilling fluid under pressure around those adjusting pins 7' into the cavities 5 in which arms 4 are hingeably mounted. On its escape outward into the cavities 5 against the inner faces of the respective arms 4 mounted therein, most of said drilling fluid (whether it be "mud" or water or air or natural gas as elected alternatively by those drilling the hole to suit appropriately the circumstances in which the hole is being drilled in the "rock formations") has to travel downwardly in those said cavities 5, from which some of said drilling fluid will flow around the sides of arms 4 through drill pipe shoe gaps 6.0, which necessarily have to

have some spare space on at least one side of said arms **4** (to permit prompt hinging of said arms **4** from their slots **5** in body member **1** into the corresponding gaps **6.0** in tubular cylindrical shoe members **6'** and **6''**). But additionally in FIG. **24** there are shown arcuate broken lines **4.10** to indicate the ceilings of multiple canals (well known to the art for carrying drilling fluid along the cutting faces of conventional drills mounting industrial diamonds to "cut" rock formations) in the lower faces of arms **4** (intermediate the lines of diamonds **100** mounted therein) through which canals **4.10** the drilling fluid will pass to carry away the rock cuttings of said diamonds **100** and simultaneously to cool those rock cutting industrial diamonds. Similar canals **4.10** are formed in the lower faces of the other two arms **4** not visible in FIG. **24**. While only one line of such diamonds **100** is shown in cross section in the lower tip of each of the two arms **4** shown in FIG. **4**, it will be appreciated that multiple lines of such diamonds (suitably staggered as desired to make them cut out all the rock beneath the lower tips of the four arms **4** beside the canals **4.10**) are mounted in the lower faces of all the arms **4**, just as similar industrial diamonds now are mounted in the drilling heads of rock bits and core drills now in use in the art for many years. Suitable mounting of such industrial diamonds is described generally in the well known college textbook by John Edward Brantly called "Rotary Drilling Handbook," which has had six editions since its original publication several years ago, and which stated in the 6th edition of 825 pages in 1961:

"The diamond pattern extends across the face and also covers a portion of the outside diameter of the matrix to provide cutting elements for maintaining the size of the hole being drilled and the size of the core. There are two methods in general use for forming the matrix which holds the diamonds. The first is a molten-metal casting process in which the diamonds are placed in a mold and held in position either by suction or by a sticking medium, or both. The metal is then poured over them. The metals most commonly used are alloys of copper, aluminum, manganese, and nickel, since the melting point has to be relatively low to prevent burning the diamonds. A temperature of approximately 2500 F. will cause permanent injury to the diamonds. The second method, and the one most widely used, is to form the matrix by a sintering process. This allows greater freedom in the choice of matrix material. Tungsten, cobalt, nickel, copper, iron, aluminum, and molybdenum among others, may be used to produce a more abrasion-resistant matrix. The diamonds are placed in a mold into which powdered metal is pressed. The mass is then sintered together in a furnace which is carefully regulated. Temperatures generally used are in the range from 2150 F. to 2400 F. The matrix is usually doweled and brazed to the steel body to form a complete core head, although some manufacturers mold the matrix to the steel body in the diamond setting process."

While the critical temperature for diamonds is recognized as about 2500 F., the sintering heat for even powdered tungsten carbide (now used most widely for manufacturing bits that are most abrasion resistant for drilling deep holes requiring many joints of drill pipe, which have to be unscrewed for removal of diamond mounting drills on the lower tips thereof in a very time consuming and therefore very expensive process for costly drill rigs employing high cost laborers) need not be anywhere near that critical temperature. Mounting diamonds **100** on the lower tips of arms **4** of course is more simple than mounting diamonds in a rotary core drill or in a matrix for drilling a full hole to great depth in the now conventional manner. There are several firms over the nation that now mount such industrial diamonds on drill bits for oil wells either for sale or on a custom basis, replacement or otherwise, charging a market price for the diamonds that have to be installed initially or for replacement of injured or worn diamonds, which often are lost in drilling.

My means shown in FIGS. **24**, **25**, **26**, and **27** for suitable slight but at times necessary rotational oscillation of central body member **1** around its vertical rotational axis on descending through drill pipe **11** and into cylindrical tubular shoe members **6**, **6'**, and **6''** screwed onto the lower tip thereof (in order that the four vertical slots **5** in the outer wall of said central generally cylindrical body member **1** will be properly aligned with the four corresponding gaps **6.0** through the lower margin of pipe shoe members **6'** and **6''** for outward hinging of the lower halves of each of those arms **4** into the respective gaps **6.0** in said lower margin of said drill pipe shoe) and my means for ultimate retention of said central body member **1** mounting arms **4** having their lower tips studded with industrial diamonds within said drill pipe shoe member (instead of slipping on out the bottom thereof at any time whatsoever) are both quite different in detail from the corresponding means for accomplishing those two respective purposes as shown in FIGS. **1**, **2**, and **3** and explained previously in conjunction therewith. In FIG. **24** there are shown (fragmentarily in small part as to arm **4** at the left of that figure) two of four plates **4'**, which respectively are fixedly mounted in a suitable notch in the outer arcuate wall of each of the four arms **4** disposed at 90° angles from each other around the rotational axis of body member **1**, all of which arms **4** and their respective plates **4'** have arcuate outer walls corresponding at least almost to the outer wall of cylindrical body member **1** in which they are hingeably mounted, as indicated in FIGS. **26** and **25**, in which latter figure also are shown broken lines to indicate that in each instance the lower notches in arms **4** referred to above are arcuate and that plates **4'** likewise are correspondingly arcuate to fit those notches, in which said arcuate plates **4'** (limiting outward hinging of their respective arms **4** into gaps **6.0** through the lower margin of drill pipe shoe members **6'** and **6''**) are fixedly mounted in said respective arms **4**. As in FIGS. **1** and **2**, in which arms **4** mount rolling cutters **2**, in FIGS. **24** and **26** the plates **4'** are fixedly attached to each of the four arms **4** studded with industrial diamonds **100** on the lower tips thereof, conveniently by multiple flathead setscrew bolts **4''** (See one such arm **4** having a plate **4'** so mounted in FIG. **26** by way of example), and alternatively also by suitable welding of the plates **4'** to their respective arms **4**. But the four plates **4'** corresponding exactly to the plate **4'** on the right-hand side of FIG. **24** and shown in FIG. **24** as attached in the respective said notch in the outer wall of arm **4** are not intended as an alternative means of adjusting the angles from vertical at which arms **4** are disposed during the drilling operation, as was mentioned as a possibility in connection with FIG. **2**. The four plates **4'** identical with the one shown on the right-hand side of FIG. **24** not only limit the outward swinging of arms **4** into their respective gaps **6.0**, having arcuate upper surfaces substantially corresponding in radius to the arcuate outer walls of the four duplicate plates **4'** (corresponding at least almost to the cylindrical outer wall of body member **1** shown as easily slidable inside cylindrical tubular drill pipe shoe member **6'** in FIG. **25**); in FIGS. **24**, **25**, **26**, and **27** the four plates **4'** fixedly attached to their respective arms **4** also serve as parts of my means of rotatably oscillating the central body member **1** by the required number of degrees within the drill pipe shoe members **6'** and **6''**, upon insertion therein from above through drill pipe **11**, to properly align the several vertical slots **5** with the corresponding gaps **6.0** in the lower margin of said shoe member **6'**, so that the respective arms **4** can hinge outward thereafter into their respective gaps **6.0**, until the outer walls of plates **4'** press upward against the arcuate roofs of those gaps **6.0** in the lower margins of shoe members **6'** and **6''** as shown in FIG. **24**.

In FIG. **26** is shown a side elevation of one of the four duplicate plates **4'** mounted on its arm **4** inside the corresponding vertical slot **5** in the outer wall of cylindrical body member **1**, into which that arm **4** is retracted (as are the other three such arms **4** shown in FIG. **25**) for slidable insertion of the entire drilling mechanism through the drill pipe **11** (either up or down). All four of the arms **4** tend to be held in such retracted positions in their respective vertical slots **5** of body member **1** by the respective almost U-shaped resilient steel springs **414** mounted in slots **5** around the respective horizon-

tal hinge pins 4.1, 4.2, 4.3, and 4.4, just as the three arms 4 in FIGS. 1 and 2 tend to be normally retracted (until otherwise forced outwardly through gaps 6.0 in the lower margin of drill pipe shoe members 6' and 6'') in vertical slots 5 by the corresponding six almost U-shaped resilient springs 414 shown and described in connection with FIGS. 1 and 2, where it was indicated that each of the arms 4 had a sharply shouldered recession in each of the sidewalls thereof adjacent its upper tip, in which recessions are mounted a pair of U-shaped springs 414 around the respective horizontal hinge pin of each arm, so that the respective springs 414 having their upper halves pressed against the roof of the vertical slot 5 in body member 1 tends to press downward by means of its lower half on the shoulder of the recession in the sidewall of arm 4 to tend to keep each said arm 4 fully retracted into its respective slot 5 because of pressure of the two resilient springs 414 mounted around the respective hinge pins of said arms 4.

In FIG. 26 it can be seen that the face of arcuate plate member 4' (like the other three such plates 4' attached most fixedly to respective arms 4 disposed at 90° intervals around the axis of body member 1 as indicated in FIGS. 24 and 25) is not quite triangular with its horizontal lower tip being very slightly blunted, in order that, when the arms 4 in their retracted positions pass downward through drill pipe 11 (for installation of body member 1 in drill pipe shoe member 6', the four almost angular horizontal lower tips of the generally triangular plates 4' attached fixedly to their respective arms 4 will come into rotatable contact with the inversely corresponding angular upper tips of the four arcuate guiding and retaining members 6.1 of suitable width and small thickness (See FIGS. 25 and 27) bolted (and alternatively welded) securely and fixedly to the inner walls of the downwardly extending lower tips remaining between gaps 6.0 provided in the lower margin of tubular cylindrical drill pipe shoe members 6' and 6'', thereby causing the four vertical slots 5 formed in the outer wall of body member 1 to become aligned with their respective gaps 6.0, when the body member 1 travels downward into shoe member 6' the maximum possible distance.

But additionally it is necessary to limit downward movement of body member 1 in shoe member 6' (just as was the case in FIGS. 1 and 2 showing arms 4 mounting rolling cutters 2 on axle pins 3), so that in FIGS. 24, 25, 26, and 27 the body member 1 mounting diamonds 100 on its hingeable arms 4 never can pass on through said shoe member 6' at any time. To accomplish such an ultimate limitation on downward movement of body member 1 into shoe member 6' at a proper level therein, the segments of the outer wall of said body member 1 (remaining between the vertical slots 5 therein and below the horizontal holes 4.1', 4.2', 4.3', and 4.4' bored in that body member for mounting respective hinge pivot pins 4.1, 4.2, 4.3, and 4.4) conveniently are turned down on a lathe about one quarter of an inch to leave a horizontal arcuate shoulder of that width on each of said remaining lower body member segments between said vertical slots 5 a small fraction of an inch below the lower two holes 4.1' and 4.3' (which are a fraction of an inch below the other two paired such holes 4.2' and 4.4', as explained previously, to provide for suitable differences of angular deviation from vertical between the pair of opposed arms 4 mounted on hinge pivot pins 4.1 and 4.3 and the other pair of opposed arms 4 pivotally mounted on pins 4.2 and 4.4 at right angles thereto, and to make body member 1 stronger in the region of the four such holes by reducing proximity as well as possible actual conflict between said four horizontal pivot mounting holes 4.1', 4.2', 4.3', and 4.4' in said originally generally cylindrical body member 1). Thereafter there is rigidly attached (conveniently by welding after doweling suitably as indicated in FIG. 26) to each of the remaining vertical segments of the outer cylindrical wall of body member 1 between said vertical slots 5 and against its above mentioned horizontal arcuate shoulder a small arcuate plate 1'' notched so gradually in the lower margin thereof that the face of its angularly serrated notch (See opposing halves of two such notches in the lower margin of two such plates 1'' on each side of the slot 5 in FIG. 26) will come in contact with the upper face of the corresponding upwardly extending arcuate guiding member 6.1' (See FIG. 27 and FIG. 25, in the latter of which the four such guiding and retaining members 6.1' at a lower level than the cross-sectional plane of FIG. 25 are indicated by arcuate broken lines, each of said guiding members 6.1' being fixedly attached to the inner wall of the corresponding lower segment of cylindrical shoe member 6', conveniently by secured bolts illustrated in FIG. 27 and thereafter alternatively welded to the respective said remaining segment of the lower margin of said cylindrical shoe member 6' between the gaps 6.0 as shown in FIGS. 27 and 25) at the exact level required for disposing each of the four hingeably mounted arms 4 at the proper angle from vertical in the drilling process, when the four notched plates 1'' fixedly attached to body member 1 come in contact with the inversely corresponding angular crests of arcuate stops 6.1' fixedly mounted in shoe member 6' between gaps 6.0 in the lower margin of that cylindrical member. All of the gaps 6.0 through the lower margin of that tubular cylindrical drill pipe shoe 6', 6'' are exactly identical, so that it makes no difference into which one of said gaps 6.0 any one of the hingeably mounted arms 4 may be hinged outward (after body member 1 reaches its lowest possible posture in shoe member 6'), even though each one of the pair of arms 4 mounted respectively on parallel pins 4.1 and 4.3 is disposed at a slightly greater angle from the vertical rotational axis of body member 1 than is each of the pair of arms 4 mounted on pins 4.2 and 4.4 at right angles thereto, in order to make the several annular rotational paths of the diamond mounting lower tips of these arms 4 overlap just enough to drill out a larger cylindrical hole segment of adequate outer diameter around the lower pilot hole PH previously drilled by the core drilling mechanism presently to be described. Alternatively the upper angular ends of the four guiding members 6.1 fixedly mounted in the shoe member 6' are blunted very slightly, and the lower angular tips of plates 4' fixedly attached to the outer walls of arms 4 hingeably mounted in slots 5 of body member 1 are similarly blunted slightly, in order that there never may be any tendency for those inverse tips to conflict in any way to prevent downward slippage of body member 1 into the drill pipe cylindrical shoe member 6' as far as necessary for proper disposition of arms 4. In order to avoid any confusion as to the vertical lines of slots 5 in which arms 4 are mounted as indicated in FIG. 26, and in order to avoid any confusion as to the vertical sides of guiding and stop member 6.1' between the vertical walls of gaps 6.0 in the cylindrical shoe members 6' and 6'' shown in FIG. 27, it will be noted that no vertical shading lines have been drawn in FIGS. 26 and 27 to indicate the often mentioned general cylindrical and arcuate nature of body member 1 and arm 4 respectively in FIG. 26 as well as the arcuate inner surface of stop member 6.1' in generally cylindrical shoe member 6' shown in FIG. 27.

It should be noted in connection with cross-sectional FIG. 24, however, that (after the lower tips of arms 4 shown therein are hinged outward on their respective pivots 4.1, 4.2, 4.3, and 4.4 to angles from vertical of arms 4 at which the diamonds 100 of the two most radically extended said arms 4 are directly below and outside the crests of gaps 6.0 through the lower margins of drill pipe shoe members 6' and 6'' as shown in FIG. 24) the cylindrical shoe members 6' and 6'' press downward in the drilling process about the midsections of said arms 4 (of adequate length and disposed at suitable angles from the rotational axis of body member 1 to complete a hole of adequate diameter for upward passage of the drilling fluid around said shoe members 6'' and 6 as well as the drill pipe couplings of the same outside diameter above them in the string of drill pipe of whatever length), so that there is not excessive strain (either of torque around the rotational axis or of downward pressure of a long drill pipe string, whose weight on the several rock cutting members may be regulated by the driller operating the drill mechanism suspended in part from the head of the

well by means well known in the art) by the arms 4 or their hinging pivots 4.1, 4.2, 4.3, and 4.4 mounting the respective arms 4 in vertical slots 5 of body member 1, which serves primarily as a means suitably disposing the four arms 4 in their respective gaps 6.0 of the drill pipe shoe members 6' and 6'', just as was indicated in FIG. 2 that the body member 1 serves primarily as a means suitably disposing through the respective three gaps 6.0 (through the lower margins of drill pipe shoe members 6.1, 6', and 6'') the three arms 4, hinging on pivot pins 4.1, 4.2, and 4.3 respectively and mounting rolling cutters 2 on axles 3 in the lower tips of said arms 4 respectively. Thus in each instance the arms 4, disposed at suitable angles from the rotational axis of body member 1 hingeably mounting them, have the respective outward swing of said arms 4 limited directly by the respective roofs of gaps 6.0 in the lower margin of shoe members 6' and 6'', which exert the necessary downward pressure of drill pipe 11 on the respective arms 4 directly, which arms 4 simultaneously are rotated around the axis of drill pipe 11 and body member member 1 (fixed therein as desired by the driller) by direct action on said arms 4 of the vertical sides of gaps 6.0 through the lower margin of the tubular drill pipe shoe members 6' and 6''.

Obviously any shortening of the four duplicate arcuate guiding members 6.1' (one of which is illustrated in radial perspective FIG. 27), fixedly attached to the respective remaining downwardly extending arcuate prongs of shoe members 6' and 6'' between the gaps 6.0 having vertical sidewalls therein, would tend to lower the limit to which arcuate plates 1'', fixedly attached to body member 1, can travel downward ultimately, before the drill mechanism ever reaches the bottom of the hole being drilled, just as inversely in FIGS. 1 and 2 any change in height of the serrations in tubular cylindrical guiding and vertical-travel-limiting member 6.1 (shown as being fixed in the lower margin of drill pipe shoe member 6' between gaps 6.0 therethrough) and in the inversely corresponding tubular cylindrical rotationally oscillating and vertical-stop member 1' (shown as being fixedly mounted around cylindrical body member 1) would change the level to which body member 1 can descend toward the lower end of downward protruding remnants of the lower margin of drill pipe shoe members 6.1, 6', and 6'' between the three duplicate gaps 6.0 therethrough, thereby making it possible to dispose arms 4 at any desired angles with respect to the rotational axis of body member 1 and its telescoping shoe members 6.1, 6', and 6''. But in either instance (whether FIG. 2 or FIG. 24) the arms 4 press outwardly and upwardly during the hole drilling process against the roofs of gaps 6.0 in the lower margin of said shoe members attached to the lower threaded tip of drill pipe casing 11 by suitable threads screwed into the internally threaded upper tip of the conventional coupling illustrated in FIG. 2 as forming the upper tip member 6 of the drill pipe shoe, whose externally threaded tubular cylindrical member 6' has its upper tip screwed into the internally threaded lower tip of said conventional coupling 6. And, while in any instance it is necessary that gaps 6.0 have sufficient width to permit easy swinging of arms 4 therethrough before drilling operations begin, all those arms 4 fit those gaps 6.0 sufficiently close that drilling fluid flowing downward through drill pipe 11 under pressure (by means well known in the art) and thence through canal 1.0 of suitable diameter as well as between body member 1 and the telescoping shoe member 6' will have to flow outward ultimately around the earth cutting means mounted on the lower tips of arms 4 as illustrated in FIGS. 2 and 24.

In both FIGS. 2 and 24 it is indicated that the lowest remaining downward vertical protrusions of shoe members 6' and 6'' extend down to within a fraction of an inch of the annular rock surface to be cut by the rock disintegrating members (2 and 100) attached to the lower tips of the respective arms 4. FIGS. 2 and 24 have been drawn to illustrate the principles of disposition of arms 4 most clearly with arms 4 disposed at angles from vertical that could be drawn conveniently by use of a T-square in conjunction with plastic triangles having angles of 30, 60, 90, and 45 degrees; but the angles at which arms 4 are disposed in those drawings are quite suitable, and obviously the lower tips of shoe members 6.1, 6', and 6'' may be made a fraction of an inch shorter or longer without coming in conflict with the rock formation to be drilled. In any event the drilling fluid which passes at considerable speed under suitable pressure beneath the lower tips of those shoe members 6.1, 6', and 6'' (whether horizontally or angularly faced between gaps 6.0) will tend to be ejected into the larger underreamed hole surrounding the lower pilot hole, so that the jet action of the drilling fluid will tend to sweep the rock cuttings (of whatever sort, whether "cut" by the diamonds 100 illustrated in FIG. 24 or disintegrated by the rolling cutters 2 illustrated in FIGS. 1 and 2) outward from beneath said cutting means and thence upward around cylindrical drill pipe shoe members 6'' (and any external coupling members of the drill pipe above having the same outside diameter) in a reamed hole of suitable diameter to permit easy entrance of the rotating drill-pipe-casing in spite of any slight deviations of the hole from a straight line, although any such deviations are made minimum with my drilling mechanism for reasons previously described, including the face that a drill pipe of 6⅝ inches in outside diameter naturally resists any bending of such a cylindrical tubular pipe.

While it is conceivable that an underreaming attachment employing industrial diamonds 100 as shown in FIGS. 24, 25, 26, and 27 alternatively may be employed with a tubular cylindrical connecting member 9 and a pilot hole and core-drilling mechanism employing rolling cutters as shown in FIGS. 8, 9, and 10, it is intended primarily (because arms 4 mounting rolling cutters 2 can be rotated much faster than it is possible to rotate a drill mounting industrial diamonds as a "cutting" mechanism of the same diameter) that the underreaming mechanism having industrial diamonds 100 mounted fixedly on the lower tips of its four arms 4 as illustrated in FIGS. 24, 25, 26, and 27 will have its lower pilot hole of suitable smaller diameter be drilled out by a drilling mechanism mounting industrial diamonds in the drilling head thereof at a lower level, whether that pilot hole drilling head be one that will drill out completely all of the pilot hole or alternatively will drill out a necessarily very deep annular groove around the remaining cylindrical core, which thereafter can be raised from the hole on the end of a cable 60 as previously explained in connection with FIGS. 11, 12, 13, 15, 16, 17, 18, 19, 20, 21, 22, and 23. Obviously it is desirable that my invention as described immediately above be so made that a driller at his option may employ with it either a conventional diamond-mounting drill head (such as has been well-known in the art for many years) to drill out entirely the upper portion of a prospective oil producing well down only through any completely nonproductive sedimentary rock system (such as has been well-known in the art for many years) to drill out entirely the upper portion of a prospective oil producing well down only through any completely nonproductive sedimentary rock system (such as are some Permian age rocks laid down "unconformably" over tilted other sedimentary rock systems (such as Pennsylvanian and Mississippian age rocks) having horizons capable in some areas of producing oil, gas, and other minerals) with a drill head that drills out all the pilot-hole PH or alternatively thereafter in the lower possibly productive rock systems to employ with the pilot hole mechanism a diamond mounting drill head for recovery of a core of at least some of the formations penetrated as illustrated by the drill head mechanism and core recovering devices illustrated in FIGS. 29 and 30. The latter two figures illustrate some novel features in the core recovering mechanism as well as in the means of connecting that core drilling and recovering mechanism with the upper underreaming mechanisms just described in connection with the central body member 1 etc. described in connection with FIGS. 1, 2, 24, 25, 26, and 27.

In FIG. 28 (corresponding in large part with FIG. 5 previously described as showing a suitable novel means for connecting, by the tubular cylindrical member 9, the underreaming rolling cutter mechanism shown in FIGS. 1, 2, and 3 with

the core drilling and retaining mechanism illustrated by FIGS. 8, 9, and 10) the lower cylindrical integral segment 1.1 below the vertical notches 5 in body member 1 is simply an alternative downward continuation of the cylindrical annular segment 1.1 (having an outside diameter of 5 inches) shown in FIG. 24, in connection with which it was explained that the hydraulically actuated and not nearly horizontally disposed adjusting pins 7' of arms 4 of the underreaming mechanism may be employed alternatively without any of the vertically disposed adjusting pins 8.1, none of which are shown at the bottom of FIG. 1 (to indicate that adjusting pins 7' slidably mounted in holes 7 leading from the vertical canal 1.0 through body member 1 wall may be employed without use of the alternative vertical adjusting rods 8.1, which are actuated in body member 1 by upward pressure of the mechanism that requires downward pressure to drill the lower pilot hole PH. But in FIG. 28 (drawn at a vertical plane bisecting two of the vertical adjusting rods 8.1 as well as the rotational axis of tubular cylindrical connecting member 9 and its partially telescoping tubular cylindrical lower integral segment 1.1 of body member 1) no lower tips of hydraulically actuated adjusting pins 7' in corresponding holes 7 (such as those previously shown disposed at angles of 45° from the horizon in FIG. 5) have been shown to indicate that the eight vertically disposed adjusting pins 8.1 in corresponding vertical holes 8 (not necessarily shown in FIG. 28 any more than in FIG. 5, for which there would be only six such vertical holes 8 into body member 1 as shown in FIG. 3) alternatively may be employed (in lieu of any hydraulically actuated pins 7' in not quite horizontal holes 7 in body member 1) to adjust angular disposition from vertical of the four arms 4 described in connection with FIGS. 24 and 25, and simultaneously to rotate connecting member 9 joined fixedly to the lower pilot hole drilling mechanism for its rotation by means of my drill pipe 11 above.

Since the eight such vertically disposed arm-adjusting push rods 8.1 for insertion in the connecting mechanism 9 shown in FIG. 28 (as well as in FIGS. 24 and 25) are of slightly smaller diameter as illustrated by FIG. 28 than the corresponding six such rods 8.1 indicated for FIGS. 2, 3, 4, and 5, it would have been possible to have made the upward extending cylindrical tip 9.2 of connecting tubular cylindrical connecting member 9 in that FIG. 8 have slightly greater external diameter than was shown in FIG. 5. But, instead of increasing outside diameter of upward extension 9.2 of connecting member 9 in FIG. 28, increased strength of that upward cylindrical extension 9.2 of connecting member 9 in FIG. 28 has been provided by making the vertical central canal 9.0 therethrough have a smaller diameter, since circulation of a smaller amount of drilling fluid under pressure through that canal 9.0 is required for carrying away the rock cuttings of the core drilling mechanism mounting diamonds 100 as shown in FIGS. 29 and 30 than is advantageously employed with a drilling mechanism using rolling cutters 2 to disintegrate the surfaces of the rock formation being drilled by rotation of body member 1. The smaller diameter vertical canal 1.0 through body member 1 in FIG. 24 also makes for increased strength of that body member 1 between the four vertical slots 5 therein as shown by FIGS. 24 and 25.

FIGS. 24 and 25 also illustrate that the eight vertical holes 8 bored into body member 1 from beneath into slots 5 for mounting in those holes 8 a corresponding number of vertical adjusting rods 8.1 for outward hinging of the four arms 4 are each only nine-sixteenths of an inch in diameter for slidably mounting corresponding rods 8.1 about one-half inch in diameter, since the eight such rods 8.1 of about that diameter are quite adequate for acting as vertical keys in cylindrical members 1.1 and 9.4 (as illustrated previously in FIGS. 6, 7) to rotate the lower core drilling mechanism screwed onto the conical lower tip of connecting member 9 (FIGS. 28, 29), as well as for simultaneously prizing the lower tips of arms 4 mounting diamonds 100 outward into their drilling postures (FIGS. 24, 25) for increasing the size of the pilot hole PH as indicated in FIG. 25. Note particularly in FIG. 24 that such rods 8.1 having upper conical points (as previously indicated in FIG. 2) inserted from beneath into the eight holes 8 indicated by broken circle lines in FIG. 25 tend tend to be kept from bending inside vertical slots 5 in body member 1, because such rods 8.1 are inserted into narrow slots (FIG. 25) between vertical ribs 1.3 of body member 1, and because the upper tips of those keying and arm-adjusting rods 8.1 (as illustrated by one such rod 8.1 in FIG. 2) are inserted between the inner walls of vertical slots 5 in body member 1 and the inner walls of the respective arms 4 hingeably mounted in those slots 5. Six such rods 8.1 only slightly more than one-half inch in diameter have been shown in FIGS. 6 and 7 for exerting outward pressure on the three arms 4, just as indicated by the one adjusting rod 8.1 shown in FIG. 2, from which it will be understood that slight vertical grooves alternatively may be formed in the inner wall of vertical slots 5 as well as in the corresponding inner walls of the respective arms 4 to keep such small adjusting and keying rods 8.1 from bending under vertical pressure, since it is to be contemplated that some outward pressure will be exerted at all times during the drilling process by those rods 8.1 on their respective arms 4 mounting rolling cutters 2 on axle pins 3 as shown in FIG. 2, because some slight such pressure is necessary to keep the outer races of antifriction bearings mounted in rolling cutters 2 suitably pressed onto such bearing assemblies mounted on the axle pins 3 mounted in the lower tips of arms 4. But no such continuous pressure on arms 4 during the drilling process is required for arms 4 mounting diamonds 100 in their lower tips as illustrated in FIGS. 24, 25, since those diamond mounting arms 4 are disposed at such radical angles from vertical that they always tend to press outward against the respective roofs of gaps 6.0 in the drill pipe shoe members 6', 6'', regardless of whether arms 4 are pressed outward originally (before the bit is lowered into drilling position) by prod rods 7' in canals 7 or by vertical rods 8.1 in their respective holes 8 in body member 1 or by both such arm adjusting means, although employment of both means for such adjustment of arms 4 is not necessary. And, since there always will be a little sediment in the bottom of the pilot hole PH to check downward travel of the core-drilling mechanism, attached by suitable threads to the conical lower tip of connecting tubular cylindrical member 9, before the lower tips of arms 4 ever reach the level of the bottom of the larger annular hole around the top of the pilot hole PH, arms 4 always will be free to hinge outward on their respective mounting pivot pins on reinsertion of my body member 1 into the drill pipe shoe members 6', 6'', which can be raised slightly in the hole by the driller otherwise (by means well known to the art, if that were necessary) before said member 1 is reinserted through drill pipe 11 into said drill pipe shoe members having gaps 6.0 in their lower tips for receiving the hinging arms 4 as previously described.

It therefore is practical as well as possible to shove each of the four arms 4 (such as the two such arms 4 shown in FIGS. 24 and 25) outward into their respective drilling positions as shown not only by a single hydraulically actuated adjusting pin 7' inserted in each of the downward sloping canals 7 (of slightly greater diameter than the cylindrical prod pins 7') as shown in FIG. 24, but also alternatively by a single vertical adjusting rod (undesignated) in the center of each of the vertical slots 5 of body member 1 (instead of two such vertical adjusting rods 8.1 in holes 8 in FIG. 25), as I have indicated by broken lines at the bottom of slots 5 in FIG. 24. In the four positions indicated by the two broken-line keying-and-adjusting rods 8.1 in that FIG. 24, however, the upper tips of the alternative four such adjusting rods 8.1 of arms 4 would come in conflict with the respective adjusting prod pins 7' directly above them, when the alternative vertically disposed rods 8.1 are pressed upward into the slots 5. But, when the four such rods 8.1 alternatively are employed in slots 5 as is indicated by the broken line tips of two such vertical keying-and-adjusting rods in FIG. 24, the other hydraulically actuated adjusting pins 6' can be removed from their respective canals 7, which then

can carry some more excess drilling fluid from the central canal 1.0 into the several vertical slots 5 in which arms 4 are hingeably mounted, and to some extent the kinetic energy of the drilling fluid flowing through those canals 7 also would tend to hinge arms 4 outward into their respective gaps 6.0 of the drill pipe shoe, where arms 4 would tend to remain extended as shown in FIG. 24. In any instance, however, the vertical holes 8 (whether there are four, six, or eight of them in body member 1) for slidably mounting therein respective keying-adjusting push rods 8.1 are located with their vertical axes approximately two thirds of the distance from the rotational axis of body member 1 to its outer cylindrical surface, since that is the radius at which the rods 8.1 in holes 8 make maximum utilization of the steel in the tubular cylindrical lower tip 1.1 of body member 1 and of the connecting generally cylindrical tubular member 9 telescoped by said tip 1.1, as is illustrated by FIGS. 3, 4, 6, and 7, which show how the several such vertical rods 8.1 in holes 8 serve simultaneously as means keying the connecting member 9 to the tubular cylindrical tip 1.1 of body member 1 for the purpose of rotating the core-drilling mechanism in the pilot hole below, even though that tubular connecting member 9 shown also in FIGS. 5 and 28 is vertically slidable within restricted limits within the telescoping cylindrical tubular tip of the body member 1. The vertical axes of push rods 8.1 in each of the two holes 8 in cross-sectional FIG. 28 are located 2 inches from the vertical rotational axis of body member 1, and in FIG. 24 the vertical axes of the two undesignated alternative pushrods (indicated with conical upper tips by broken lines at he center of the lower part of two slots 5 in body member 1) also are 2 inches each from the vertical axis of the body member 1 to correspond with the eight holes 8 for such push rods 8.1 in FIG. 25. It will be noted, however, that such a disposition of the four such alternative vertical pushrods 8.1 (in the middle of each of the four slots 5 and with the respective vertical axes of the pushrods 2 inches from the rotational axis of body member 1) for adjusting their respective hingeably mounted arms 4 mounting diamonds 100 as shown in FIG. 24 would make it necessary to cut a small channel in the inner wall of each of the arms 4 as indicated by the diagonally disposed broken lines in the two arms 4 shown in FIG. 24; but such small channels in the arms 4 are no handicap, since those arms 4 are wide enough to permit setting of enough diamonds 100 on each side of the respective channel to carve adequately the annular path in the rock formation around the pilot hole PH to make the larger underreamed hole of sufficient diameter to permit installation of the external casing couplings of drill pipe casing 11. And note also in FIG. 24 that, if the adjusting prod rods 7' are removed from the four respective canals 7 in body member 1, and if the vertically disposed adjusting pushrods 8.1 (indicated by broken lines at the bottom of that FIG. 24) are forced upwardly in the middle of each of the slots 5 of body member 1 by the lower connecting member 9 (having seats for the respective four rods 8.1 in the midsection 9.4 of body member 9 as illustrated by two such rods 8.1 in FIG. 28), those pushrods 8.1 alternatively would be forced upward against the lower diagonally disposed face of rib 1.3 of body member 1, so that the alternative four such rods 8.1 (illustrated in broken lines by two such pushrods having conical tips in the two slots 5 of body member 1 in FIG. 24) in their upward positions would lock the respective arms 4 in the gaps 6.0 of the drill pipe shoe members 6' and 6'' as shown in the extended positions of arms 4 in FIG. 24.

Just as in FIG. 5, in my FIG. 29 are shown diagrammatically conventional coarse tool-joint threads on the radically tapered lower tip 9.3 of tubular and generally cylindrical connecting member 9 (necessarily shown only fragmentarily at the top of FIG. 29, but shown more completely in FIG. 28) for quick disconnection from and later connection to tubular cylindrical connecting member 9 of a special adapter bushing 10' (having external threads screwed into the internally threaded upper tip of outer tubular cylindrical core drill member 10) by rotation of said adapter bushing 10' a few rounds with respect to said connecting member 9, which is nonrotatable (by virtue of vertical keying rods 8.1, two of which are shown in FIG. 28) with respect to lower cylindrical segment 1.1 (of body member 1), around which suitable chain tongs well known to the art can be attached outside the well hole being drilled. In FIG. 29 the external diameter of bushing 10' screwed onto the conical lower tip of connecting tubular member 9 has been tapered down from 5 to 4¾ inches, so that, if and when desired, there can be attached to said bushing 10' the internally threaded upper tip of an outer cylindrical tubular barrel of a conventional coring mechanism of that "outer core barrel" dimension on the market for many years with industrial diamonds mounted on its lower core drilling bit having an annular head, which obviously in the past has had to be removed from the well being drilled by unjointing the drill pipe into segments that can be stacked vertically in the derrick (or sometimes alternatively laid out on the ground adjacent the well head with great labor by the drilling crew), although some modification of that conventional coring mechanism (long known in the art) would be required for alternative use with my connecting member 9, whose coarsely threaded radically tapered tool-joint lower tip 9.3 is screwed into the corresponding female (box) tool-joint threaded bushing 10', in which the coarse threads shown and the conical taper of the tool-joint shown in FIG. 29 are only schematic and do not purport to represent in detail any one of the several tool-joints that have been on the market for the oil and gas industry for a half century. But the outer core barrel 10 having an outside diameter of 4¾ inches has been shown in FIGS. 29 and 30 because a very strong pipe of that outer dimension is available on the tubular steel market in 30 and even 60 foot lengths for mounting an industrial diamond core drilling bit (corresponding in some part to that shown in FIGS. 29 and 30) that will just barely slip through my tubular cylindrical drill pipe shoe member 6.1 shown in other figures of the present application. The bushing 10' and the other cylindrical segments of the connecting members 9 shown in FIGS. 5 and 28 alternatively can be constructed to make them correspond more nearly at higher levels thereof with the outside diameter of the tubular cylindrical pipe 10 shown in FIGS. 29 and 30 as having an outside diameter one-fourth inch less than bushing 10' having a maximum diameter of 5 inches, just like lower cylindrical segment 1.1 of body member 1, whose lower outside diameter is in part dictated by the features such as the vertical pushrods 8.1 in holes 8 shown in FIGS. 5, 6, 7, and 28, in which it is obvious that adequate strength has to be provided for the vertically slidable but non-rotative connection between body member 1.1 and the lower core drilling mechanism shown in FIGS. 29 and 30.

Since my core drilling mechanisms can be withdrawn (together with body member 1) from a well through the drill pipe 11 quite rapidly at frequent intervals by means of the cable 60 attached to a high speed reel well known to the art, it is not necessary that an extremely long cylindrical pipe 10 be employed in connection therewith, as now is required with core barrels fixedly attached to the lower tip of a long drill pipe of many joints that have to be removed from the hole by unscrewing a very substantial number of tool-joints (depending on the height of the derrick in which the drill pipe is stacked as well as on the depth of the well), in order to remove a core segment of a rock formation penetrated by the drill from the core barrel inside such an "outer core barrel" fixedly attached to the lower tip of the drill string that has to be unjointed. But, regardless of the much shorter suitable length of my cylindrical pipe 10 for recovery of cores drilled around thereby, in FIG. 29 there is screwed into the threaded lower tip of tubular cylindrical pipe 10 a generally conventional annular drill head 91, such as long has been known to the art of coring. The central cylindrical hole 92 through that annular drill head 91 is for recovery therein of a "rock" core about 2 inches in diameter, that protrudes upward therein as a result of "cutting" of the rock formation by the many industrial diamonds 100 mounted within and around and beneath the lower annular drill bit segment 91.1 having a lower surface that is substantially hemispherical in vertical cross section (as

shown in vertical cross-sectional FIG. 29) and that is channeled by suitable conventional canals (indicated by broken lines 91.10 at the roofs thereof) well-known to the art for carrying drilling fluid under pressure through said small canals (intermediate the rows of diamonds 100 mounted in the face thereof as shown in FIG. 29) for cooling said diamonds 100 and their matrix 91.1, in which they are mounted by conventional sintering means (well-known to the art of mounting such industrial diamonds and described in a small book called POWDER METAL PROCESSES published by the American Society of Tool Engineers), while simultaneously carrying the fine rock cuttings outward (not necessarily exactly radially as indicated in the drawings) beneath and thence upward around the annular drill bit mechanism 91 (screwed into the lower tip of "outer core barrel" pipe 10) and thence to the surface of the earth around the rotated cylindrical drill pipe 11, as is well known to the art of drilling for oil, gas, sulfur, and other minerals.

The upper half of the annular drill bit 91 (having its external threads screwed into the internally threaded lower tip of cylindrical drill pipe 10 of the coring mechanism as shown in FIG. 29) has formed out in the center thereof a vertical cylindrical hole 91.0 having a diameter of about 3¾ inches (for carrying downward the drilling fluid under pressure therein) halfway down through that bit unit 91. And multiple small vertical holes 91.2 (only two of which are shown in FIG. 29, but with the respective locations of the other ten indicated by fragmentary FIG. 30) are formed in the annular lower half 91.1 of that annular drill bit 91 to connect said central hole 91.0 with the extreme lower face of the annular core drill bit 91, in the lower segment 91.1 of which the diamonds 100 are mounted by means well-known to the art for many years and previously mentioned in the present application in connection with the quotation from J. E. Brantly's ROTARY DRILLING HANDBOOK mentioned above in connection with the industrial diamonds 100 mounted in the lower tips of arms 4 of FIGS. 24 and 25. The vertically disposed holes 91.2 usually are formed at the present time in such annular core bits by inserting vertical rods of suitable heat resistant material in a corresponding mould for casting powdered tungsten carbide in said mould containing the multiple diamonds of suitable approximately uniform size, as is well-known to the art of diamond mounting in core bits.

But, since (for keeping diamonds 100 cool and simultaneously carrying away rock cuttings) it is necessary to pass some cooling drilling fluid downward past the rock cutting diamonds 100 mounted in the face of the annular drill bit segment 91.1 adjacent the remaining core R (not shown in space 92 in FIG. 29 for reasons to be explained later herein), the cylindrical vertical center hole 92 for receiving core R remaining is formed conically to make its walls (at about three-fourths of an inch above the bottom of the annular integral segment 91.1 of drill bit 91) begin to slope outwardly and upwardly at a suitable angle of about 30° from vertical to come in contact with the larger cylindrical hole 910 through the upper half of the drill bit beginning at the approximate upper limits of the multiple small vertical holes 91.2, as in dictated indicated in FIGS. 29 and 30. Inside that interior conical cavity 91.3 of the annular drill bit 91 is mounted a generally cylindrical combination core-catching device 93, whose outer member 93.1 (at least almost 2 inches in height) has a lower conical outer face at least partially fitting the internal conical face of previously mentioned conical cavity 91.3, and whose outer cylindrical vertical wall above said conical lower tip thereof has a diameter about three-fourths of an inch less than the aforesaid cylindrical vertical hole 91.0 in annular member 91, in which it is centrally mounted, and whose internally threaded upper tip is screwed on the externally threaded lower tip of an inner core barrel 94 (considerably smaller in outside diameter of outer core barrel cylindrical pipe 10), and which has a conical cavity 93.2 therein (immediately beneath the lower end of that inner core barrel 94) that extends downward to the sharp lower end of that inner core barrel 94) that extends downward to the sharp lower annular tip of that outer core-catching member 93.1, which at that lower end has a diameter barely larger than the core R remaining after the diamonds 100 on the inner face of the annular drill bit segment 91.1 have cut an annular groove around said core R approximately 2 inches in diameter, as shown in those FIGS. 29 and 30. If the rock formation being penetrated by the annular drilling mechanism 91 having the lower integral segment 91.1 is relatively unconsolidated (as are shales and some of the more recently formed sedimentary deposits), the core-catching device member 93.1 will tend to remain seated on the corresponding conical face 91.3 of that drilling head segment 91.1. But, if the rock formation of the remaining core R is firm or hard, so that the diamonds 100 have some difficulty in cutting it, the sharp lower annular tip of the core-catching device 93.1, which fits that remaining core R snugly, will tend to rise from that conical face 91.3 and thereby leave an annular space above that conical face 91.3, down through which annular space within drill bit 91 a suitable amount of the drilling fluid will flow (under pressure of the pump at the head of the well through drill pipe 11) to pass downward around the core R remaining in situ and thereby cool the cutting diamonds 100 adjacent said core in the inside of annular integral matrix 91.1 of coring drill bit head 91.

Inside the conical cavity 93.2 of outer core-catching member 93.1 is an inner generally cylindrical core-catching member 95 of the collet variety, which long has been known to the mining art. The outer face of that generally cylindrical collar 95, whose interior face around the core R is shown in FIGS. 29 and 30 as cylindrical, is slightly conical to fit inside the corresponding conical cavity 93.2 of outer member 93.1, so that, when the inner core barrel 94 is raised with the entire drill mechanism in its removal by means of cable 60 from the hole being drilled, the inner resiliently flexible core-catching collet 95, which has one side slit vertically as illustrated to permit contraction of its diameter, tends to slip down (relatively speaking) in the slightly conical inner cavity 91.3 of outer member 93.1 (beneath the horizontal shoulder formed by the lower end of core barrel 94 attached thereto) against the conical face 93.2 thereof to make the inner core-catching collar member 95 contract inwardly and thereby grip the core R and raise it thereafter regardless of hardness of the "rock" core R about 2 inches in diameter, which has to be pulled loose from the rock formation penetrated by the core drilling mechanism 91. Note in FIG. 29 that the collar 95, having a vertical slot 95.1 in one side thereof to provide for expansion and contraction of said collar 95 for the purpose of gripping and thereby holding the core R (not shown in cross-sectional FIG. 29) in a conventional way long known in the art of mining, has at least three vertical ribs 95.2 (integrally attached to the resiliently flexible collar 95), whose outer surfaces are made to fit the internal conical face 93.2 of annular core-catching segment 93.1 screwed on the lower tip of core barrel 94. Obviously the foregoing construction of collar 95 as shown in FIGS. 29 and 30 for ease of diagrammatic illustration may be replaced alternatively by a similar collet (well known in the art of mining for many years) in which the almost cylindrical portion of collar 95 having a vertical slot in one side thereof would be made (as such collars more often have been) with multiple vertical ribs inside the similar collar 95 having a smooth outer slightly conical surface suitably fitting inside the conical interior face 93.2 of generally cylindrical member 93 screwed onto the externally threaded lower tip of core barrel 94.

The inner core barrel 94 (and the corresponding "outer core barrel" 10, depending on the kind of rock formations being penetrated by annular core drill 91) may be of any suitable length up to as much as 60 feet or even more (according to present unusual circumstances requiring attachment to drill pipe joints that have to be removed from the hole to remove a core from the core barrel 94); and thus the long core barrel 94 may have considerable weight to hold it down around the core R, until the entire mechanism (retaining that core R) is removed from the hole being drilled thereby. But, since such

"rock" cores (no matter how soft or hard) usually are transported considerable distances from the site of the well being drilled for oil exploration to the office of a geologist of the company, for whom said "cores" are being recovered for study of the rock formations being penetrated, it is desirable that those "cores" be broken into shorter segments for shipment to the offices of the geologists in a suitable length tubular retainer. In the past oil companies have employed very long core barrel assemblies for recovering such "cores" of rock formations being penetrated, because it has been a very expensive process for them to remove from a well a "rock core" segment contained in a core barrel mounted in a diamond studded coring bit assembly attached to the lower tip of a long tip of a long jointed drill pipe, whose removal from the well not only would involve some slight danger to the drillers in removing the drill pipe, but also would require a long time and thereby almost prohibitive inherent expense for cores from deep wells, because the long jointed segments of the drill pipe string would have to be unscrewed from each other at suitable intervals in the removal process and stacked at the well head in order to remove the core barrel containing the rock core segment from the lower tip of the drill pipe. On the contrary, however, because my entire core drilling mechanism (with the connecting member **9** and its attached body member **1**) can be removed from the hole in a few minutes by means of a cable **60** (as previously described above in connection with FIGS. **13**, **15**, **15—16**, **16**, **17**, and **18**) through my rotatable conventional drill pipe casing **11**, which need not be unjointed and removed from the hole being drilled by my coring mechanisms (whether they employ steel rolling cutters **18**, **24**, **25** illustrated by FIGS. **8**, **9**, and **10** or alternatively employ a corresponding industrial diamond mounting rock-coring assembly as illustrated in FIGS. **29** and **30**), it is practical for me to remove cores of even quite short length at any time.

It therefore is convenient as well as economical in all ways for me to employ much shorter internal core barrels **94** (with correspondingly shorter external core barrels **10**, which actually are a sort of drill pipe segment of suitable length for my bit mechanism drilling the annular groove around the remaining central core R, although a similar such outer pipe of a conventional core drilling assembly usually is referred to in the oil fields as "the outer core barrel" of such an assembly attached to the lower tip of a drill pipe string.

Accordingly, in FIG. **29** I have illustrated an additional means (besides weight of the core barrel **94**) keeping my core-catching member **93.1** (and its inclosed collet or collar **95** held therein beneath the lower end of core barrel **94**) pressed down firmly on the core R within my drill bit segment **91**, just hard enough to control flow of drilling fluid down around that core R within the annular drilling segment **91.3** of core drill member **91** without washing the core R away unduly, if the "rock" is somewhat unconsolidated like a shale. The upper internally threaded tip of nonrotating core barrel **94** of suitable length (disposed in the center of an outer rotating cylindrical core barrel drilling member **10** of corresponding suitable length) is closed by screwing into its upper end an externally threaded cylindrical section attached integrally to the lower face of a horizontally disposed plate **96**, through the center of which is a round hole **97** loosely fitting around a vertically disposed upper-tip-threaded bolt **98** of suitable short length, whose head beneath the closure plate **96** of core barrel **94** keeps that bolt **98** from slipping through said hole **97**, whenever that bolt **98** is employed to pull the core barrel **94** and its contents (including the recovered core R) out the top of the outer core barrel **10** at the top of the well, after the entire drilling mechanism (with the exception of shoe members **6.1**, **6'**, **6''**, and **6** screwed on the lower tip of drill pipe **11**) has been drawn up through said drill pipe **11** by means of cable **60**. Obviously it would be possible alternatively to disassemble the core-drilling mechanism by unscrewing the threaded upper cylindrical segment of core drill bit **91** from out the internally threaded lower tip of outer core barrel member **10**. But it is more convenient for the drill crew to simply raise the drill mechanism up within drill pipe **11** by means of cable **60** (attached to a suitable powered reel), until the top of the outer core barrel **10** is slightly above the top of the drill pipe **11** at the head of the well and then place at least three conventional "slip wedges" (well-known in oil fields, where they are kept in stock in supply houses in suitable sizes for different pipe sizes, and where they usually are simply called "slips") around the upper tip of core barrel **10** and within the upper tip of drill pipe **11**, so that said cylindrical pipe **10** is held firmly in the center of that cylindrical casing-drill-pipe **11**, in which the smaller pipe **10** cannot move either downward or rotationally because of said conventional "slips." In FIG. **29** multiple small lugs **10.1** have been welded to the outer upper tip of cylindrical pipe **10** to insure that said smaller pipe **10** cannot slip downward through those multiple "slip wedges," which, however, should hold it securely anyway because of the weight of the drill suspended in those "slips" in the upper tip of drill pipe **11**. But note in FIG. **29** also that the slightly tapered bushing **10'** having a maximum outside diameter of 5 inches would not slip through the "slips" inserted in the upper end of drill pipe **11** anyway.

Around the bolt **98** above the closure member **96** screwed into the upper tip of core barrel **94** is a resilient flat annular washer **96.1**, which fits snugly around bolt **98** and therefore serves to keep drilling fluid from flowing down through the hole **97** in closure plate **96**, although any air trapped in core barrel **94** could escape upward to facilitate settling down of that inner core barrel **94** onto the core R projecting upward into said inner nonrotating core barrel. Pressure is exerted downward onto washer **96.1** and upon core barrel closure **96** by a thrust ball bearing assembly **96.2** around bolt **98**, which permits the inner core barrel **94** to remain nonrotational in the drilling process, while the "outer core barrel" **10** is being rotated to rotate its annular bit head **91** on the lower tip thereof. Downward pressure in turn is exerted on the thrust bearing assembly **96.2** by the circular bottom plate (having a hole in its center through which bolt **98** protrudes upward) of a cylindrical cup **98.2**, whose vertical cylindrical walls have multiple holes **98.3** therein, through which holes drilling fluid coming down under pressure through the vertical canal **9.0** in the center of connecting tubular member **9** flows outward freely into the pipe **10** and thence downward to the drill bit head **91** in the annular space between inner core barrel **94** and outer core barrel pipe **10**. Cylindrical cup **98.2** limits upward movement of core barrel **94** within outer pipe **10** and thus limits the slight distance core-catching member **93**, screwed on the lower tip thereof, can rise above the conical cavity **91.3** of drill bit head **91.1**, for the perforated cup **98.2** as shown in FIG. **29** has its upper annular surface substantially against an annular shoulder formed on the tool-joint threaded lower tip **9.3** of tubular connecting member **9**, which is screwed into the adapter bushing **10'**, which in turn is screwed into the internally threaded upper tip of outer core barrel **10**. But a spiral coiled compression spring **98.4** within cylindrical cup **98.2** is continually pressing downward on the bottom plate of that cup **98.2** (and thus in turn on members **96.2**, **96.1**, **96**, and core barrel **94** to keep core-catching member **93** (screwed on the lower tip of that nonrotating core barrel **94**) only a fraction of an inch above annular bit head segment **91.1**, since only a small such separation is required to permit a proper part of the drilling fluid to travel downward between the two conical surfaces and thence downward into direct contact with multiple diamonds **100** cutting the groove around the core R remaining in cylindrical space **92**, in which in FIG. **29** only an illustrative few of the multiple diamonds mounted inside annular drill bit **91.1** are shown. If the "rock formation" being penetrated by annular bit **91.1** is soft (such as a shale or unconsolidated material of recent geologic age), coiled compression spring **98.4** will keep core-catching member **93** on the lower tip of core barrel **94** pressed down snugly on the core R projecting upward inside that inner nonrotating core barrel **94**, so that excessive flow of the drilling fluid under pressure will not be permitted to pass below segment **93.1** of

core-catching member 93, where it might tend to wash away too much of the soft remaining core R.

As soon as the core drilling assembly shown in FIG. 29 is raised to the top of the hole by means of cable 60 and is secured in the upper tip of drill pipe 11 by the conventional "slips," which hold it against rotation, a suitable chain tong (well-known to the art) can be attached around the upper tip of adapter bushing 10' (or alternatively around the lower cylindrical segment 1.1 of body member 1, which is keyed to tubular cylindrical connecting member 9 against rotation by vertical push rods 8.1 in vertical slots and holes 8 in said body member segment 1.1 as well as in corresponding hemicylindrical slots in connecting member 9 as indicated in FIGS. 3, 4, 6, 7, and 28) to break loose the coarse tool-joint threads schematically indicated on the lower conical tip 9.3 of connecting member 9 screwed into bushing 10'. The tool-joint threads on the lower conical tip of connecting member 9 mounting a rotary coring mechanism studded with diamonds 100 in FIG. 29 are somewhat shorter than the corresponding threads on lower tip 9.3 of connecting member 9 shown in FIG. 5 (as well as in later FIGS. herein), which is intended to illustrate schematically indicated on any one of the several well-known tool-joints of sufficiently large dimensions to rotate even a conventional bit (either diamond or rolling cutter) capable of boring a very large hole. It is intended to show only schematic representations of the well-known threads on lower tip 9.3 of connecting member 9 in both FIGS. 5 and 29, since there are various kinds of threads on tool-joints mounting drill bit strings at the present time, and since it would be impossible to make a connecting member 9 with tool-joint threads that would fit in the "box" or "female segment" of all the tool-joints on the market, although obviously (as will be explained later herein) an adapter bushing 10' can be made with external threads to fit into any one of such tool-joint boxes. In any event my connecting member 9 can be removed from the adapter bushing 10' quite quickly by a few revolutions of that radically tapered tip 9.3 of connecting member 9, connecting member 9, after which removal from the adapter bushing 10' the coiled compression spring 98.4, cup 98.2, and the entire core retaining mechanism attached thereto can be drawn upward a suitable distance (limited by the upper shoulder of member 93 screwed on the lower tip of core barrel 94) through the hole in the center of adapter bushing 10'. At that time a cylindrical lifting tool 31 of suitable length and having an externally threaded lower tip (but shown fragmentarily in FIG. 29 by broken lines without any suitable upper grasping tip) is screwed into a nut 98.1 secured on the upper threaded tip of bolt 98 installed through a hole in the center of the bottom plate of cup 98.2, so that said suitable lifting tool 31 screwed into the upper tip of thick nut 98.1 can raise bolt 98 screwed into the lower half of that nut 98.1 and thereby raise closure member 96, core barrel 94, and any rock core contained therein. (In FIG. 28 one of the lifting tools 31 with a nut screwed on its upper tip is shown in the central canal 9.0 of connecting member 9, but the lifting tool 31 should be removed from the lower nut 98.1 before reassembly of the mechanism.) Beneath the nut 98.1 and around its bolt 98 is an annular washer 98.1', which presses down on a slightly larger flexible washer 98.5 around the same bolt 98 and against the horizontal bottom plate of cylindrical cup 98.2, so that drilling fluid cannot flow down around bolt 98 into the thrust bearing assembly 96.2 through the hole in the bottom of cup 98.2, which fits bolt 98 loosely to facilitate easy rotation of cup 98.2 with respect to the entire nonrotating core retaining mechanism beneath it during the drilling process. The extreme lower tip of connecting member 9 extending down into the upper half of coiled compression spring 98.4 is not essential to the drilling process, but it serves to keep that spring 98.4 centrally aligned and facilitates reassembly of connecting member 9 with cup 98.2 and its inclosed coiled compression spring 98.4, after the core R has been removed at the head of the well.

In drilling some rock formations it will be found easier to get the core into core barrel 94 during the drilling operation than to get it out of the core barrel 94 at the head of the well, unless special provision is made for that purpose, which is quite important with my invention, which makes it possible to reduce costs of coring to such extent that a continuous core may be recovered of virtually all the formations penetrated—at least during early exploration of a field. In FIG. 29, in which it has been necessary to cut away the midsections of core barrels 10 and 94, which are of any suitable length, it may be seen that inside completely cylindrical core barrel 94 is another smaller cylindrical core barrel 94' having a thin wall, which is slotted vertically at one side from top to bottom, and which extends downward substantially to the upper horizontal face of collet 95 mounted in core-catching member 93 screwed on the lower tip of core barrel 94. Light and slightly flexible core barrel 94' snugly fitted (when expanded) inside core barrel 94 has multiple circular holes adjacent its upper end, into which said holes project corresponding short horizontal buttons integrally attached to the circumference of a plate 94'', which is inserted in the upper tip of that slightly flexible core barrel 94' before the latter ever is shoved completely into core barrel 94. At the center of closure plate 94'' is shown attached an externally threaded small cylindrical upper projection, onto which can be screwed a suitable internally threaded grasping tool, after closure plate 96 has been removed from the upper tip of core barrel 94, when its upper tip has been raised upward a suitable distance through the hole in adapter bushing 10' at the head of the well. The above mentioned suitable grasping tool then can be employed to pull inner core barrel 94' and the rock core R contained therein out of core barrel 94 easily, after which the light inner core barrel 94' is not impracticably long.

Since the diamond studded coring assembly shown at the bottom of FIGS. 29 and 30 has an overall diameter of 5⅝ inches, and since the stops 6.1' mounted in the shoe member 6' screwed on the lower tip of drill pipe 11 will have a maximum clearance of no more than 5¾ inches, multiple plugs 99 of easily destructible material have been shown inserted in the lower tips of holes 91.2 in FIG. 29 for possible alternative attachment of a suitable easily destructible plate 99' (FIGS. 29 and 30) to the lower tip 91.1 of annular drill bit 91, in order that diamonds 100 may be kept from contact with the steel in descending through drill pipe 11 and shoe members 6.1' attached to its lower tip for purposes previously explained herein. Since core-catching member 93 will rest directly on conical surface 91.3 of annular segment 91.1, before the drill bit reaches the bottom of the hole being drilled, the drilling fluid can be employed by the driller to blow plugs out of holes 91.2 immediately before the drill bit is lowered to the bottom of the hole. Plugs 99 can be made conveniently of wood, so that they will float to the surface of the drilling fluid immediately; and on reaching the bottom of the hole, the plate 99' (conveniently made of suitable cardboard) will be chewed up almost instantaneously by the diamonds 100 on slight rotation of the drill pipe 11, in whose shoe members 6, 6', 6'', and 6.1 the central body member 1 comes to rest for such rotation of the entire assembly.

Employment of my generally cylindrical tubular connecting member 9 as a nonrotationally keyed and telescoped linkage (substantially straight and unbendable) between telescoping lower integral segment 1 of body member 1 (installed snugly and nonrotatably by means of arms 4 thereof in gaps 6.0 in the lower margin of shoe members 6.1, 6', 6'', and 6 fixedly attached on the lower tip of cylindrical drill pipe 11) and the pilot hole core-drilling mechanism shown in FIGS. 29 and 30 serves effectively to make the entire hole (underreamed hole as well as pilot hole) as straight as possible. And it will be appreciated that the vertical dimensions of telescoping segment 1.1 of body member 1 and the telescoped connecting member 9 shown in FIGS. 5, 6, 7, 28, and 29 may be increased in length as desired to insure that the vertically slidable but nonrotational connection of tubular member 9 within that tubular

cylindrical segment of body member 1 always keeps that generally cylindrical central body member 1 (fixedly mounted in the drill pipe shoe members during the drilling operation) so accurately aligned with respect to the core-recovering drill assembly shown in FIGS. 29 and 30 that the pilot hole and the larger hole drilled by the arms 4 of body member 1 always will have to be very straight, particularly unless other means known to the art may be employed for deviating the hole in the earth from vertical in the process called "whipstocking" in the oil fields. And additionally it will be appreciated that the mechanisms shown in FIGS. 1 to 28 inclusive may be employed to ream out a smaller pilot hole drilled by conventional means previously known to the art with a hole diameter in excess of 5 inches, so that my jointed casing drill pipe excess of 5 inches, so that my jointed casing drill pipe 11 having an outside diameter of 6⅝ inches connected by threaded collars having an outside diameter of at least 7¼ inches may be installed in my underreaming process during the drilling operation and left in the enlarged hole for production through said jointed casing of oil, gas, sulfur, etc. without any necessity ever for unjointing said drill pipe 11 having my tubular cylindrical shoe members 6.1, 6′, 6″, and 6 screwed on the lower tip thereof as illustrated. Only a short mast pole is required to install my drill pipe 11 in single joints, which in most circumstances never would require a tall strong derrick for "pulling" the drill pipe 11 from the larger underreamed hole drilled by suitable cutters (employing either diamonds or rolling cutters 2) installed on the lower tips of hingeable arms 4.

For the purpose of thus reaming out a previously drilled pilot hole, sunk by conventional means previously known to the art, and simultaneously installing my casing drill pipe 11, FIG. 31 illustrates a novel cylindrical tubular mechanism 110 screwed onto a tool-joint threaded lower tapered tip of my lower segment 1.1 of body member 1 5 inches in diameter, as illustrated at the bottom of FIGS. 1 and 2 with the connecting member 9 alternatively left out entirely to make the connection of mechanism 110 to body member 1 perfectly rigid. Note that in this instance in FIG. 31 one of the three adjusting prod pins 7′ (for hydraulically actuating hingeable arms 4) has been shown in one of the three upward sloping canals 7 (just as in FIG. 2) whereby hydraulic pressure on the drilling fluid (at the election of the driller coming downward through drill pipe 11 and thence through vertical canal 1.0 in the center of body member 1 having a lower cylindrical segment 1.1) whereby the multiple arms 4 (illustrated in FIGS. 1, 2, 24, and 25) are hinged outward at their lower tips through gaps 6.0 of the drill pipe shoe to ream the previously drilled pilot hole out to suitable diameter. The schematic "pin" of the tool-joint on the lower tip of tubular cylindrical body segment 1.1 is quite conventional as shown in FIG. 31; and the adapter bushing 111 screwed onto that schematic "pin" quite easily can be made (in order to take advantage of mass production of such tool-joints for the oil industry by steel fabricators of tubular goods) from the upper tip of an old tool-joint "box" (of any kind still in use in the oil fields). Adapter bushing 111 of suitable length (but requiring no great strength comparable to such a "box" in a drill pipe string of the same diameter) has its lower tip reduced in outside diameter and externally threaded to receive the upper internally threaded tip of a pipe 112 of suitable length of several feet and having the same outside diameter of 5 inches; and it will be appreciated that any bit always drills a hole having slightly larger diameter than the maximum diameter of the drill bit head, although holes sometimes appear to be smaller, when they are not straight enough to install suitable casing therein. The lower tip of cylindrical pipe 112 is internally threaded to receive the externally threaded upper tip of a short round closure member 113 having a slightly tapered lower surface to guide it into the pilot hole, which probably would be a fraction of an inch in excess of 5 inches in diameter to permit easy downward slippage of rotatable mechanism 110 therein.

Closure member 113 has an internally threaded cylindrical hole in the center of the upper half thereof for receiving the externally threaded lower tip of a vertical pipe of 1 inch internal diameter as shown. The upper tip of vertical pipe 114 of suitable length is kept in the center of pipe 112 by means of three spider arms 115 fixedly attached to that pipe 114 about an inch from the upper end thereof at intervals of 120° around the vertical axis with each arm 115 having a radius around the common axis of the two pipes 112 and 114 slightly less than the internal radius of larger pipe 112. Onto the externally threaded upper tip of pipe 114 is screwed an internally threaded closing member 116 of the canal 1.0 through the lower tip of generally cylindrical lower segment 1.1 of body member 1. In order to keep suitable pressure of the drilling fluid in canal 1.0 for slidable actuation in holes 7 of adjusting prod pins 7′ to hinge arms 4 outward in slots 5 of body member 1 at the election of the driller, a flexible annular washer 117 is installed between an annular shoulder 118 of annular closure member 116 and the horizontal lower end of segment 1.1 of body member 1. Additionally an annular leather cup 119 is installed inside of canal 1.0 to rest on the horizontal upper face of closure member 116, which has multiple indentations 120 in the upper surface thereof whereby said closure 116 of enlarged canal 1.0 can be screwed down on the threads of pipe 114 for vertical adjustments with respect to the lower annular horizontal face of tool-joint threaded lower segment 1.1. Cylindrical pipe 112 has four openings about 1 inch in height through its wall, at intervals of 90° below the level of spider arms 115, and sloping downwardly toward the vertical rotational axis of pipe 112, so that small segments of rock carried upward in suspension by the drilling fluid flowing upward around pipe 112 can fall into said otherwise closed pipe, which thus becomes a receptacle for receiving some of the heavier rock cuttings, although most of the smaller such rock cuttings tend to travel on upward in fluid suspension around pipe 112 and thereafter around drill pipe 11 above.

Such rock cuttings as fall through holes 121 in the wall of guiding and retaining drum pipe 112 may be emptied from that receptacle by overturning it after unscrewing the coarse tool-joint threads of adapter bushing 111, and at least in most instances it will not be necessary to remove closure member 116 or pipe 114 from the retainer 112 in order to empty the rock cuttings therefrom. Such a retainer for cuttings is particularly important for eventually dredging such rock cuttings of whatever size from the bottom of the pilot hole, in which it is possible to employ closure member 113, having a sharp edged conical hole 122 in the lower tip thereof, as a means of quickly breaking up any such larger rock cuttings in the bottom of the hole by vertically reciprocating said closure member 113 by means of cable 60 attached to central body member 1 as previously explained or alternatively by vertical reciprocation of drill pipe 11 by means well known in the art of well drilling. In order to insure that suitable fluid pressure may be maintained in canal 1.0 of body member 1, FIG. 31 illustrates an annular reducer bushing 124 screwed into hole 123 leading downward from the end of pipe 114 to the conical hole 122 in the lower tip of closure 113, which alternatively may be removed from pipe 112 at the head of the well for the purpose of emptying rock cuttings from retainer pipe 112, from which closure 113 may be unscrewed alternatively by employing a suitable wrench tool having projections to fit into multiple cavities 125 formed in the lower tip of that closure member 113.

FIG. 32 illustrates a novel means (employing a conventional drill pipe now on the market, and basically similar to other such jointed drill pipe of other manufacturers of tubular steel goods) for drilling a pilot hole and recovering rock cores therefrom before utilizing my mechanism shown in FIG. 31 to ream the pilot hole out to suitable size and simultaneously install the drill-pipe-casing 11 (available from several manufactures) having an outside diameter of 6⅝ inches by means of the mechanisms shown in FIGS. 1, 2, 3 and 24,25. FIG. 32 illustrates that the core recovering mechanism illustrated in FIGS. 29, 30 can be employed even with the most unusual

kind of drill pipe joints described by the manufacturer in his sales catalogue as "Internal Upset Drill Pipe with Reed API Full Hole Tool Joint—Attached by Flash Welding." The Reed Tool Co. (another manufacturer) of course was making similar tool joints a half century ago, although flash weld attachment in lieu of another threaded juncture of the drill pipe joint to the tool-joint segments has been employed by various manufacturers of drill pipe joints only in more recent years. API is abbreviation for American Petroleum Institute. This particular drill pipe, which is quoted in five different sizes (of which this is the middle one), has an outside diameter of 4 inches with a quoted minimum diameter of the internal upset tips thereof approximately 2¾ inches, although that internal diameter might be nearer the quoted flashwelded tool-joint segments bored to 2 13/16 inches with an outside diameter of 5¼ inches. A probable level for the flashwelding of a tip of the 4 inch outside diameter drill pipe to the "pin" of the tool joint segment **10'** is indicated by the two "Delta" triangles immediately above the designation "FIG. **32**" beside my drawing; but necessarily the midsection has been cut away from that segment of the flashwelded tool-joint, which is quoted as having a "tong space" 7 inches long, the length of the "tong space" for lower "box" **10** being 10 inches. In FIG. **32** the closure member **96** for core barrel **94** is cut away necessarily; but in FIG. **36** the core barrel **94** screwed onto the lower tip of the same closure **96** would be not quite 30 feet long to correspond with this "outer core barrel" member **10** (FIGS. **32, 35, 36, 37,** and **39**) usually about 30 feet in length, although such "outer core barrel" drill pipe **10** for the lowest joint in the pilot hole can be shortened as desired, when core barrel **94** is shortened accordingly, for (instead of relying on the weight of a core barrel **94** and an auxiliary compression spring **98.4** as illustrated in FIG. **29**) this nonrotating core barrel **94** in FIG. **32** alternatively is held down on core R by the novel lugs **35** illustrated in FIG. **32**, in which the lug arrangement (having 3 lugs **35** disposed at angles of 120° around the rotational axis of the core barrel) generally resembles the larger and much stronger dog arrangement shown in FIGS. **11, 12, 18, 18, 19, 20,** and **22** for holding down the rotating body member **1** in the much larger drill pipe **11**.

As shown in FIGS. **32** and **35** the three scotching lugs **35** are mounted on their respective pivot pins **33** so that the upper tips of those lugs **35** can hinge outwardly from the positions indicated by broken lines in FIG. **32** through the three corresponding holes **36** in cylindrical lifting sleeve **50**, until those three lug tips protrude into the conventional partially threaded annular space in tool-joint "box" segment **10** below the lower end of tool joint "pin" segment **10'**, above which end the tips of the three lugs **35** cannot move upward, until the driller chooses to pull the core barrel **94** and its inclosed R to the surface of the earth by the cable **60** indicated in FIGS. **33** and **34**, which correspond substantially to the grappling arrangements attached to the lower tip of cable **60** in FIGS. **15** and **16** with some modifications necessitated by having some much smaller parts that can slip vertically through the "internal upset" tip segments having an internal diameter of 2¾ inches described for the drill pipe members **10'** and **10** in FIG. **32**. Note in that FIG. **32** that it has not been necessary to modify the tool-joint members in any way from the dimensions quoted by a large manufacture, which will, however, make some modifications to suit the customer (according to its advertising), when such modifications do not cost too much in proportion to the potential market. In this connection it may be noted that the drill pipe joints **10'** and **10** employed as an "outer core barrel" for the long drill pipe of the smaller pilot hole (to be reamed later by arms **4** of body members **1** shown in FIGS. **1, 2, 3** and **24,25**) in FIG. **32** have a quoted wall thickness of thirty-three one-hundredths of an inch and have greater resistance to torque and tension than corresponding pipes **10** made of casing of the same outside diameter but ordinarily made of lower grade steel as well as less wall thickness.

Unlike the generally cylindrical body member **1** having a verticanal **1.0** through the center thereof in FIG. **2**, since the closure member **96** in FIG. **32** of core barrel **94**, into the upper tip of which that closure member is screwed (FIG. **36**), has to have no canal through the center thereof vertically, because all the necessary drilling fluid passes downward in the annular space between cylindrical core barrel closure member **96** and the larger diameter internal upset segments of drill pipe joints **10** and **10'**. The cylindrical closure member **96** in FIG. **32** (corresponding only in part to body member **1**, in which the three scotching dogs **35** are hingeably mounted in FIGS. **11, 12, 18, 19,** and **22**) is joined to the upper cylindrical segment **78** of that closure member **96** by a single bolt **79** inserted through a central vertical hole of slightly larger diameter in member **96** and having its upper threaded tip screwed into member **78** as shown in FIG. **32**. A flexible spacing washer **96.1** for convenience in adjusting the pivotal mounting of pins **33** of lugs **35** is inserted around bolt **79** between members **96** and **78** at line **35–35'**, which is the plane of horizontal cross-sectional FIG. **35**, in which the lower substantially cylindrical segments of those three lugs **35** can be seen mounted in the upper tip of closure member **96**. In FIG. **32** the outer halves of the three lugs **35** are shown extended through suitable orifices **84** in a cylindrical adjusting member **87**, which is vertically slidable with respect to cylindrical member **78** and to the upper tip segment of member **96** as well as with respect to a lifting tubular cylindrical member **50** (of the same outside diameter as core barrel **94** and its closure member **96**, shown as 2⅝ inches, because such tubing is widely used in the oil fields with an internal diameter of 2 inches, which is the maximum for recovering a core in an "outer core barrel" **10** of the size shown), whose lower internally threaded tip is screwed onto a threaded reduced diameter segment of closure member **96** as shown in FIG. **32**.

Lifting member **50**, one of whose functions is to serve as a means of lifting closure member **96** and core barrel **94** upward through the pilot hole "outer core barrel" drilling tube member **10**, as soon as the drill mechanism **91** shown in FIGS. **29** and **30** (by way of illustration) has settled downward over a core R of sufficient length to justify recovery of the rock segment on the end of a cable **60**, has substantially rectangular holes **36** (FIGS. **32** and **35**) cut in the lower wall thereof slightly above the level of the axes of pivot pins **33** in scotching lugs **35**, whose upper tips can retreat into the respective holes **36** (disposed at 120° intervals in tubular cylindrical lifting member **50** in FIG. **35**) as indicated by broken lines in FIG. **32**, showing one of the three recessions **80** in cylindrical member **78** for accommodation of lugs **35**, when the latter are in their upward positions, to which they are lifted (for subsequent removal of core barrel **94** and its core R at the election of the driller employing cable **60**) by the lower faces of suitably disposed holes **36** in cylindrical lifting member **50**, provided with a suitable grappling device (to be explained presently) for attachment of cable **60** shown in FIGS. **33** and **34** and explained generally in principle previously in connection with other FIGS. **15, 16,** and **15—16**.

Except when the core catching assembly of members **93, 94, 96,** etc. is being lifted by means of cable **60** from the hole being drilled, however, scotching lugs **35** tend to remain extended outwardly through holes **36** in tubular cylindrical member **50** just as far as possible within the limits of the walls of drill pipe sections **10** and **10'**, whose principal midsections (usually something slightly less than 30 feet in length) have an internal diameter of about 3⅜ inches as shown at the top of FIG. **32**, in which it can be seen that scotching lugs **35** even might tend to expand outwardly into the annular gap between every two joints of the drill pipe, when the core recovering assembly is falling through the drilling fluid in the "outer core barrel" drill pipe **10** (made up of multiple joints as indicated by FIGS. **32, 36,** and **37**), although further falling of that core catching assembly below the position shown with respect to two such tool-joint members in FIG. **32** would retract those lugs **35** automatically for free passage through the internally

upset tips of the tool-joint of the drill pipe **10**, until the core catching member **93** mounted on the bottom of core barrel **94** reaches its ultimate seat on the annular segment **91.1** of the annular drill bit **91**, at which time the lugs **35** must be disposed in the annular space between the two tip ends of tool joints **10** and **10'** as shown in FIG. **32**, whether the drill pipe section (illustrated in FIG. **32** as having an outside diameter of 4 inches, although some such drill pipes are larger and some are smaller) having the tool-joint **10** as shown in that FIG. **32** alternatively is short or long or even made up of two such 4 inch joints of conventional drill pipe.

When the core R is not being lifted in the drill pipe **10** by means of cylindrical member **50** (as will be explained further presently), scotching lugs **35** are held outward in their maximum outwardly extended positions by a coiled compression spring **88** within that member **50** (generally corresponding to tubular cylindrical retaining member **50** inclosing a coiled compression spring **88** in FIGS. **13** and **18**) provided with a short cylindrical tubular sleeve **89** therein, which is fixed with respect to the wall of lifting member **50** in its midsection and has fixed within it three spider arms **73.1**, whose inner tips are attached fixedly to the outer wall of an internally threaded tube **73** in the center of cylindrical member **50**. The upper tip of coiled compression spring **88** presses upward against short tubular sleeve **89**, and the bottom tip of that spring presses down continually on the upper end of cylindrical adjusting member **87**, having holes **84** in the wall thereof (as shown and described previously in other FIGS.) whose upper and lower faces respectively keep scotching lugs **35** hinged outward by suitable amounts, during the drilling process and at all other times, until the lower faces of the rectangular holes **36** in lifting member **50** (at the election of the driller controlling a cable **60** provided with my suitable grappling means) are raised and in turn raise the tubular cylindrical adjusting member **87** of lugs **35** in spite of any downward pressure of coiled compression spring **88** on the upper end of that adjusting member **87**.

To the upper tip of the inner wall of cylindrical tubular adjusting member **87** are fixedly attached, at intervals of 120° and midway between the 120° intervals of holes **84** in the wall of that cylindrical adjusting member **87**, three vertically disposed rods **85** nearly 5 inches in length, whose upper cylindrical tips are externally threaded and extend through corresponding holes in a circular plate **69**, above which are nuts **85'** screwed down tightly on the threaded upper tips respectively of those rods **85**, whose outer walls do not conflict with their vertical movements with respect to short tubular sleeve **89** in the lifting tube **50** or with the coiled compression spring **88** surrounding them. Lifting plate **69**, to which the upper tips of rods **85** are fixedly attached, has in the center thereof a cylindrical hole **69.0** of diameter sufficient for receiving freely the inwardly contracted grappling devices **67** attached to the restricted lower tips of vertically disposed rods **65**, whose upper tips are shown in FIGS. **33** and **34** as suitably attached fixedly (by means permitting easy removal from the tip of cable **60** by the drilling crew) to the lower tip of cable **60** for pulling the core barrel **94** and its inclosed remaining core R from the hole at any time without need to unjoint and remove the drill pipe joints **10** and **10'** (of whatever number and length) from the hole being drilled, whether it be 10 or 10,000 feet deep or even more, if cable **60** is long enough. On passing downward through the hole **69.0** in the center of lifting plate **69**, the four grappling devices **67**, which are tied tightly together by means of a strong string wrapped around the lower tips of their respecting lifting rods **65**, will fall on downward with considerable force (in spite of the drilling fluid in the drill pipe), until their lower suitably beveled tips reach a conical spreading member **72** integrally attached on the upper end of a vertically disposed threaded adjusting rod **72.1**, which is screwed into internally threaded cylindrical tube **73**, above and below which are screwed nuts **73.2** and **73.3** on the rod **72.1** whereby that rod and its integrally attached upper conical tip **72** can be suitably adjusted vertically at a suitable level with respect to the lifting tube **50** in which it is fixedly mounted, so that, as soon as grappling devices **67** on the lower tips of their lifting members **65** pass downward through central hole **69.0** of lifting plate **69** and come in contact with conical spreading member **72** and thereby break the restraining string **68**, those grappling devices **67** on the lower tips of lifting members **65** will tend to spread apart to the naturally separated positions of those four members **65** shown in FIGS. **33** and **34** with square cross sections.

The lower face of lifting plate **69** has a suitable conical slightly downward extension adjacent the central hole **69.0** therethrough, so that, when the driller starts to raise cable **60** by means of his reel (well-known to the art for such purposes) at the head of the well, the grappling devices **67** will have their outer tips caught by that conical surface of the lower face of lifting plate **69**, which will not permit grappling devices **67** to pass upward through that hole **69.0** in the center of plate **69**, until the mechanism is raised to the top of the ground, at which time the drilling crew can simply use their hands to pull the lifting rods **65** together to permit their disengagement from the core-catching assembly.

But note in this last connection that, when the cable **60** has raised the lifting plate **69** and the rods **85** fixedly attached thereto (inside the tubular cylindrical lifting member **50**), the tips of those rods **85** will be raised from their almost extreme lower positions shown in FIG. **32**, until those rods **85** press against the annular plate **70**, which is screwed into the internally threaded upper tip of tubular cylindrical lifting member **50** a suitable distance (by means of suitable notches **70.1** in the upper tip of annular plate **70**), and which has in the center thereof a hole only very slightly larger than the hole **69.0** in the center of lifting plate **69** for easy downward passage of grappling devices **67** therethrough. Therefore, lifting of the four rods **65** by means of cable **60** will raise plate **69**, rods **85**, and thereby the annular plate **70**, which in turn will raise tubular lifting member **50** and all the core catching and retaining members attached thereto—but without in any way disturbing the annular drill bit **91** attached to the lower tip of the drilling pipe **10** as previously illustrated in FIG. **29** (as well as in FIGS. **37**, **45**, and **53** to be explained later herein), since such annular drill bits mounting diamonds **100** at times may drill as much as several thousand feet in comparatively soft rocks without replacement of the diamonds, which often are injured during removal and reinsertion in the well, and whose cost is generally estimated as having been about 20 times that of rolling cutter bits, which never have been designed for workable use in drilling around cores R as illustrated in my FIGS. **8**, **9**, and **10**. In FIG. **35** the rods **85** are shown by broken lines as being almost square in cross section; but in FIG. **32** it can be seen that the midsections of those rods **85** are reduced in thickness in order to insure adequate room for outward movement of the grappling tips **67** on lifting rods **65** beneath the lifting plate **69**, and those rods **85** obviously can be made alternatively arcuate in cross section to make them thinner for even greater clearance of grappling tips **67**, for the three rods **85** have to lift only the adjusting tubular member **87** and thereby the outer tips of lugs **35** without having to lift the tubular cylindrical member **50**, to which closure member **96** of core barrel **94** is fixedly attached as indicated in FIGS. **32**, **36**, **37**.

Note in FIG. **32** that the upper tip of cylindrical lifting tube **50** has a conical upper face **50'**, and that annular plate **70** screwed into the upper tip of that tube **50** has a corresponding inwardly and downwardly sloping conical face, so that the beveled lower faces of grappling members **67**, when held together tightly by string **68**, will slip readily into the hole in annular plate **70** and thence into hole **69.0** in the center of lifting plate **69**, the lifting rods **65** being sufficiently long above their tips having reduced cross sections respectively that they all tend, when tied together by strong cord **68**, to remain substantially vertical in the drill pipe at all times. But to insure that the grappling members will start into the conical upper face **50'** of lifting tube **50** to begin with, when they fall

downward (attached to the lower tip of cable **60** as shown in FIGS. **33** and **34** and having sufficient weight by virtue of their length to pull down rapidly that cable **60**, whose upper tip is attached to a suitable reel at the head of the well) inside the jointed drill pipe **10'** having a restricted "internal upset" segment adjacent the tool-joint segment thereof at its lower tip, it is essential that the top of the lifting tubular member **50** shown in FIG. **32** be suitably below (at least 1 inch below as shown) the tip of that restricted "upset," at which level the diameter of the drill pipe gradually increases upwardly, until it reaches the long midsection of uniform internal diameter, which of course extends all through the drill pipe joint with the exception of the "internal upset" tips thereof. Since approximately 6 inches has had to be cut away from the tong segment of tool joint segment **10'** in FIG. **32**, it can be seen that the upper end of tubular lifting member **50** is more than enough below the conical segment **10.0'** of the "upset" segment of that tool joint segment **10'** in that FIG.; and the same arrangement of course works just as well in a pipe joint **10'** having an "external" upset segment, flashwelded or otherwise. The point here is that I have made an assembly for the core barrel **94** that will work in all kinds of drill pipe for drilling the pilot hole, the "internal upset" type of drill pipe being the most difficult (previously impossible) to employ with my means of retrieving the core barrel **94** for recovery of the core R therefrom without having to unjoint the drill pipe for the pilot hole PH except to replace the diamonds in the annular drill bit **91** on the lower tip thereof, not to mention again that I can remove the entire drilling mechanism through the larger casing drill pipe **11** to replace diamonds in the annular bit **91.1** of the core drilling mechanism as well as the diamonds in arms **4** hingeably mounted on body member **1**.

More complete insurance that the grappling tips **67**, shown with suitable angles in FIG. **32**, will not hang on the upper end of lifting tubular member **50** is afforded by three vertically disposed narrow spacing vanes **50''**, which are disposed at angles of 120° from each other around the axis of that tubular member **50**, to which each is attached fixedly, and which they all serve to keep in the center of drill pipe tool-joint **10'** having an internal wall radius only slightly larger than the outer walls of those vanes **50''**, which are not disposed at the same level in order that flow downward of the drilling fluid around lifting tubular member **50** may be as free as possible in that restricted area of the "internal upset" drill pipe **10', 10**. In order to increase flow of such drilling fluid inside the drill pipe members **10'** and **10** in these two joints of the drill pipe adjacent the bottom of the pilot hole (which hole in some instances might even be as large as desired for later production of oil, gas, etc. by those drilling the pilot hole, particularly in in unexplored "wildcat" territory), it is possible (without having to ream out the internal upset segments at the tips of all the drill pipe joints) to make the outside diameter of core barrel **94**, its lower core catching cylindrical segment **93** (FIG. **37**), its closure member **96**, and the lifting member **50** fixed thereto above it slightly smaller than the outside diameters of 2⅜ inches, which however allows adequate flow of the drilling fluid during the drilling operation past those above mentioned members inside the two lower joints of the drill pipe **10** having a maximum outside diameter of 5¼ inches, which is about the largest size of drill pipe tool-joint permissible for passage through the shoe member segments **6.1** of a followup underreaming casing-drill-pipe having an outside diameter of 6⅝ inches with an internal diameter slightly less than 6 inches, as illustrated in FIGS. **1, 2, 3** and **24, 25**. Note, however, in FIG. **37** that the outside diameter of the core-catching member **23** screwed on the lower tip of core-barrel **94** can be at least almost as large as the minimum internal diameter of the pilot hole drill pipe string through which that cylindrical member **23** has to slip, for, as will be explained hereafter in connection with FIG. **37**, the drilling fluid can pass downward around that core-catching member **93** in the larger cylindrical canal **91.0** of the drill bit member **91** beneath the lower end of the pilot hole bottom drill pipe tool joint **10**.

FIG. **36**, which is a downward continuation of FIG. **32** (with about 2 inches being left out of the tong segment of drill pipe tool-joint **10** and the inclosed core barrel upper closing member **96** within it to conserve space for the drawings), shows one of three spacing vanes (undesignated) attached to the upper tip of core barrel **94** at angles of 120° from each other within the tool-joint "box" segment **10** just as described above in connection with the three vanes **50''** attached to lifting tube **50** within tool-joint "pin" member **10'**, although it is not necessary to have such multiple spacing vanes in both of the tool-joint segments **10'** and **10** in order to keep the core barrel assembly and its lifting tube **50** disposed in the center of those tool-joint members for the purpose described above. FIG. **36** also shows a nut **79'** screwed onto the lower threaded tip of bolt **79**, whereby closing member **96** is joined fixedly to cylindrical upper segment **78** thereof, thereby permitting the three scotching lugs **35** to be pivotally mounted between those two members **78** and **96** and with their upper tips extending through holes **84** and **36** respectively in cylindrical tubular members **87** and **50** (without any necessary but impossible rotation in assembly between the slots **80** in mounting member **78** and the respective holes **84** and **36** in tubular cylindrical members **87** and **50** shown in FIGS. **32** and **35**).

FIG. **36** also illustrates that, when the tool-joint "box" segment **10** (of which the upper portion is shown in FIG. **32**) alternatively is to be welded to the long uniform midsection of the tool pipe joint having an outside diameter of 4 inches with a wall thickness of about thirty-three one-hundredths of an inch, it is possible to cut off the "internal upset" of the latter and flash weld the section of pipe having a straight internal wall directly to the tool-joint segment **10** forming the upper tip of that joint of drill pipe, so that a 90° annular shoulder will be formed as indicated by broken lines in FIG. **36**. With a suitable modification of length of core barrel **94**, the scotching lugs **35** then alternatively can be disposed against that novel created annular shoulder in the drill pipe **10** to hole the core barrel **94** down with its lower core-catching member **93** substantially against the conical face of annular drill bit segment **91.1** of the bit head **91** drilling the pilot hole around core R. But such an alternative construction of an annular shoulder in the upper part of drill pipe joint **10** is inferior to that shown in FIG. **32**, simply because closing member **96** and the scotching lugs **35** shown in FIG. **32** are so disposed with respect to the annular space between the two drill pipe tool joint segments **10'** and **10** that it is not necessary to create any such annular shoulder against which to scotch the lugs **35** extending through holes **84** and **36** in tubular cylindrical members **87** and **50** respectively.

Cylindrical tubes having an internal diameter of 2 inches (or less and with wall thicknesses of three-sixteenths and also one-eighth inch) come on the market in lengths of only about 20 feet, while the drill pipe joints with their tool-joint tips are usually about 30 feet in length, depending on the style of their tips. But it is possible to secure suitable lengths of the core barrel **94** for use with a 30 foot length of drill pipe simply by splicing core barrel segments about 10 feet in length (using conventional internally threaded pipe couplings as illustrated by half of such a threaded coupling **94.1** in FIG. **36**), because those pipe couplings **94.1** will have an outside diameter considerably less than the internal diameter of the midsection of the drill pipe having an outside diameter of 4 inches as illustrated in FIG. **36**, which also illustrates that the internal core barrel **94'** made of thin sheet metal may be made alternatively in multiple segments as shown to permit shipment therein of the rock cores in suitable lengths for easy handling without need of removing the rock cores from such core barrel segments of corresponding length, until those cores reach a geologist inside those light core barrel segments **94'**.

FIG. **37** illustrates novel features in a diamond mounting annular drill bit (generally resembling the pilot hole drilling mechanism shown in FIGS. **29** and **30**) screwed onto the conventional tool-joint member **10** integrally attached to the lower end of the 4 inch drill pipe segment (of suitable length) shown in part in FIG. **36**. In FIGS. **37** and **38** the multiple

diamonds **100** are shown mounted for the most part in **12** steel segments, each of which is attached by horizontal bolts **91.4** and **91.5** to an annular generally cylindrical drill bit framework **91**, which quite simply is cut (with suitable modification) from the upper segment of the "box" **91** of a conventional tool-joint screwed onto the lower "pin"segment **10** of the lowest joint of rotatable drill pipe (in the pilot hole), in whose cylindrical central canal **10.0** are mounted the core barrels **94** and **94'**, which of course do not rotate during the drilling process, the tool-joint "pin" **10** in FIG. **37** being the conventional lower tip of the fragmentary drill pipe **10** shown in FIGS. **36**, **35**, and **32** just described and having an outside diameter of 5¼ inches. These **12** steel alloy segments **91.1** having vertical cross sections that are generally J-shaped (instead of having each such segment formed and machined integrally) alternatively may be formed of a lower generally hemicylindrical member **91.1**, to which is welded a vertical strap stem **91.6** having two holes therein for accommodation of flathead bolts **91.4** and **91.5** extending inwardly through each such vertical strap three-eighths inch thick and thence through corresponding threaded holes in the annular bit member **91** as shown in FIG. **37**. The 12 upper bolts **91.5** extend through generally cylindrical bit member **91** into its central canal, which has been bored out of the original "box" of the conventional tool-joint to make that canal **91.0** about 3⅜ inches in diameter down almost one inch from the remaining suitable tool-joint threads of that "box" **91**; and the inner tips of those bolts **91.5** are bradded slightly (or alternatively touched with an electric arc-welding rod suitably) to secure them in their respective holes in annular bit member **91**, which has its canal **91.0** bored out conically at an angle of 30° from vertical to meet a lower vertical cylindrical hole through the center of the "box" having a diameter of 2⅞ inches, which extends downward only a quarter of an inch until it is expanded horizontally to a diameter of 3 inches for accommodation therein of the generally cylindrical tubular insert **91.7**, in whose inner face some of the diamonds **100** are mounted for reaming out the rock around the rock core R remaining in the center thereof, as indicated previously in connection with FIGS. **29** and **30**. Each of the lower bolts **91.4** is long enough to have its conical inner project into a corresponding hole in the generally cylindrical tubular insert **91.7** mounting said diamonds **100**, so that this insert **91.7** is held up against the slight one-sixteenth inch horizontal annular shoulder of "box" member **91**, when the drill bit assembly is lifted from the pilot hole to remove the core R.

But it must be mentioned in connection with FIG. **38**, which shows the "box" member **91** of FIG. **37** from beneath, that tubular insert **91.7** is not absolutely cylindrical, as one might assume from a too hurried glance at FIG. **37**. Note from FIG. **38**, which looks upward at the diamonds **100** mounted in J-shaped segments **91.1** attached to annular "box" **91** from beneath, that in the interior cylindrical face of insert **91.7** there are vertical canals **91.8** between the inner faces of the above described J-shaped steel segments **91.1**; and these 12 vertical canals **91.8**, made for the purpose of carrying drilling fluid downward around core R, are extended on up vertically by milling corresponding notches **91.8** in the inner cylindrical face of insert **91.7** to the respective radial depths indicated by the vertical broken lines adjacent the inner tips of bolts **91.4** in FIG. **37**, in which the surfaces of those canals correspond generally to the surfaces of similar canals in annular drill bit member **91.1** indicated by broken lines **91.10** in FIG. **29**. Likewise in FIG. **38** the 12 generally corresponding vertical canals **91.2** are indicated as being formed in the inner wall of tubular "box" member **91** (as indicated also by the broken vertical lines **91.2** in FIG. **37** to indicate the outer walls of such vertical channels) permitting drilling fluid to flow straight downward in those vertical canals **91.2** outside the inserted tubular generally cylindrical member **91.7**, all of those canals in FIG. **38** thus joining their corresponding small canals indicated by broken lines in FIG. **37** to flow outwardly (and radially as indicated in FIG. **38**) between the J-shaped strong steel segments **91.1** having multiple diamonds **100** mounted therein as shown schematically and thence upward in the corresponding canals **91.9** shown in FIG. **38** and indicated by broken lines in FIG. **37**, in which those broken lines are simply downward extensions of the original outer cylindrical wall of "box" member **91**, in which outer wall were milled the 12 slots for vertical segments **91.6** of those J-shaped segments having lower sections **91.1** that have semicircular lower faces as shown in FIG. **37**. Note, however, that (as indicated by the broken circular lines **91.10** at the tops of the radially disposed canals between the J-shaped members **91.1**, which are thus held in between the vertical notch walls of such downward protrusions of the annular "box" member **91**, which thus keeps those J-shaped members **91.1** from slipping rotationally during the drilling process. Also note that lower segments **91.1** of the J-shaped members have slight upward projections inside the generally cylindrical tubular member **91**, so that all those 12 J-shaped members **91.1**, in which diamonds **100** are mounted, cannot slip outward radially, even if they were not held to some extent by the bolts **91.4** and **91.5**, whose primary function is to keep the J-shaped members **91.6**, **91.1** contained in their corresponding slots in "box" member **91**. The J-shaped members (each composed of segments **91.1** and **91.6** integrally attached to each other by suitable means such as welding) thus are held fixedly mounted by suitable notches in the lower tip of tubular cylindrical drill bit member **91**, so that those J-shaped members (in which diamonds **100** are mounted individually than in the entire annular drill bit at one time) are very fixedly held with respect to that bit member **91**, against which they are pressed by the multiple diamonds **100** mounted respectively therein during the drilling process.

But, when it is desired to pull the drill bit from the pilot hole being drilled (to remove a core section or to replace some of the diamonds **100** in the annular drill bit **91**), there is no strain on those J-shaped members mounting said diamonds **100** therein as schematically illustrated, for the 12 bolts **91.4** having their respective inner conical tips extending into the outer wall of generally cylindrical insert member **91.7** (but having vertical slots **91.8** therein corresponding to the 12 vertical slots **91.2** in tubular member **91**) serve effectively to lift that insert **91.7**, which in turn lifts the core-catching member **93**, whose outside diameter is just barely small enough to permit it to be inserted from above through the central hole **10.0** of drill pipe member **10**, although alternatively the diameter of core-catching member **93** (corresponding generally to the core-catching device **93** previously described in connection with FIG. **29**) can be increased slightly inside the enlarged canal **91.0** (made large enough to carry adequate drilling fluid downward around cylindrical member **93**), if the core barrel assembly **93,94** inside drill bit **91** be inserted from beneath, after the generally cylindrical "box" member **91** is unscrewed from the drill pipe "pin" segment **10**, into which it will be rescrewed subsequently, after the core barrel segments **93,94, 96**, etc. have been inserted in the annular drilling mechanism of the core drill for the pilot hole. Note in FIG. **37** that the conical lower face of core-catching member **93** is almost down on the corresponding face of the generally cylindrical (except for the above mentioned vertical slots **91.8** and **91.2** therein for carrying drilling fluid downward) insert **91.7**. But during the drilling process the scotching lugs **35** shown in FIG. **32** will permit closure member **96** and its core barrel **94** fixedly attached thereto to slip upward a fraction of an inch in the annular space beneath the lower end of tool-joint member **10'** immediately above those three scotching lugs **35**. And thus a greater amount of drilling fluid can pass between the lower conical face of core-catching member **93** of core barrel **94** and the upper corresponding face of insert **91.7** mounting a limited number of diamonds **100** that have to be cooled on the interior faces between the slots therein, which also will carry some of the rock cuttings downward to pass through the canals **91.10** beneath the annular "box" member **91**. But the core-catching member **93** will still remain in the center of the rotating drill bit assembly mounted in cylindrical "box" **91**,

for three vanes 94.1 (at intervals of 120° from each other) are fixedly attached around the lower tip of core barrel 94 at varying levels inside the cylindrical canal 10.0 within tool-joint "-pin" segment 10 of the drill pipe into which bit segment 91 is screwed, it being understood that the threads of said tool-joint shown only schematically may be any of those now being used and available on the market.

At the present time it is the general practice to mount all of the diamonds 100 on an annular drill bit at one time in a single mould, and the present applicant makes no claims as to those methods of mounting diamonds on such a bit by a sintering process known to the art for many years. But it is obvious from FIGS. 37 and 38 that I have illustrated a means whereby the diamonds 100 can be mounted in moulds adapted to each of the J-shaped attachable and detachable members individually with great facility and moreover without necessity to remount all the diamonds, when just a few of them on any one or more of the J-shaped segments may have been worn out or otherwise damaged more probably. And it is a comparatively simple process to make a mould whereby the diamonds 100 in the insert member 91.7 can be mounted in the central almost cylindrical cavity thereof, although the need for any replacement of the diamonds 100 in that insert 91.7 would be minimum. But there always is danger of unusual damage to any of the other diamonds 100, which also will not wear out completely simultaneously. Since the clearance of the diamonds 100 on the outsides of J-shaped members 91.6 in FIGS. 37 and 38 would be very little, if that drill bit assembly is inserted through drill pipe shoe members 6.1 illustrated in FIGS. 24 and 25 (as well as FIGS. 1, 2, and 3), it has been found expedient in FIG. 37 to illustrate a cup 101 conveniently inserted over those exterior diamonds 100 before inserting the drill assembly into the larger drill-pipe-casing 11 having an inside diameter only very slightly less than 6 inches. The diamonds 100 of course will cut the bottom out of the cup 101 (conveniently made of extruded thermoplastic material) almost instantaneously, when the pilot hole drill 91.1 reaches the bottom of its hole PH under the great pressure necessary for making the diamonds 100 cut various kinds of sedimentary rocks in exploring for oil, gas, sulfur, etc.

FIG. 39 is a fragmentary vertical cross section through the same tool-joint segments 10 and 10′ of the pilot hole drill pipe shown in FIG. 32 in order to show (in view of the fact that all of the drilling fluid has to pass downward inside the outer drill pipe around rather than partially through closing member 96 of core barrel 94, and that the lifting assembly mounted in tubular lifting member 50 in FIG. 32, while most convenient in operation, is slightly complicated in construction) an alternative means of lifting the core barrel 94 (and the core R caught therein), having a generally cylindrical closure member 96 of any suitable length to give sufficient weight to press downward over core R in the drilling process, which core barrel 94 in this instance does not necessarily have to have the top of its closure member 96 located at the plane of juncture of tool-joint members 10 and 10′ of the pilot hole drill pipe, although for convenient comparison diagrammatically the crest of closure member 96 in FIG. 39 actually is shown approximately at said juncture plane of those tool-joint members 10 and 10′ at line 40–40′, at which FIG. 40 (to be described later herein in connection with FIGS. 43,44) shows a horizontal cross section of all the alternative members free to travel vertically in the central canal 10.0 of the entire drill pipe of the pilot hole. Note in FIG. 39, however, that the core barrel 94 is of such length that its three spacing vanes 94.3 (disposed at angles of 120° around the vertical axis of core barrel 94, but not at exactly the same level in order to permit passage of the maximum amount of drilling fluid more freely in the limited annular space around said core barrel 94) all must be located within the "internal upset" segments of the drill pipe joints (including the tool-joint segments 10 and 10′ flash welded thereto and having substantially the same internal diameter, only one-sixteenth of an inch more than the quoted minimum inside diameter of those "upset" segments at the tips of said 4 inch drill pipe), in order that the closure member 96 of core barrel 94 must remain substantially in the center of the drill pipe for reasons that will be evident presently. Spacing vanes 94.3 attached to core barrel 94, however, do not have to be located during the drilling process within the internally restricted segments of the drill pipe tool-joints 10, 10′ in all instances, for in FIG. 39 is shown one of three such corresponding spacing members 96.4 mounted around the closure member 96 for the same purpose of keeping that closure member 96 and its fixedly attached core barrel 94 in the at least approximate center of the drill pipe that is easily rotatable around it, there being no scotching lugs 35 in this instance to tend to rotate the closure member 96.

In FIGS. 39 and 40 it can be seen that there is fixedly attached to the upper surface of generally cylindrical closure member 96 a short cylindrical segment 96.1, to whose upper end is integrally attached a conventional spear segment 96.2 having a conical upper face and a lower horizontal cylindrical annular face having a diameter slightly greater than the connecting cylindrical segment 96.1 and thereby providing a substantially horizontal annular shoulder 96.3, which serves as a means of catching and retaining a generally circular resilient metal spring member 67.1 having a suitable width notch provided in one side thereof permitting said almost circular spring 67.1 to pass over the spear segment 96.2, when that resilient spring 67.1 is pressed downward beneath a generally cylindrical member 65.3 of the same outside diameter as closure member 96 and having a conical cavity 65.4 in the lower tip thereof loosely accommodating the conical spear 96.2, when cylindrical member 65.3 is pressed downward over that spear. The lower tip of generally cylindrical member 65.3 is reduced in diameter and threaded externally for accommodation of an internally threaded upper tip of a tubular member 65.5 having the same maximum outside diameter as cylindrical member 65.3 of suitable length, which can be made longer than shown for the accommodation of a suitable wrench well-known to the art. The lower tip of tubular cylindrical member 65.5 has its internal diameter reduced to such extent that, while said member 65.5 will pass downward over the conical spear member 96.2, the circular resilient spring 67.1 having a horizontal upper face, which becomes caught on the horizontal lower annular shoulder 96.3 of that spear, cannot thereafter pass through the central hole of reduced diameter in the circular lower tip of grappling member 65.5, which thereby completes a kind of generally conventional "fishing" assembly known in the oil fields as an "overshot" device. But note that the internal face of circular resilient spring 67.1 is conical and thus has a greater diameter at the bottom than at the top, in order that said spring 67.1 will tend to expand its diameter and thus pass down over conical spear member 96.2 quite easily under sufficient pressure. And the outer lower face of spring 67.1 is also inversely conical, so that spring 67.1 tends to have its diameter reduced slightly around cylindrical segment 96.1 beneath horizontal shoulder 96.3, when metal having a lower melting temperature, so that, when tubular member 60.1 is screwed onto tubular member 65.2, it forms a suitably strong means of attaching cable 60 to said member 65.2 and the other members attached thereto as explained previously.

The externally threaded lower tip of cylindrical closure member 96 shown in FIG. 39 is screwed into the internally threaded upper tip of core barrel 94 which extends through the uniform midsection of the drill pipe 10 joint having an outside diameter of 4 inches (except for the tool-joint tips thereof, as explained previously in connection with FIGS. 36 and 37). In FIG. 39 there is room enough on the sheet to show all of an internally threaded tubular coupling member 94.2 whereby the external threaded adjacent sections of core barrel 94 are joined together inside a section of the 4 inch drill pipe in which the internal diameter is sufficient to permit easy passage downward of the drilling fluid around the pipe coupling 94.2 inside said drill pipe 10, the outer diameter of the core barrel coupling member 94.2 being small enough to

permit easy vertical passage thereof through the central canal 10.0 of the "internal upset" tip segments thereof at least about 2⅞ inches in diameter. FIG. 39 also shows that sections of the light inner core barrel 94', which are vertically slit at one side thereof, have notches in the adjacent tips thereof whereby the slits of one section of that inner core barrel 94' are disposed 180° from the corresponding slit of the adjacent section, so that there is no tendency for the sections to pass into each other, because they all fit rather snugly (but not tightly until expanded by the core R on occasion) into the larger cylindrical tubular core barrel 94.

It would be possible to invert the special "overshot" or grappling arrangement shown in FIGS. 39 and 40 to connect the spear segments 96.1, 96.2, and 96.3 to the cylindrical member 65.3 while simultaneously making the conical cavity 65.4 for the loose accommodation of that inverted spear in the upper end of cylindrical closure member 96 of core barrel 94. But such an inverted arrangement would be impossible in operation, because sediment in the drilling fluid coming down inside the drill pipe member 10' would tend to accumulate inside the inverted cavity 65.4 during the drilling process, so that the alternatively conical spear 96.2 could not enter spring 67.1 is drawn down later in lifting said spear, as the spring 67.1 simultaneously is drawn down to some extent into the conical upper face of the reduced lower tip of grappling member 65.5 being pulled upward by cable 60 for recovery of the core R in core barrel 94. The "overshot" device thus provided with special features will lift great weight and will break loose the rock core R (shown as having a diameter of almost 2 inches) by means of core-catching member 93, which is of small enough outside diameter (as shown in FIG. 37) that it can pass upward through the restricted "internal upset" tip segments of drill pipe tip members 10 and 10'.

Note in FIG. 39 that there is mounted on cylindrical grappling member 65.5 a spacing vane 65.7, which is one of three such vanes that tend to keep said grappling member 65.5 in the center of the drill pipe at the sections thereof having reduced diameter, so that spear segment 96.2 must pass most readily through the lower tip of member 65.5 and into the cavity 65.4 of cylindrical member 65.3, when that member 65.3 falls with suitable force even with the lower tip of cable 60 attached thereto. Onto the externally threaded upper tip of cylindrical member 65.3 is screwed the internally threaded lower tip of a suitably long cylindrical tubular member 65.1, which also has mounted on its external lower tip multiple spacing vanes 65.8, which tend to keep it in the center of the adjacent tool-joint segment 10'. Tubular member 65.1 is filled with sufficient pieces of heavy material (conveniently pieces of metal, rocks, and sand, not shown) to give it sufficient weight to draw cylindrical member 65.3 (of the same outside diameter) and the members connecting it to the lower tip of cable 60 downward over spear member 96.2 to be retained thereby. The internally threaded upper tip of tubular member 65.1 is screwed onto the lower externally threaded reduced tip of a cylindrical member 65.2 of suitable considerable length to add more weight as needed; and the externally threaded reduced upper tip of that member 65.2 is screwed into the tubular cylindrical lower segment 60.1 of an inverted cup having a cylindrical closure at the top thereof having a hole in the center thereof through which the lower tip of cable 60 is passed before attachment of the cup to the cylindrical member 65.2. The lower tips of the metal wires forming the conventional cable 60 are flared out inside the cup, which then is filled with melted such an inverted conical cavity 65.4 in the upper tip of closure member 96 readily, if at all on account of such accumulated sediment.

The same kind of a spear having members 96.1, 96.2, and 96.3 is shown in FIG. 41 with those spear members disposed just as in FIG. 39. But in FIG. 41 a portion of the cylindrical closure member 96 of core barrel 94 is cut away to make room on the same sheet for showing other features of an alternative device attached to the threaded lower tip of a different closure member 96 whereby, during the drilling process, core barrel 94 is held down with slight resilience by three scotching lugs 96.35 mounted similarly to the way in which lugs 35 are shown mounted at the top of cylindrical closure member 96 in FIG. 39, but with these alternative lugs 96.35 in FIGS. 41 and 42 having their upper tips extending out beneath an alternative annular shoulder formed at the level at which the tool-joint tip of the drill pipe 10 in the pilot hole PH is flash welded to the straight-wall midsection of the drill pipe segment having an outside diameter of 4 inches, the upper "internal upset" tip of that long midsection (slightly less than 30 feet for instance) being omitted entirely—by the original pipe fabricator or by the persons fabricating this alternative drill pipe joint 10 from a conventional such drill pipe joint. The plane of such alternative flash welding (in lieu of any other kind of welding available) is indicated in FIG. 41 by the broken line at the two Delta triangles conventionally indicating a horizontal plane of such flash welding. In FIG. 41 all the members providing limited resiliency and other special characteristics for the linkage between the cylindrical member 96 mounting spear point 96.2 and the core barrel 94 at the bottom of the sheet have the numeral 96 as a common component thereof to indicate that they all are a part of that novel resilient linkage, which also enables the core barrel 94 to remain fixed rotationally with respect to the core R within it, while the three lugs 96.35 rotate with the drill pipe 10 and its substantially horizontal annular shoulder, against which the upper outwardly extended tips of those lugs 96.35 normally might remain in contact during the drilling process, since the core R may have some friction holding core barrel 94 up to some extent, even if core R is cut slightly smaller than the diameter of core barrel 94' inside core barrel 94 by the diamonds 100 mounted in the annular drill bit in FIG. 37.

As may be seen from FIG. 41 and its horizontal cross section in FIG. 42, the three scotching lugs 96.35 have their respective pivot pins 96.33 pivoting in suitable recessions 96.35' in parallel circular plates 96.86 and 96.87 respectively above and below those pivot pins 96.33. Such plates are easily stamped out as a means providing suitable bearings for the respective tips of pivot pins 96.33; and a circular spacing plate 96.88 has been shown both above and below said mounting plates 96.86 and 96.87 as means securing exact adjustment of the pivot pins 96.33 with respect to the horizontal annular shoulder against which the upper tips of scotching lugs 96.35 are to have their upper tips disposed, when the lower tip of core-catching member 93 mounted on the lower tip of core barrel 94 (FIG. 37) is resting almost on the annular drill bit below it, which is to say on the tubular insert 91.7 in FIG. 37.

But the presently to be described assembly at the upper tip of core barrel 94 shown in FIG. 37 provides for means operating vertically whereby scotching lugs 96.35 are released from the said annular horizontal shoulder in drill pipe segment 10, when it is desired to pull the entire core barrel assembly upward through the drill pipe in the pilot hole by means of a cable 60 attached to the spear 96.2,96.3,96.1 of cylindrical closure member 96 of core barrel 94 at the bottom of FIG. 41. Onto the lower tip of cylindrical member 96 at the upper part of FIG. 41 is screwed the internally threaded upper tip of a tubular cylindrical member 96.5 having rigidly attached to its outer wall three spacing vanes 96.4 whereby said cylindrical tubular member 96.5 is kept in the center of tool-joint segment 10. About halfway down toward the bottom of cylindrical member 96.5 less than 6 inches long there is fixedly mounted therein (conveniently by means of pins 96.51 secured in small holes in the wall of tubular cylindrical member 96.5) a rigid short cylindrical diaphragm 96.6 having a hole 96.7 in the center thereof, through which is slidably mounted a substantial vertically disposed rod 96.8 (less than 5 inches in length), on whose upper threaded tip is screwed and secured a nut 96.81. Beneath that nut there is mounted on cylindrical rod 96.8 an inverted cylindrical cup 96.61, in which there is loosely mounted around rod 96.8 a coiled compression spring 96.62, whose lower tip rests on diaphragm 96.6 and keeps spring 96.62 under some compression to try to

raise cup 96.61 (easily movable with respect to the spring having its upper tip mounted therein) and thus cylindrical rod 96.8 having the nut 96.81 secured on the upper tip thereof. But rod 96.8 cannot rise more than a fraction of an inch, because below the lower face of diaphragm 96.6 a small suitable distance the diameter of cylindrical rod 96.8 is reduced slightly, thereby providing an annular shoulder against which there is fixedly pressed an originally general cylindrical member 96.83 of suitable thickness (nearly three-fourths of an inch) having a hole in the center snugly fitting the upper part of the lower segment (not quite 2 inches in length and approximately five-eighths inch in diameter) of vertically disposed rod 96.8 having its lower threaded tip screwed securely into a hole in the center of the upper tip of a generally cylindrical member 96.82, whose upper half is slidable inside the lower tip of tubular member 96.5, and whose lower half is of the same outside diameter as that tubular member 96.5 and core barrel 94. Rod 96.8 is screwed into lower cylindrical member 96.82 so tightly that its small horizontal annular shoulder forces members 96.82, 96.83, 96.86, 96.87, and 96.88 together as a single fixed unit, for there are three vertical holes in all of those members (intermediate the three sockets for the lower tips of respective scotching lugs 96.35 as shown in FIG. 42) in which holes respectively are inserted small cylindrical pins 96.89 (FIGS. 41 and 42), which keep all of the aforesaid generally cylindrical members from rotating with respect to each other around the axis of rod 96.8, which holds them together. Disposed at angles of 120° from each other there are formed in the outer wall of member 96.83 three notches 96.80, which accommodate respectively the three scotching lugs 96.35, when the upper tips of those lugs recede respectively into three suitably shaped orifices 96.84 in the wall of tubular member 96.5 (as indicated by broken lines for one of the three duplicate pins 96.35 in FIG. 41), when the outer halves of lugs 96.35 are raised by the lower faces of rectangular orifices 96.84 through the wall of tubular member 96.5, whenever that member 96.5 is raised with respect to hinging pivot pins 96.33 by means of the spear member 96.1 connected to the cable 60 by means illustrated schematically in FIGS. 39, 40. It can be seen from FIG. 41 that there will be no strain whatever on hinge pins 96.33 in the lifting of the core barrel 94 by means of cable 60, for each of the scotching lugs 96.35 simply is pressed upward and inward against the top of the respective notch 96.80 in generally cylindrical member 96.83, which thereby raises the entire core barrel assembly by its lifting of central rod 96.8 and all the other cylindrical members attached thereto, although cylindrical diaphragm 96.6 fixedly mounted in tubular member 96.5 is vertically movable with respect to cylindrical rod 96.8 because the hole 96.7 in the center of that diaphragm is slidable with respect to that central connecting rod 96.8. But at all other times (except when the cable 60 is pulling upward on spear 96.1, 96.2, 96.3) the three duplicate scotching lugs 96.35 have their upper tips pressed outward just as far as possible by means of the upper faces of rectangular orifices 96.84 in tubular member 96.5 held down with respect to rod 96.8 and the members fixedly attached thereto by means of coiled compression spring 96.82 as previously explained. In FIG. 42 the three spacing members 96.4' have been crosshatched to indicate that they keep cylindrical tubular member 96.5 centrally disposed with respect to the broken circular line indicating a restricted " internal upset" section of the inclosing drill pipe 10, but actually core barrel 94 is made of such length that those three spacing vanes 96.4' will be slightly staggered in their levels with respect to each other in the upper "internal upset" restricted tip section of drill pipe joint 10. And additionally the three duplicate scotching lugs 96.35 also tend to keep their entire assembly in the center of drill pipe 10, because the coiled compression spring 96.62 is acting on all of those scotching lugs 96.35 simultaneously by means of the upper faces of rectangular orifices in the wall of tubular cylindrical member 96.5.

The lower half of cylindrical member 96.82, whose maximum outside diameter is the same as core barrel 94 and upper cylindrical member 96.5, has a cylindrical vertical cavity in the center thereof, in which is mounted an antifriction thrust bearing assembly 96.95, through the center of which extends a second vertical cylindrical rod 96.9, whose threaded upper tip is securely screwed into the threaded lower end of the hole in member 96.82 into whose upper end the lower tip of rod 96.8 is screwed, so that lower rod 96.9 becomes substantially a downward extension of upper rod 96.8. Above and below thrust bearing assembly 96.95 are suitable spacing washers, of which the upper one is nonrotatable with respect to the cylindrical wall of the cavity in cylindrical member 96.82, and of which the lower spacing washer is rotatable with respect to member 96.82 and the rod 96.9 fixedly attached thereto. Immediately below the lower spacing washer is the upper face of the upper cylindrical projection of a cylindrical inverted cuplike member 96.93 provided with an annular sealing washer (undesignated) whereby drilling fluid is kept from reaching the said antifriction thrust bearing assembly 96.95, which thus permits generally cylindrical member 96.82 (and the various members above it previously described as being fixed with respect thereto) to rotate with respect to member 96.93 and the members presently to be described below it, including core barrel 94 which per forms no rotary drilling function and merely slips downward over the core R, which is recovered thereby above the lower tip of core-catching member 93 with as little tendency of core barrel 94 to rotate as is possible because of the antifriction thrust bearing assembly 96.95.

Inverted cuplike cylindrical member 96.93, which is rotatable with respect to cylindrical rod 96.9, has installed within its lower cylindrical cavity a short coiled compression spring of considerable strength, above and below which are mounted circular spacing washers (undesignated numerically) around rod 96.9 in that cylindrical cavity, into which projects the upper cylindrical tip of member 96.92, which has its lower cylindrical threaded tip screwed into the interior threaded upper tip of core barrel 94, thereby forming a substantial closure of the upper end of said core barrel 94 previously described. Member 96.92 is rotatable with respect to member 96.93 (with which it remains substantially aligned by virtue of the length of the cylindrical cavity in member 96.93 into which the upper cylindrical tip projects a suitable distance beneath coiled compression spring 96.94, which serves as a cushion for the core barrel 94, when the entire assembly falls downward against insert member 91.7 prior to further drilling of the pilot hole, but which also serves as a means whereby it is assured that scotching lugs 96.35 (having their upper tips outwardly extended as far as possible by virtue of downward pressure of the upper coiled compression spring 96.62) will pass downward sufficiently to permit their upper tips to be caught by the horizontal annular shoulder in the interior wall of the drill pipe 10, whether that annular shoulder be formed as indicated alternatively in FIG. 41 or be the annular gap between the lower end of tool-joint 10' and the substantially cylindrical (but slightly conical) cavity in the tool-joint 10, as shown in FIG. 32, it being understood that the length of core barrel 94 and the several members attached thereto as shown in FIGS. 41 and 42 will have their combined lengths varied in construction to correspond with the alternative chosen for the said annular shoulder of the drill pipe against which the upper tips of scotching lugs 96.35 are brought into contact during the drilling of the pilot hole PH. In either instance there is plenty of room for downward flow of the drilling fluid around those scotching lugs 35 in FIGS. 32 and 35 and around corresponding scotching lugs 96.35 shown in FIGS. 41 and 42. And note in FIG. 41 that the nut 96.91 screwed and secured on the threaded lower tip of rod 96.9 will lift the closure member 96.92 screwed into the upper tip of core barrel 94, just as in FIG. 36 the nut 79' screwed onto the lower tip of rod bolt 79 performs the same function of lifting closure member 96 screwed into the upper tip of core barrel 94 shown in FIGS. 32, 35, 36, and 37.

Whether the arrangement shown in FIG. 39 for attachment at intervals of the lifting assembly attached to the lower tip of cable 60 by the spear indicated by numerals 96.2, 96.3, and 96.1 attached fixedly to the cylindrical closure member 96 of core barrel 94 as indicated in that FIG. 39, or whether that same grappling assembly attached to the lower tip of cable 60 be attached to the spear indicate indicated by the same numerals 96.2, 96.3, and 96.1 in FIG. 41 showing the more complicated linkage between the upper member 96 and the cylindrical core barrel 94 below it, it is to be understood that there will have to frequent such attachments to and detachments from the spear, for the ease and speed with which the core barrels 94 and the rock core segments 4 recovered therein can be raised to the surface (without the dangerous, expensive, and time consuming need to remove all the drill pipe sections from the hole to recover each section of the core drilled by the annular drill bit attached to the lower tip thereof) immediately creates a need for a quick and easy means of separating the member 65.5 of that grappling assembly and the almost circular spring 67.1 contained therein (FIGS. 39 and 40) from the respective spear, when that spear is raised to the well head by means of the cable 60. It is quite easy to employ suitable wrenches known to the art to unscrew inverted cup member 65.5 from cylindrical member 65.3 of that lifting assembly, but removal of the spring 67.1 and its surrounding cup 65.5 from the respective spear is more difficult. If the operation were only occasional, as it has been in the past because of the necessity of removing all the jointed drill pipe from the hole, it might be practical to employ a suitable wedge to be driven between the two prongs of the almost circular resilient spring 67.1, even though that circular spring has to be very stiff in order to raise the core barrel 94 and thereby break loose and lift the core R inclosed therein, particularly if the spring and its supporting restricted lower section of inverted cup member 65.5 were not designed as shown and described in connection with FIGS. 39 and 40. But a more easy and less time consuming means of separating spring 67.1 and grappling cup member 65.5 from the spear is required for removal of all the multiple core segments from the pilot hole at very frequent intervals.

A simple but effective means of hurriedly removing spring 67.1 and its inclosing grappling cup member 65.5 from a spear is illustrated in FIGS. 43 and 44 (on the same sheet as FIG. 40), the latter of which is a vertical cross section of the former at the line 44–44′ in a plane including the longitudinal axis of a horizontally disposed pipe 126 several feet in length and having an outside diameter of 2 inches and quite considerable strength. Pipe 126 has a pair of horizontal holes 127.0 a suitable distance of several inches from one end thereof; and through said holes 127.0 is inserted rotatably a horizontally and laterally disposed pivot bolt 127, which thus mounts the prize lever pipe 126 pivotally in a U-shaped or channel metal framework 128 having corresponding holes in which the bolt 127 is fixedly mounted. The channel framework 128 is in turn fixedly mounted in a metal channel member 129 (shown as 6 inches long) having corresponding holes in which bolt 127 is similarly fixedly mounted, there being spacing washers 130 on the bolt 127 at each side of the pipe 126. At the left end of FIGS. 43 and 44 is shown a suitable restricted slot 131 in the bottom of channel member 129 slightly wider than the cylindrical rod section 96.1 of the spear attached to closure member 96 of core barrel 96.4, which actually is the same core barrel 94 shown elsewhere in my drawings. Slot 131 is 2 inches long, and spear member 96.1 is slipped into the slot substantially all the way. Less than an inch from the left-hand end of pipe 126 is a hole about five-eighths inch in diameter in the lower wall of that pipe, which has to be tilted downward at the right-hand end thereof to make it possible to insert in the upper portion of grappling cup 65.5 a suitable arcuate wedge 133, which is welded to the lower wall of the pipe 126 a fraction of an inch to the right of the hole 132. Therefore, when the long right-hand handle of the pipe 126 is raised from the horizontal position shown in FIG. 44, the arcuate member 132 having its side suitably sloped to form a suitable wedge of suitable width for insertion between the two tips of circular spring 67.1 simply spreads those tips of spring 67.1 apart sufficiently to make spring 67.1 pass around the enlarged upper segment of the spear, when simultaneously the raising of the handle pipe 126 also raises the right-hand side of the cup 65.5, into which that arcuate wedge 133 is simultaneously projected. But the spring 67.1 cannot fly on out of the cup 65.5 completely to become lost, for the hole 132 in the tip of pipe 126 simultaneously slips down onto the upper tip of the spear to confine said almost completely circular spring 67.1 beneath the tip of pipe 126, until the spring 67.1 and its surrounding cup 65.5 can be recovered by the person operating the simple mechanism shown in FIGS. 43 and 44, which may be called simply a novel device for completely separating from the cable attached grappling mechanism the core barrel 94 and the core R contained therein at the head of the well for removal of the core segments from said core barrel 94 and its interior auxiliary core barrel 94′. But, by way of contrast, when a driller raises one of the core barrels 94 shown in FIGS. 32 and 35 to the head of the well by means of the cable 60 mounted on a suitable reel well-known to the art, all the driller has to do, in order to detach the cable 60 and its grappling assembly shown in FIGS. 33 and 34 from the previously shown lifting tubular member 50 shown in FIG. 32, is to slacken the cable 60 (after the core barrel 94 and its closure member 96 have been secured adequately at the head of the well, conveniently by means of suitable "slip wedges" inserted in the drill pipe around the core barrel 94) and then have a "roughneck" helper grasp the four lifting members 65 in his hands and squeeze them together closely for tying them together by a strong cord 68 for reinsertion in the drill pipe again a short time later to recover another core segment R in core barrel 94, as soon as the annular drill bit on the lower tip of the drill pipe 10 has drilled the pilot hole down farther a suitable distance for recovery of another core segment by means of the cable 60 without ever removing a joint of the drill pipe 10, unless the diamonds 100 may have become worn or otherwise damaged in some way that hinders further drilling to a greater depth.

While in the figures immediately preceding it has been illustrated that the drill pipe 10 of the bit drilling the annular groove around the core in the pilot hole conveniently may be of the type having "internal upset" end segments flash welded to the tool-joint tips thereof, it will be appreciated that the pilot hole PH may be drilled by employment of another type of drill pipe now on the market for many more years. In FIG. 45 is shown an annular drill bit 91 having its threads screwed onto what the manufacturer describes in a sales brochure catalogue as "External Upset High Strength S-135 Drill Pipe with Reed Super Shrink Grip-R Tool Joint." The name Reed of course does not refer to the present manufacturer; and S-135 indicates a grade of steel having a yield strength of 135,000 minimum per square inch, whereas other grades are listed at 55,000 and 75,000. But it will be realized that the greatest strain on such drill pipe is from hanging it in a well that may be more than 10,000 feet deep with only a few thousand pounds of pressure resting on the rotating diamonds 100. Tensile strength of Grade S-135 is 147,000 minimum per square inch in comparison with other grades of steel having 95,000 and 100,000. The thread type of the drill pipe proper in this instance is described as "Modified Acme;" and the threads shown schematically in FIG. 45 are only approximations not only for the threads of the lower tip of the drill pipe joint 10 screwed into the upper tip of tool-joint segment 10.2, but for the threads on the conical lower tip of that tool-joint segment 10.2 which are screwed into the corresponding threads of the annular bit, whose main annular segments 91 and 91.1 actually are made from the lower "box" or "female" segment of the same tool-joint. Outside diameter of that tool-joint is 4¾ inches, which passes through the members 6.1 of the cylindrical shoe members 6,6′, and 6″ previously indicated as being screwed on the lower tip of cylindrical drill pipe 11 having an

outside diameter of 6⅝ inches with an internal diameter slightly less than 6 inches, depending on the weight of the pipe necessary for drilling to the depth contemplated. This tool-joint having a bore of 2 and 11/16 inches with an outside diameter of 4¾ inches is not quoted as being as strong as the straight "external upset" drill pipe segment having an outside diameter of 3½inches with a wall thickness of .368 of an inch; but a larger size tool joint for use with the same straight "external upset" drill pipe of 3½inches outside diameter of 5⅝ inches, which is quite large for insertion through the above enumerated shoe members 6,6', 6'', and 6.1, which are screwed on the lower tip of my drill pipe-casing having an outside diameter of 6⅝ inches, which is the most common size of pipe for completing deep oil and gas wells.

The drill pipe for the pilot hole shown in FIGS. 45, 46, and 47 as having an outside diameter of 3 ½inches with tool-joints having an outside diameter of 4 ¾ inches is quite adequate for drilling my pilot hole PH for my reaming drill bits shown in FIGS. 1, 2, 3 and 24, 25 to be employed with a cable 60 as a means of replacing all the drill bit members through either the drill pipe 10 or the drill pipe 11, unless extraordinary weights are to be permitted by the driller on the pilot hole drill bits for too rapid drilling, and unless the holes to be cored thereby are to be of most unusual depths well beyond 10,000 feet.

In FIG. 45 it is illustrated that the members 91.11 mounting diamonds 100 (by means well known to the art) are three-eighths inch in thickness and are almost U-shaped (instead of only J-shaped, as previously described in connection with FIGS. 37, 38) with the generally cylindrical internal inset member 91.7 previously shown in FIG. 37 being replaced by upward extensions of the internal segments of those members 91.11 mounting the diamonds 100 around the core R in the cylindrical space 92, above which the lower circular tip of the core-catching member 93 rests to receive the core R cut around by those diamonds 100. Drilling fluid passes downward around core R in the spaces shown in FIG. 46 adjacent that space 92 and between said upwardly extending members 91.11 having an outer sintered veneer 91.12 in which the diamonds 100 are mounted in a process well-known in the art of diamond mounting. In FIG. 45 it can be seen that these upward extensions of members 91.11 are disposed at symmetrical angles very slightly from vertical, which disposition tends to keep them pressed into the 12 grooves provided therefor in the annular "box" member 91.1, whose general outline between each two of those members 91.11 is indicated by the broken lines representing the canals in which the drilling fluid has to travel around that annular segment 91.1 of "box" member 91. The grooves in which those members 91.11 are mounted are only about one-sixteenth inch deep at the upper internal tips of said members 91.11 mounting diamonds 100; but elsewhere those grooves become much deeper, and the external upper tips of those members 91.11 mounting diamonds 100 are held in their respective grooves by the 12 bolts 91.5 which alternatively are shown staggered slightly in height above the base level of the annular drill bit in order to increase strength of the tubular wall of the cylindrical "box" member 91, which has been reamed out in the area of the tips of those 12 bolts 91.5 to an internal diameter of about 3⅜ inches. Note that those bolts 91.5 extend through that modified cylindrical wall of "box" member 91, where their inner tips are bradded (or alternatively welded slightly) to keep their positions secure in the members through which said bolts are inserted. Not too much strength is detracted from "-box" member 91 by reaming out the threads therein below those bolts 91.5 to carry the drilling fluid downward around member 93 (attached to the lower tip of core barrel 94) inside the annular bit member 91 with complete ease under suitable pressure through the drill pipe 10 shown at the top of FIG. 45. Note also that the lower tip of tool-joint segment 10.2 has been cut off about a half an inch; and thereafter the hole 10.0 in the center thereof (having a listed bore of at least 2 11/16 inches) has been flared out at its lower tip to permit adequate flow of drilling fluid past the core-catching member 93. That member 93 has to be only slightly less in outside diameter than the above mentioned bore through tool joint "pin" segment 10.2, in the center of which said member 93 is held during the drilling operation by the fact that the cylindrical upper tip of that member 93 is long enough to be serrated suitably, so that the upper projections (as at the left-hand side of FIG. 45) of member 93 reach upward into that straight bore, while at other places (as at the right-hand side of FIG. 45) suitable wide notches are milled in the upper edge of that member 93 to permit easy flow of more drilling fluid through said notches of suitable width. All the foregoing are simply means whereby provision is made for passage of drilling fluid around core-catching member 93 of only slightly less outside diameter than the bore of tool-joint "pin" segment 10.2, below which there has been provided an annular space of sufficient dimensions to permit easy adequate flow therethrough of drilling fluid to service the diamonds 100 on the annular bit assembly and carry away their cuttings, even though core-catching member 93 can be hoisted upward as desired through the drill pipe of small bore by means of cable 60 at any time without unjointing any of the drill pipe and removing it from the pilot hole.

Large amounts of the drilling fluid under pressure from the pump at the well head can flow downward around the core-catching member 93 in cylindrical cavity 91.0 of the drill bit 91 and thence between the respective internal tops of members 91.11 disposed at suitable angles with respect to the horizon (30° shown for convenience in FIG. 45) and with respect to the conical outer face of the lower tip 93.1 of core-catching member 93 (conveniently 30° from vertical in FIG. 34); but, if it is desired to permit more unrestricted flow of the drilling fluid directly over the tops of those members 91.11 toward core R being cut by diamonds 100 mounted in the sintered interior faces 91.12 of those members 91.11, that result alternatively is accomplished by making the upper interior faces of six alternate members 91.11 at different angles (conveniently indicated in FIG. 45 broken lines as 45° from the horizon). In that event the lower tip of conical member 93.1 then will rest on six rather than 12 of the upper internal tips of almost U-shaped members 91.11, whose upper outer tips are attached to the annular drill bit 91 by the twelve bolts 91.11. But each of the inner upper tips of those members 91.11 conveniently can be welded (through the center of member 91 detached from "pin" 10.2) to the conically sloping lower face of canal 91.0 of annular drill bit 91, as indicated in FIG. 45. Thereafter, if it is desired to remove any one of the almost U-shaped members 91.11 from the annular segment 91.1 to replace the diamonds 100 mounted thereon in veneer 91.12 (by a sintering process well-known to the art of diamond drill mounting), it is easy to reach the short beads of said electric arc welds with a suitable grinder inserted through the upper end of bit member 91, from which the tool-joint segment 10.2 is easily unscrewed for removal therefrom of grind away those weld beads.

Additionally in FIG. 45 is shown an alternative kind of core barrel 94 with its lower tip inserted in the upper tip of core-catching member 93 alternatively provided with a suitable cylindrical cavity therein. Since ease of removal of the detached core segments from the core barrel 94 is increasingly important because of the great number of such core segments to be recovered by means of my cables 60 without need of removing the pilot hole drill bit 91 from the hole in the time-consuming methods previously required to unjoint and remove all the segments of the drill pipe from the hole, note in FIG. 45 that the core barrel 94 (made of slightly resilient metal only about one-sixteenth inch in thickness) is vertically bisected to form two half-cylindrical segments, which together fit snugly around the inner core barrel 94' of similar construction but having the vertical bisecting plane disposed 90° from that of the first said snugly inclosing core barrel 94. The lower tips of these two core barrels 94, 94' are held together as a single unit inside the upper half of core-catching cylindrical member 93 by four small flathead bolts 94.2 inserted in suitable holes 90° from each other in members 93, 94, and 15. The

notched lower tip of inner core barrel segments 94' (vertically bisected as explained above) end a fraction of an inch above the lower end of core barrel 94, into which at that level there is inserted a suitable core-catching cylindrical resilient spring member 15 having upward diagonally disposed projecting lugs 16, which tend to catch the core R passing therethrough, but which can recede into the corresponding rectangular notches in the lower tips of core barrel segments 94', as explained previously in connection with the vertically slit inner core barrel 14 of FIG. 8 showing that core barrel 14 vertically bisected at one side only indicated by line 14'.

In FIG. 45 the lower tip of canal 10.0 in drill pipe segment 10 (near the top of the sheet) has been flared out conically, as explained previously (in connection with "pin" 10.2) and the upper tip of the corresponding canal through the tool-joint segment 10.2 has been flared out similarly, so that in combination those adjacent tips of said two drill pipe tool-joint segments by their respective flared canal segments 10.4 and 10.3 form an enlarged channel around a means whereby the four segments of core barrels 94 and 94' are held together at a level somewhat above the core-catching member 93, in whose upper tip they all are mounted. At that level two roundhead brads 94.3 are shown inserted through holes in outer core barrel 94 and into notches in the vertical edges of the two segments of inner core barrel 94' to hold the four segments of core barrels 94 and 94' in proper positions with respect to each other at that particular level. But those core barrels 94 and 94' are held together as a single unit primarily by a light metal cylindrical band 93.4 installed snugly around outer core barrel 94, down which it cannot slide because said band 94.4 is provided with slits in its lower margin to form two corresponding flaps bent outward and thence downward over the rounded heads of the brads 94.3, which thereby are held in their respective horizontal holes in core barrel 94, so that the cylindrical band 94.4 cannot move downward over the rounded heads of brads 94 held in the respective holes in said core barrel 94 by the above described flaps formed in the lower margin of cylindrical band 94.4. Note particularly that the band 94.4 can be installed from below as well as from above, before the brads 94.3 are installed in their respective holes, and obviously before the multiple segment core barrels 94 and 94' are installed in the drill pipe members 10 and 10.2, where those multiple segments become a single unit of cylindrical nature. The same result alternatively can be accomplished by installing a rubber band about three-fourths inch wide around the core barrel 94 and over the rounded heads of brads 94.3 installed in their respective holes in core barrel 94; but such a rubberband, while very easily installed, would tend to rub against the wall of canal 10.0 during installation through a long drill pipe segment 10 (if the drill pipe is to be made to reach to the top of the hole being drilled in the earth particularly, instead of simply being screwed on the lower tip of a connecting member 9 as previously described generally) and thereby might tend to wear out the rubber band or otherwise be removed from its position on brads 94.3 in holes in core barrel 94, at whatever level those holes may be bored in that core barrel. Means of installing such a cylindrical band 94.4 around core barrel members 94 and 94' at another higher level will be explained presently in connection with FIGS. 48 and 49.

FIG. 47 illustrates the novel preferred embodiment (for many purposes) of the attachment of the upper tip of "outer core barrel" drill pipe 10 to the lower tip of a connecting member 9 corresponding to the connecting member 9 explained previously in connection with FIG. 28. And the upper tip of the pilot hole drill pipe 10 (usually called the "outer core barrel" by the oil industry suppliers, when such relatively short such pipe of perhaps 30 to 60 feet is attached to an annular drill bit, from which the core is recovered by removing all the drill pipe segments from the hole, as explained previously) shown in FIG. 47 may be considered as the upper tip of the same drill pipe segment 10 whose lower tip is shown at the top of FIG. 45, the straight uniform cylindrical midsection segment of that conventional drill pipe joint 10 being 3½inches in outside diameter with a wall thickness of .368 of an inch (weighing 13.3 lbs. per foot) as illustrated at the bottom of FIG. 47. Onto the suitably threaded upper tip of that drill pipe joint 10 is screwed the lower tip of a conventional tool-joint lower "box" segment 10', whose upper half is modified slightly in an annealed state. The midsection of tool-joint "-box" segment 10' has its minimum internal diameter increased a fraction of an inch over that of the conventional drill pipe 10 in order to assure free flow of suitable drilling fluid around the upper attachments to the core barrel 94, which is an upward extension of the same core barrel 94 shown in FIG. 45 as snugly fitting around inner core barrel 94', which is almost 2 inches in internal diameter. Note also in FIG. 47 that the internally threaded upper tip of conventional tool joint 10' has been bored out cylindrically for over an inch, so that its lower threads are partially removed to make the diameter about 3⅝ inches for accommodation of easy flow of drilling fluid around novel core barrel capping member 98.2 to be described presently.

The upper tips of core barrel segments 94 and 94' are mounted on the lower tip (slightly reduced in diameter) of cylindrical closure member 96, against whose annular horizontal shoulder at the level of reduction the upper ends of those core barrels 94 and 94' are held by four horizontally disposed flathead short bolts 94.5 screwed into four corresponding thread-tapped holes in that lower tip of closure member 96 at intervals of 90°.

Through the center of cylindrical closure member 96, having the same outside diameter as core barrel 94, is a vertical cylindrical hole 97, through which is loosely installed a cylindrical bolt 98, whose head on the bottom thereof is below the bottom of closure member 96 and whose upper threaded tip is screwed into the internally threaded lower part of a hole 98.20 through the vertical axis of a mostly cylindrical member 98.2. Generally cylindrical member 98.2 has in the lower tip thereof a cylindrical cavity having vertical walls about 1 inch high; and into this cylindrical cavity extends the upper cylindrical tip (having suitably reduced diameter) of closure member 96, with respect to which (and its fixedly attached core barrel 94) the aforementioned member 98.2 is freely rotatable by virtue of the fact that there is mounted around bolt 98 between members 96 and 98.2 a thrust ball bearing assembly 96.2, around which are installed suitable felt washers to insure that drilling fluid does not enter said ball bearing assembly 96.2.

The upper tip of generally cylindrical rotatable member 98.2 is made slightly conical to facilitate installation therearound of the lower tip of coiled compression spring 98.4, whose lower end presses against a horizontal annular shoulder formed around cylindrical rotatable member 98.2 for holding that member 98.2 and thereby core barrels 94 and 94' together with core-catching member 93 (FIG. 45) down against the upper inner tips of diamond mounting members 91.11, unless for some reason the core R happens to be of a nature that for any reason it fits too snugly into the core barrel 94' and the core-catching devices mounted below it in core-catching member 93, which thus needs some vertical pressure applied to said member 93 to trim the exterior wall of the remaining core R very slightly. Coiled compression spring 98.4 is formed a little conically, so that its upper end is pressed against the horizontal lower end of the conical lower tip of generally cylindrical connecting member 9 provided with suitable tool-joint threads for accommodating the coarse threads of the suitable female "box" segment of a tool-joint 10' such as that shown schematically in FIG. 47, although it is not intended to imply by the foregoing that the lower tip of connecting member 9 will be made to fit any single tool-joint of any one manufacturer of drill pipe strings to the exclusion of the tool-joints distributed by others. Disposed at intervals of 120° around the cylindrical lower half of rotatable member 98.2 are three spacing vanes 98.6, one of which can be seen in FIG. 47; but all three of those narrow spacing vanes 98.6 rigidly attached to generally cylindrical member 98.2 have

their outer walls at a similar uniform distance from the vertical axis of bolt 98 to keep the aligned cylindrical members 98.2, 96, and 94 disposed in the center of tool-joint member 10', even if such a central disposition were not accomplished by the coiled compression spring 98.4 having its lower tip mounted around the upper tip of member 98.2, which rotates with that tool-joint member 10' into which the upper tip of "outer core barrel" member 10 is screwed with corresponding "modified acme" threads as schematically indicated.

Obviously it would be possible alternatively to remove inner core barrel 94 (and its inclosed segments 94') from the drill pipe member 10 shown in FIGS. 45 and 47 by unscrewing the threads at the top or even the bottom of that drill pipe member 10. But either of these suggested alternatives would require many revolutions of pipe member 10 with respect to the tool-joints into which those tips are screwed; and, as indicated previously in connection with FIGS. 5, 28, and 29, and as can be seen from FIG. 47, it is much more simple and faster to turn the tool-joint threaded more sharply conical lower tip of connecting member 9 (See at the top of FIG. 47) only a few turns to unjoint the tool-joint 10' therefrom, so that those two joints can be separated completely for removal of core barrels 94 and 94' from the drill pipe 10 by means of a suitable tool having a lower threaded tip 31 that can be screwed into the upper end of internally threaded hole 98.20 through the center of rotatable member 98.2, connected rotatably with the core barrel 94 by means of bolt 98 extending through closure member 96 of core barrels 94,94'. FIG. 47 shows a spacing washer between the lower face of that closure member 96 and the upper face of the head of that bolt 98, so that alternatively that annular spacing washer can be removed to make closure member 96 more freely rotatably with respect to rotating bolt 98, whose upper threaded tip extending into the correspondingly threaded central hole in member 98.2, to which it is fixedly attached, has a conventional right-hand thread that makes clockwise rotation of member 98.2 along with the drill pipe members 9, 10, and 10' tend tend to tighten bolt 98 into that threaded member 98.2 as a result of any friction between bolt 98 and the nonrotating closure member 96 fixedly attached to the upper tip of core barrels 94 and 94', which tend to remain nonrotating with the core R extending upward therein.

FIG. 48 shows one quadrant of one of the desired number of bands 94.4 installed around the core barrel 94 at suitable intervals of several feet between the upper tip of core barrel 94 in FIG. 47 and the corresponding such cylindrical band 94.4 shown near the lower tip of that core barrel 94 in FIG. 45. FIG. 49 shows the same such band 94.4 in vertical cross section through the axis of the brad 94.3 shown below in FIG. 48; but the band 94.4 in FIG. 45 is more narrow than the band 94.4 in FIG. 49 serving the same purpose. In FIGS. 48 and 49 there is more than adequate room in the annular space around cylindrical band 94.4 (between the ends of segments of pipe 10 cut horizontally and threaded for that purpose) for free flow downward of the drilling fluid inside drill pipe 10 having an internal diameter of at least 2 11/16 inches, because brads 94.3 and the overextending flaps 94.4' are disposed between the spaced ends of the externally threaded tips of two segments of the drill pipe 10 connected by means of the pipe coupling 10'' provided with suitable internal threads at each end thereof. The spaces between the ends of each two such segments of drill pipe 10 serve to make that drill pipe 10 of suitable length with respect to the core barrel 94, which, however, alternatively may be made of any suitable length to suit the drill pipe 10 instead. It is most convenient to make the several segments of core barrel 94' about 5 feet in length, since such a length is suitable for handling and shipment as well as for correlation by a geologist of the logs of the cores to determine height of the various rock formations therein to within less than a foot with respect to sea level, because that elevation is quite important in exploring for oil and gas and other minerals. Note in FIG. 49 that the inner core barrel 94' is divided into two segments at the brad 94.3, for which accommodation is made by clipping off the corners of the two segments of that core-barrel 94' adjacent said brad 94.3. Each of the two segments of the other surrounding core barrel 94 extend all the way from core-catching member 93 to upper closure member 96 (FIGS. 45 and 47); but, when the core barrels 94 and 94' are detached from those cylindrical members 93 and 96, and thereafter when the several bands 94.4 are removed from around the two vertically bisected segments of inclosing core barrel 94, all of those two core barrel segments can be laid apart to expose the recovered core segments R without even breaking it further, presuming that it may be broken into 5 foot lengths as indicated above. And of course the multiple segments of core barrel 94' can be replaced around the correspondingly broken core segments for any possible handling, shipment, examination at intervals, and storage of said core segments.

While I have indicated previously that it is most convenient in most respects to make the conical lower tip of connecting tubular cylindrical member 9 have conventional tool-joint threads of some one of the several manufacturers now supplying the oil industry market with such tool-joints for drill pipe not differing too greatly between manufacturers, in order to take advantage of mass production of those elements required in the construction of my invention elements, it will be noted in FIG. 50 that I have illustrated that (alternatively) the lower tip of my connecting member 9 with integral lower segment 1.1 of body member 1 (See FIGS. 24 and 25 in which arms 4 mount diamonds 100 on the lower tips thereof and also FIGS. 1 and 2 showing rolling cutters 2 rather than diamonds on the underreaming arms 4) may have "Modified Acme" threads screwed into a tool-joint "pin" segment 10' screwed into a tool-joint "box," into which is screwed the correspondingly threaded upper tip of a drillpipe joint 10 shown in the middle of FIG. 53, to be explained presently. FIG. 50 also illustrates some other alternative characteristics of the connecting member 9 in connection with its telescoping lower cylindrical segment 1.1 of central underreaming body member 1.

In FIG. 50 the connecting body member 9 is made from a cylindrical sleeve 9.11 inserted into the lower "externally upset" tip of the midsectional primary member of a joint of drill pipe designated 10 and previously described in connection with FIG. 45, although the corresponding threads in FIG. 45 are slightly deeper than those shown in FIG. 50. But, since that segment 9 of the drill pipe joint lower tip is only 3¾ inches in outside diameter, in FIG. 50 I have made the enlarged upper section 9.4 of that connecting member 9 (originally described in connection with FIGS. 5, 6, and 7 and thereafter in connection with FIG. 28 for the diamond mounting equivalent mechanism) out of a separate generally cylindrical tubular segment 9.4 indicated in FIG. 50 by broken lines but shown clearly in horizontal cross-sectional FIG. 51, in which it can be seen that the four adjusting and keying pushrods 8.1 (shown in FIG. 50 as extending vertically into body member 1.1 in the four corresponding holes 8, which become only half cylindrical slots 8.0 in the lower half of that cylindrical tubular member 1.1 shown in FIG. 50) are mounted in the four keyways 9.1 in the outer margin of that upper section 9.4, where those four pushrods 8.1 are held fixedly against their respective mounting bases in that enlarged section 9.4 by the four horizontal key pins 8.2. Note particularly in FIG. 50 that the juncture of tubular cylindrical member 9 with its encircling segment 9.4 of greater outside diameter (also welded to the tubular cylindrical member 9.11 inserted therethrough) slopes downward toward the common vertical axis of all these tubular cylindrical members. And it can be seen in FIG. 50 that the beveled lower tips of the four adjusting pushrods 8.1 (whereby alternatively are outwardly hinged the lower tips of arms 4 mounting diamonds in said lower tips as previously explained in connection with FIG. 24) will tend under pressure from above by the arms 4 to try to slide their lower tips toward the vertical axis of tubular generally cylindrical segment 9.4, in the outer cylindrical wall of which are provided the vertical grooves 9.1 (FIG. 51) provided for the respective four rods

8.1, each of which (as explained above) is joined to that cylindrical member 9.4 (as well as to central cylindrical tubular sleeve 9.2) by the four respective key pins 8.2 having their outer tips welded in the holes through the respective vertical rods 8.1 provided for said horizontally disposed keying pins 8.2, which serve to pull those rods 8.1 downward, when the mechanism is lifted from the bottom of the hole being drilled by the pilot hole drilling mechanism of whatever nature. But in FIG. 50 there are shown slight notches in the upper edge of tubular cylindrical member 9, in order to weld the lower tips of pushrods 8.1 simultaneously to that member 9 and to its larger encircling segment 9.4, the welds in each instance being made where it will not conflict with vertical movement of those push rods 8.1 in their respective slots 8.0 of telescoping tubular lower segment 1.1 of body member 1 shown also in FIG. 24.

FIGS. 50 and 52 also illustrate a vertically disposed central bolt 98 having a nut 98.1 screwed on the threaded upper tip thereof whereby alternatively is supported a novel flexible core barrel 94 (to be explained hereafter in connection with FIGS. 53, 54, and 55) rotatably on an antifriction bearing assembly 96.2 resting on a tubular cylindrical segment 96 of a spider arrangement having three spokes 96.3, whose inner tips are attached rigidly to said cylindrical segment 96, and whose outer tips extend out radially onto a narrow annular horizontal shoulder in the tool-joint "box" member 10' immediately below the lower end of tubular connecting member 9. But, since the antifriction bearing mechanism 96.2 in FIG. 50 protrudes upward into the central vertical canal 9.0 through that connecting member 9 (having a vertically disposed tubular cylindrical sleeve 9.11 welded fixedly therein) and thereby impedes downward flow of the drilling fluid through that canal 9.0 to some extent, it now is deemed unnecessary to make further explanation of this supporting device (for the core barrel 94), which was shown in FIG. 50 primarily to conserve space, for in FIG. 53 there is shown a substantially equivalent supporting device for the said flexible core barrel 94, 94' in which latter FIG. 53 the entire mechanism designated for rotatably supporting that novel flexible core barrel is entirely below the lower end of tubular cylindrical connecting member 9 having a suitable central vertical canal 9.0 therethrough.

In FIG. 53 a slight horizontal annular shoulder has been formed in tool-joint segment 10' by increasing slightly the diameter of the central canal therethrough for a vertical distance of about three-quarters of an inch. On this annular shoulder are mounted the outer tips of four spider members 98.6, each of which (disposed at 90° angles from each other) has its lower half rigidly attached to the outer wall of a cylindrical cup 98.2 having a hole 97 in the center of the bottom plate thereof, through which hole a vertical rod 98 is rotatable. Inside the cup 98.2 and around rod 98 is mounted an antifriction thrust bearing assembly 96.2, above which is a flexible annular washer snugly fitted around bolt 98 to keep drilling fluid from entering the cup 98.2 and thereby the bearing assembly 96.2. On the upper threaded tip of rod 98 is screwed a suitable nut 98.1, which rests on said flexible washer, thereby suspending rod 98 rotatably by means of cup 98.2 and its four rigidly attached radially disposed spider members 98.6 having their outer tips resting on the shoulder around the vertical canal through the center of the tool-joint "box" member 10'.

The lower threaded tip of rod 98 below the supporting cup 98.2 is screwed into an internally threaded hole 96.0 in the center of the cylindrical closure member 96 having an outside diameter of about 2 inches at its horizontal top, which is the same as the outside diameter of the novel flexible core barrel now to be described. One-fourth inch below the top of closure member 96, which is more than an inch in height, its diameter is reduced to about 1 ½inches. Over the reduced lower cylindrical segment of closure member 96 is snugly forced an annular band 94.6 (of suitable outside and inside diameter and at least three-fourths inch in height) over the top of which is folded the upper wall of the flexible cylindrical core barrel 94, 94', although those double numerals do not apply in the same sense as do numerals 94 and 94' designating the thin pair of core barrels 94, 94' although those double numerals do not apply in the same sense as do numerals 94 and 94' designating the thin pair of core barrels 94, 94' previously described in connection with FIGS. 45, 47, 48, and 49, for in FIG. 53 the core barrels 94, 94' actually are simply a single tubular cylindrical member formed by rolling into a tubular cylinder of suitable length a single sheet of thermoplastic (polyethylene) material, which sheet is too thin to indicate its thickness schematically in FIG. 53 by any means except to show multiple lines to indicate the vertical cross section of the cylindrical core barrel formed therefrom and designated 94, 94'. In the middle of FIG. 53 is shown a separated vertical cross section through a short segment of the straight uniform midsection of drill pipe 10 having an outside diameter of 3½ inches; and within this short cross section (taken from the long central section of the drill pipe 10 mounting the annular bit 91 as indicated by the tool-joint segment 10.2 in FIGS. 45 as well as FIG. 53) is shown the exterior of the cylindrical flexible core barrel 94, 94' formed by the single sheet of thermoplastic polyethylene. Around this combination flexible core barrel 94, 94' (suitably formed initially by wrapping the thin polyethylene sheet around a cylindrical piece of wood or metal pipe) at suitable vertical intervals is wrapped gummed thermoplastic tape about one-half inch wide of a length sufficient to reach around the core barrel several times; and thereafter a vertically disposed segment of the same kind of tape about 1 inch wide alternatively also may be placed over the outwardly exposed edge of the plastic sheet, although it is not desirable to make this piece of 1 inch wide gummed plastic tape extend the full length of the core barrel 94, because it will be difficult to remove such a vertically disposed gummed plastic tape to unroll said core barrel 94, 94' for removal of the inclosed core segment R therefrom, after said core barrel 94, 94' has been removed from the "outer core barrel 10 at the head of the well or elsewhere. Slitting the upper margin of the core barrel 94, 94' so formed of a single sheet of polyethylene plastic to remove very narrow sections of the material from that margin to a vertical extent of about 1 inch, makes it easier to fold the upper margin of said rolled plastic material over a suitable cylindrical band 94.6, whereby the upper margin of the rolled plastic material is joined fixedly (but removably quite quickly and easily) to the reduced diameter lower cylindrical section of closure member 96, which is provided with multiple internally threaded horizontal holes, into which are screwed the inner tips of small flathead bolts 94.5 inserted through holes in the plastic material and through corresponding holes through the midsection of the cylindrical ring 94.6 conveniently made of metal. The lower edge of the rolled plastic polyethylene material is similarly folded over a corresponding cylindrical tubular ring 15, which is snugly forced into the serrated upper edge of the core-catching member 93 and held there securely by multiple small flathead bolts 94.2 having threaded tips inserted through the corresponding holes in the rolled plastic sheet and in core-catching member 93 as illustrated schematically in FIGS. 53 and 54. In those two drawings it is illustrated that core-catching member 93 rises almost an inch above line 54–54' of FIG. 53 at three places 120° from each other for insertion therethrough in suitable holes of three of the small bolts 94.2 and that at three other intermediate places similar small bolts 94.2 are installed three-eighths of an inch below that line 54–54' and directly below the respective short diagonally disposed segments 16 of the annular spring steel member 15 projecting inwardly through corresponding holes in the plastic-roll core barrel 94, 94'. FIG. 53 also shows that the lower tip of tool-joint member 10.2 is flared outward at the lower tip of the vertical canal therethrough, so that pressure of the downward flowing drilling fluid on the core-catching generally cylindrical member 93, will be minimized by its relatively free flow through the three wide slots milled in the upper margin of cylindrical member 93, as soon as the lower edge of that core-catching member 93 finally comes to rest on

the upper tips of the multiple J-shaped members 91.11 previously described and mounting in sintered veneers 91.12 the diamonds 100 suitably installed thereon by sintering in suitably powdered tungsten carbide in a way long known to the art to keep the sintering heat from exceeding the critical temperature of the industrial diamonds suitably below 2500° F., as indicated previously herein.

It will be appreciated that some modifications of the constructions of the various features shown in my drawings and described in connection therewith may be made without departing from the principles of my invention. For instance, in FIG. 27 it is indicated that the sidewalls of the two gaps 6.0 in tubular cylindrical drill pipe shoe members 6' and 6'' are parallel and vertical, although it was explained in my descriptive specifications that these sidewalls of the multiple gaps 6.0 deviate very slightly from vertical and are modified slightly otherwise to facilitate outward hinging into those gaps 6.0 by respective hingeably mounted arms 4 (whether those arms 4 mount multiple diamonds 100 on their lower tips as shown in adjacent FIG. 26 or alternatively mount rolling cutters 2 on axle pins 3 as illustrated in FIGS. 1 and 2). But in actual construction it is only necessary that the rotationally rear side of each of the gaps 6.0 be substantially vertical, in order that such vertical sidewall of the respective gap 6.0 will rotate (by means of drill pipe 11) the respective arm 4 hinged therethrough without any tendency of the arm 4 to become misplaced relative to the roof and sidewalls of the gap 6.0. It therefore follows that it is most advantageous (although not absolutely necessary, and slightly more difficult to construct shoe member 6' and 6'') to make the other rotationally forward sidewall of each gap 6.0 deviate very slightly from vertical, so that each gap 6.0 will thereby be made slightly wider at the bottom of member 6' and 6'' than at the respective arcuate roof of each such gap 6.0. And as another example of a suitable change of construction that may be made alternatively, it may be noted in FIG. 24 that the three cylindrical canals 7 mounting therein prod rods 7' in body member 1 are shown as being at substantially the same level therein; but a stronger construction of that body member 1 in the area of those four canals 7 (as well as a more satisfactory arrangement for the diametrically opposed adjusting prod pins 7' having their longitudinal axes perpendicular to the cross-sectional plane of FIG. 24) probably would be secured by making the two canals 7 below the other two parallel hinge pivot pins 4.2 and 4.4 with their longitudinal axes a fraction of an inch higher than the one canal 7 and arm adjusting prod pin 7' shown in the middle of canal 1.0 in that FIG. 24. Similarly, in FIG. 37 the outside diameter of tubular cylindrical core-catching member 93 screwed onto the lower threaded tip of core barrel 94 appears so large in the drawing that it will just barely slip through the "pin" segment of the tool-joint 10 above it; but it will be appreciated that the outside diameter of said core-catching member 93 can be turned down on a lathe very slightly as desired, so that the core barrel 94 to which said member 93 is attached can be pulled upwardly with ease even through a long string of drill pipe (by means of a cable 60, as illustrated and described in connection with other drawings) without any need to bore out the "internal upset" segments of the drill pipe joints and without any need alternatively to reduce the size of the rock core recovered in a smaller diameter pair of core barrels 94, 94'.

I claim:

1. An earth-boring mechanism employing in continued workable cooperative conjunction in all kinds of rocks: a rotatable tubular cylindrical drill pipe having threaded means on the lower tip thereof whereby is fixedly attached to said lower tip a tubular cylindrical shoe having through the lower margin thereof multiple gaps, equally spaced from each other around the rotational axis of said shoe and drill pipe with each gap having one vertical side thereof in said shoe margin; means attached to the interior cylindrical wall of said shoe intermediate said gaps therein whereby there is rotationally oscillated within said shoe, around its rotational axis, a generally cylindrical central main body member, having an outside diameter very slightly less than internal diameter of said drill pipe, and having a vertical cylindrical canal through the center thereof having adequate diameter to carry downward under pressure sufficient drilling fluid to carry all rock cuttings upward around said shoe, of a rock drilling mechanism installable through said drill pipe and having means attached to the cylindrical exterior thereof that operate in conjunction with said means attached to the interior cylindrical wall of said shoe, when said body member enters said shoe from said drill pipe, thereby so rotationally disposing said drilling mechanism with respect to the gaps in the lower margin of said shoe, when the means attached to the interior wall of said shoe ultimately limit downward movement of the drilling mechanism in said shoe and thereby prevent passage completely through said shoe, that arms hingeably mounted adjacent their upper tips in vertically disposed slots in the exterior wall of said central body member and having rock disintegrating means attached to the lower tips thereof are free to hinge outward into said respective gaps in the lower margin of said shoe, which thereafter in rotational drilling limits outward hinging of said arms and simultaneously rotates directly, around the rotational axis of the drill pipe, said arms, whose rock disintegrating means attached to the lower tips of said arms respectively serve to underream the drillpipe shoe in the rotational drilling process.

2. An earth-boring mechanism specified in claim 1 in which the cylindrical main central body member thereof, having an external diameter almost as the tubular cylindrical drill pipe through which it is installed in the tubular cylindrical shoe, fixedly attached to the lower tip thereof and having means preventing said central body member from passing on out the lower end of said drill pipe, is provided with means in the upper part of that main central body member whereby hydraulic pressure of drilling fluid, descending through the drill pipe, (at the election of the driller controlling connection of said drill pipe with a pump driven by suitable means adjacent the head of the well, and into a suitable vertical canal passing through the center of the generally cylindrical main body member, actuates the upper tips of multiple suitable dogs pivotally mounted in respective vertical slots in the upper portion of said main body member to force said upper tips of said dogs outward from said main body member and into an annular space below the lower end of the drill pipe having its threaded lower tip screwed into the tubular cylindrical shoe fixedly attached thereto, thereby causing said main body member pivotally mounting said dogs in the slots therein to remain fixed with respect to the shoe and drill pipe in which it thus becomes fixedly mounted until such time as the hydraulic pressure of the pump at the head of the well is cut off by the driller, at which time suitable small springs mounted in the respective slots in the main body member cause said dogs to recede into said slots to such extent that said main body member can be drawn upward through said drill pipe by means of a suitable cable having attached to its lower tip a grappling mechanism of sufficient weight that the grappling mechanism becomes attached to a lifting device attached to the upper part of the main body member, when the said grappling mechanism and the lower tip of the cable to which it is attached descends sufficiently through the drill pipe from a suitable reel from which it unwinds at the head of the well.

3. An earth-boring mechanism specified in claim 1 in which the central body member of the drilling mechanism has a vertical cylindrical canal through the center thereof, carrying drilling fluid downward and having a diameter at least about one-fifth as great as the diameter of the drill pipe, and has multiple vertically disposed slots, around said vertical canal, in the exterior wall of the generally cylindrical central body member, through which slots, near the upper tips thereof, are mounted corresponding horizontally disposed hinge pins at different elevations in the said generally cylindrical main body member, on which hinge pins are hingeably mounted said arms that hinge outward toward their lower tips into the respective gaps

in the lower margin of said drill pipe shoe, below which the rock-disintegrating means in the lower tips of said arms in the rotational drilling process underream a hole of sufficient diameter for the drilling fluid to carry most effectively the rock cuttings upwardly around the drill pipe shoe and the multiple threaded couplings by which the joints of the drill pipe are joined together.

4. An earth-boring mechanism specified in claim 1 in which the generally cylindrical central body member of the drilling mechanism has a central vertical cylindrical canal, carrying drilling fluid downward through the center thereof and having a diameter at least about one-fifth as great as the diameter of the drill pipe, and has in the exterior wall of the generally cylindrical central body member and disposed around said vertical fluid carrying canal of said approximate diameter, multiple vertically disposed slots, in each of which is hingeably mounted on a horizontal pivot pin a vertically disposed arm, which during the drilling process, after the cylindrical main body member becomes fixedly mounted in the drill pipe shoe with respect to which it will not rotate thereafter, is hinged outwardly at its lower tip into one of the duplicate gaps in the drill pipe shoe by means of pressure of the drilling fluid, descending through the central canal of the main body member at the election of the driller controlling a suitable pump at the head of the well, exerted outwardly on the lower half of each said arm by a short cylindrical prod rod mounted loosely in a small canal disposed at an angle with respect to the horizon and connecting the central canal to the vertically disposed exterior slot in the outer wall of the main body member in which said arm is hingeably mounted.

5. An earth-boring mechanism specified in claim 1 in which the generally cylindrical main body member of the drilling mechanism has a vertical cylindrical central canal, carrying drilling fluid downward through the center thereof to the multiple rock-disintegrating means and having a diameter at least about one-fifth as great as the diameter of the drill pipe, and has in the exterior wall of the generally cylindrical central body member, and disposed around said vertical fluid-carrying canal of at least the said dimension, multiple vertically disposed slots, in each of which is hingeably mounted on a horizontal pivot pin a vertically disposed arm, which during the drilling process, after becoming mounted in the drill pipe shoe, is hinged outward at its lower tip, mounting rock disintegrating means, into one of the duplicate gaps through the lower margin of the drill pipe shoe by means of the following mechanism: a pair of duplicating vertically disposed cylindrical holes, spaced apart from each other and from the vertical central canal, drilled upward in the central body member into the corners of the floors of the vertical slots in which the said arms are hingeably mounted; a cylindrical push rod, having a conical upper tip, slidably mounted in each of said holes beneath the diagonally disposed lower face of the lower tip of the arm mounting the rock disintegrating means so disposed that upward pressure on the pair of duplicate pushrods will force the conical upper tips of said rods between the inner face of the vertical slot and the inner face of the arm mounted hingeably therein, which arm thereby has its posture adjusted from vertical and has its lower tip hinged outwardly through the respective gap in the lower margin of the drill pipe shoe; and means reciprocating said multiple arm-adjusting push rods consisting of a tubular cylindrical integrally attached downward extension of the main central body member, of smaller outside diameter than said main central body member, into which all of the multiple said vertical holes, accommodating the respective paired arm adjusting pushrods, extend, but have their lower approximate halves converted into hemicylindrical slots by virtue of the increased diameter of the vertical canal in the lower half of said tubular cylindrical downward extension of said central body member, onto whose externally threaded lower tip is screwed a suitably threaded cup-collar that slidably retains in said enlarged lower half of said downward tubular cylindrical extension of the central main body member a tubular aligning and connecting member having a midsection, of greater outside diameter than the tips thereof, to which the lower tip of each of the multiple vertically disposed adjusting pushrods is attached fixedly, so that reciprocation of said tubular cylindrical connecting member with respect to the main body portion of the drilling mechanism hingeably mounting the several arms therein serves to adjust the angle of disposition of said arms from the vertical positions to which they tend to be held inside their respective slots inside the cylindrical tubular drill pipe by means of small resilient springs mounted around the respective hinge pivot pins on which the respective arms are hingeably mounted; and means of effecting such reciprocation for adjustment of the angles of disposition of said arms from vertical consisting of suitable tool-joint accommodating threads mounted on the conical lower tip of the said tubular cylindrical aligning and connecting member onto which is screwed, below the above-mentioned internally threaded cup-collar, an adapter bushing having corresponding internal tool-joint threads whereby there is attached fixedly to said tubular cylindrical aligning and connecting member a drilling mechanism boring a pilot hole, downwardly ahead of the aforesaid underreaming mechanism, having a diameter almost as large as the internal diameter of the drill pipe through which the generally cylindrical central body member is made to descend, until further downward travel is limited by the shoe mounted on the lower tip thereof.

6. An earth-boring mechanism specified in claim 5 in which the drilling mechanism boring the pilot hole ahead of the underreaming mechanism bores an annular groove around a rock formation core, which thereafter is retained in an inner core barrel provided with a suitable core-catching mechanism, whereby the rock core segment of the formation penetrated is lifted to the well head by means of a cable attached to the upper portion of the main generally cylindrical body member by a grappling member attached to the lower tip of the cable descending through the drill pipe and provided with means whereby said grappling member of sufficient weight to draw the tip of the cable downward and to attach itself to means connected to the said main generally cylindrical body member.

7. An earth-boring mechanism specified in claim 1 and employing the following: a generally cylindrical central main body member which has in its outer wall four vertically disposed slots, in width about one-third of the outside diameter of the drill pipe shoe, in the upper inner tips of which are located vertically disposed ribs, about one-half as wide and one-half as long as said slots respectively, integrally attached to the central section of the body member intermediate said slots, in each of which is hingeably mounted an arm, having industrial diamonds mounted on the lower tip thereof, on a pivot pin having its tips fixedly mounted in said body member, with its horizontally disposed longitudinal axis parallel to the axis of one of the other pivot pins and at right angles to the other two, which have parallel axes disposed at a level almost an inch higher than the axes of the first two pivot pins, and extending through the upper tip of said arm, which tip in horizontal cross section is substantially U-shaped and extends around its respective body rib, which is almost square in cross section at the axis of its hinge pivot extended therethrough, below which the outer face of the respective rib gradually slopes inwardly, at an angle about 30° from vertical, toward the inner wall of the respective slot and disappears as a rib about halfway downward toward the bottom of said slot, which is at the same level as the bottoms of the other three slots; a pair of resilient U-shaped springs mounted around the hinge pivot pin of each of the respective arms tending to keep inclosed in its respective slot each of the said arms, on the lower tip of each of which are suitably mounted industrial diamonds, which tend in combination, by virtue of the fact that the lower tips of all said arms reach downward to the same substantial arcuate level in their respectively accommodating slots, while one diametrically opposed pair of the mounting pivot pins is mounted higher in the body member than the other two

diametrically opposed pivot pins at right angles thereto, to underream in the drilling process an enlarged hole of suitable diameter, in excess of the outside diameter of the drill pipe shoe, around a pilot hole, having a diameter almost but not quite as great as the inside diameter of the drill pipe, drilled by suitable means below the generally cylindrical main body member in which the four arms are hingeably mounted; hydraulic means whereby the driller, at his election, can hinge all four of said diamond-mounting arms outwardly, into their respective gaps in the lower margin of the drill pipe shoe by the full arc for each arm permitted by each of the respective duplicate gaps in said shoe, by control of pressure in the drill pipe connected to the vertical cylindrical canal in the center of the generally cylindrical main body member, in which said canal its diameter is reduced slightly in the midsection thereof and below four small cylindrical canals, suitably disposed at angles with respect to the horizon and at right angles to each other in pairs at slightly differing levels, leading from the upper segment of said central canal having the larger diameter to the respective four slots through the central ribs in the upper inner corners of those slots, into which project the outer tips of four cylindrical prod rods of suitable short length that fit loosely in their respective canals, in which pressure from the central vertical canal, at the election of the driller, forces the outer tips of those prod rods against the said diamond-mounting arms intermediate the tips thereof and thereby forces the outer wall of each of the four arms against the roof of its respective gap in the lower margin of the drill pipe shoe; and means keeping the underreaming mechanism, and the larger hole drilled in the rock formations thereby, suitably aligned with the lower smaller pilot hole by employing the following: a tubular cylindrical downward extension of the main body member, said downward extension having an outside diameter only slightly less than the diameter of the cylindrical pilot hole, on whose lower tip are provided suitable threads whereby there is attached to said tubular cylindrical downward extension a guiding tubular cylindrical member, of suitable length and outside diameter to slip easily through said lower pilot hole, whose lower internally threaded tip is closed by a slightly conical member having a vertical hole through the center thereof, in which is fixedly mounted a much smaller vertically disposed pipe having suitable means at the upper tip thereof connecting it to the lower tip of the aforesaid downward tubular extension of the main body member, there being adjacent the upper tip of the guiding tubular cylindrical member multiple orifices through the wall thereof to permit larger rock cuttings to drop into that retaining bucket member from the drilling fluid flowing upward around said tubular cylindrical guiding member.

8. An earth boring mechanism employing in continued workable cooperative conjunction: an internally threaded tubular cylindrical shoe screwed on the lower tip of a rotatable vertically disposed string of tubular cylindrical drill pipe, through which is installed from the head of a well a drilling mechanism whose generally cylindrical main central body member, having an outside diameter almost as great as the internal diameter of the drill pipe through which it is easily slidable, is prevented by said shoe from passing out of the lower tip of said drill string at any time; a tubular cylindrical linkage member fixedly attached by suitable internal threads to the upper threaded tip of said main body member, having a vertical canal through the center thereof with a diameter nearly one-third that of the cylindrical drill pipe, and to the lower tip of a threaded and aligned second tubular retainer member, of smaller diameter than the first and of suitable short length of several inches, whose upper externally-threaded tip is screwed into the lower tip of a lifting and aligning tubular cylindrical member several feet in length having a suitable upper tip, whose outside diameter is almost as great as the internal diameter of the drill pipe through which it is easily slidable, and whose upper face slops downward conically toward the rotational axis of the drill pipe and of the main body member of the drilling assembly installable and removable through said drill pipe; a horizontally disposed circular lifting plate, having a suitable round hole in the center thereof, fixedly attached to said lifting and aligning tubular cylindrical member, immediately above the upper end of the short tubular retainer member, whose upper tip is screwed into the lower tip of said lifting and aligning tubular member, provided with a suitable spider framework attached fixedly to the cylindrical wall of said retainer member and mounting fixedly in the center thereof a small vertically disposed tubular cylindrical seating member, through whose internal threads is screwed a threaded cylindrical adjusting rod having an upper tip with a conical upper face, whose level of disposition in said retainer member is secured by a pair of nuts screwed on the threaded cylindrical adjusting rod immediately above and below the tubular seating member; and a suitable grappling means attached to the lower tip of a cable inserted through the drill pipe when desired and employing the following: four vertically disposed lifting members of sufficient length to provide sufficient weight to pull downward rapidly through said drill pipe filled with drilling fluid the lower tip of the retrieving cable, around which all the four said substantially straight lifting members are fixedly attached thereto by means separating said lifting members from each other and disposing them with their lower tips tending to remain separated from each other by at least the same distances as at the lower tip of the lifting cable, there being attached to the lower tip of each such substantially straight lifting members, having lower ends that slope upwardly toward the axis of the vertically disposed cable, multiple angular latching devices whose upper faces slope upwardly toward their outer tips, which during downward travel of the cable tip are drawn together by a strong cord wrapped and tied tightly around the four vertically disposed lifting members immediately above said latching devices, whose combined horizontal extent is thus minimized to such degree that said latching devices pass readily downward through the suitably shaped round hole in the center of said horizontal lifting plate, whose lower face slopes upwardly from said center hole so that the latching devices will not return upward through said center hole in said lifting plate, in response to subsequent lifting of the cable, after the aforesaid strong cord is broken by downward falling of the four said lifting members against the aforementioned conical upper face of the spearlike cylindrical adjusting rod, mounted fixedly in the center of the tubular cylindrical retainer member a suitable distance below said horizontal lifting plate, which spreads apart the lower tips of the four substantially straight lifting members to which respectively the latching devices are rigidly attached, thereby affording a suitable linkage between the lower tip of said cable and the generally cylindrical main body member of the drilling device.

9. An earth-boring mechanism employing in continued workable cooperative conjunction: an internally threaded tubular cylindrical shoe screwed onto the lower tip of a rotatable vertically disposed string of tubular cylindrical drill pipe, through which is installed from the head of the well a drilling mechanism whose generally cylindrical central main body member, having an outside diameter almost as great as the internal diameter of the drill pipe through which it is easily slidable, is prevented by said shoe from passing out of the lower tip of said drill pipe string; a tubular cylindrical aligning retainer member at least nearly one foot long and having the same outside diameter as the generally cylindrical main body member, to which it is fixedly attached by threads in the lower tip thereof screwed onto the external threads of an upper reduced diameter segment of said main central body member, above the upper end of which by a fraction of an inch are the lower faces of at least two diametrically disposed generally rectangular openings openings, about 1 inch wide and nearly 2 inches high, through the wall of said aligning retainer member, through which openings in said wall respectively are extendable the upper tips of suitable diametrically opposed scotching dogs, whose upper tips during the drilling process are projected into the annular space inside the drill pipe shoe im-

mediately below the lower end of the drill pipe, and whose lower cylindrical tips are mounted in cylindrical cups in the upper face of the main central body member, to which each of said scotching dogs is pivotally attached at its lower tip by means of an arcuate plate having a notch in one side for accommodation of the pivotally mounted oscillatable scotching dog, whose hinge pivot pin is held to the upper horizontal face of the main central body member by bolts extending through holes in said arcuate plate, so that it is possible to pivotally attach the respective dogs to the central body member of the drill mechanism, after there has been mounted on said central body member the tubular cylindrical retainer member and suitable means of adjusting tilt of the said scotching dogs in unison; means of retracting the upper tips of the scotching dogs in unison from their positions in the annular space in the drill pipe shoe, beneath the lower end of the drill pipe, consisting of a tubular cylindrical adjusting member vertically slidable in an annular cavity in the upper tip of the main central body member and within the tubular cylindrical retainer guiding member, said adjusting member having suitable rectangular notches in its upper margin to accommodate the respective scotching dogs, each of which rests substantially on the lower face of its respective notch in said cylindrical adjusting member, when the upper tip of the scotching dog is extended outwardly through the hole in the wall of the tubular cylindrical retainer member, which has attached to its inner upper margin multiple vertical adjusting rods, intermediate the respective notches in said tubular cylindrical adjusting member, whereby the tubular cylindrical adjusting member is fixedly attached by the upper tips of said vertical adjusting rods of suitable equal short length to a horizontally disposed circular lifting plate, slidably mounted inside the said tubular cylindrical guiding retainer member, provided with a suitable hole in the center thereof, whereby a suitable grappling mechanism fixedly attached to the lower tip of a cable extending downward, when desired, from a suitable reel at the head of the well is employed to raise the horizontal lifting plate, the multiple vertically disposed adjusting rods fixedly attached thereto, and the tubular cylindrical adjusting member fixedly attached to the lower tips of said adjusting rods, thereby slightly raising in unison all the outer tips of said pivotally mounted scotching dogs and thus retracting them inwardly, from the annular space in the shoe beneath the lower end of the drill pipe, toward the rotational axis of the drill pipe, so that the upper tips of said hingeably mounted scotching dogs become retracted into their respective holes through the wall of the tubular cylindrical guiding retainer member, which in turn lifts the main central body member rigidly attached to its lower tip, when the horizontal lifting plate rises a fraction of an inch and thereby comes in contact with the movement limiting lower face of an annular cylindrical member, having an outside diameter the same as the outside diameter of the guiding retainer member, easily slidable in the drill pipe, having external threads, formed on a lower segment of reduced diameter, screwed into the upper guiding retainer member, whereby directly the entire drilling mechanism is lifted through the drill pipe, when the suitable grappling mechanism on the end of said cable descends through the downward sloping conical upper face of said annular cylindrical member provided with a cylindrical hole at the center thereof very slightly larger in diameter than the hole in the center of the horizontal lifting plate; a diffusing spear member having a conical upper face fixedly disposed in the center of said tubular cylindrical guiding retainer member, a suitable distance below the hole in the center of the horizontally disposed circular plate attached to the upper tips of the four adjusting rods, whereby multiple latching members attached to the lower tips of vertical members of the grappling device attached to the lower tip of a cable extending downward, at the election of the driller, through the drill pipe are brought into contact with the lower face of the horizontal lifting plate around the hole through the center thereof, when the cable is raised upward to effect such lifting of the drilling mechanism through the drill pipe for any reason; and means tending to keep the upper tips of the hingeably mounted scotching dogs caught beneath the lower end of the drill pipe in the drill pipe shoe, until such time as the cable lifts the tubular cylindrical adjusting member through whose notches those scotching dogs are disposed, said means of keeping the upper tips of the scotching dogs outwardly extended employing the following: a short tubular cylindrical sleeve, fixedly attached to the wall of the tubular cylindrical guiding retainer member in the midsection thereof, beneath which is mounted the upper tip of a resilient coiled compression spring, whose lower tip rests on the upper end of a short tubular cylindrical sleeve, having an outside diameter slightly less than the tubular cylindrical guiding retainer member, in which it is easily slidable, whose lower end, suitably rounded in cross section for easy accommodation of the several scotching dogs, rests on the diagonally disposed upper faces of the multiple hingeably mounted scotching dogs, whose upper tips thus tend to be forced outward as far as possible by the downward force of the resiliently flexible coiled compression spring acting on all said scotching dogs in unison.

10. A rotary coring mechanism employing in continued workable cooperative conjunction the following: a tubular cylindrical outer core barrel serving as a rotatable drill pipe whose lower tip core barrel fixedly attached by suitable threads to the upper tip of an annular drill head member, having an outside diameter the same as said rotatable drill pipe, whose upper conical face slopes downward to a cylindrical hole, in the center thereof and about an inch deep, internally threaded for receiving a second rotatable core barrel, whose inner diameter is the same as that of the smaller cylindrical hole extending almost all the way through said annular drill head member with that diameter and thereafter all the way through with a slightly smaller diameter, there being a narrow circular horizontal shoulder adjacent the lower tip of said annular drill bit member, somewhat longer than its horizontal outside diameter, on which shoulder rests a nonrotating core-catching device, of the same internal diameter as the lower smallest cylindrical hole through the lower tip of said annular drill head member, on which in turn rests a notched nonrotating inner core barrel having the same internal diameter as the nonrotating core-catching member and the hole through the lower tip of the aforesaid annular drill head member, which has an outside diameter more than halfway upward from its lower end that is only slightly more than three-fifths of the diameter of the tubular cylindrical drill pipe attached to its upper threaded tip; a diagonally disposed face, conveniently 30° from vertical, cut across said annular drill head member and extending upward diagonally outward from the lower end of the smallest hole through the center of said annular drill head member, into which a hole of suitable diameter is drilled perpendicularly, at a suitable distance upward from said lower tip, and internally threaded for receiving a tip-threaded stud bolt secured in said annular drill head member and serving to mount therearound the inner race of a suitable antifriction bearing, whose outer race is mounted in a suitable rolling cutter, made of suitable hardened steel alloy, whose rolling lower teeth disintegrate the surface of the rock formation immediately around a cylindrical core of small enough diameter to slidably enter the smallest diameter cylindrical hole in the lower tip of said annular drill head member; a second annular drilling head member having an outside diameter at its upper end equal to the outside diameter of the outer core barrel drill pipe and to the maximum diameter of the upper section of the first said annular drill head member, around the lower generally cylindrical section of which is fixedly mounted the second said annular drill head section, which has a generally conical upper face, corresponding to a conical lower face of the upper section, sloping downward toward the rotational axis of the two sections as an auxiliary means keeping the two sections aligned under vertical pressure, and which has multiple keys imbedded in said conical surface serving as very

strong means, in addition to multiple bolts inserted perpendicular to the contact surfaces of the two annular drill head members, keeping the upper section from rotating with respect to the lower section, whose lower approximate three-fifths has integrally formed on its outer cylindrical surface four vertically disposed outward extensions by a small fraction of an inch, respectively having arcuate outer faces disposed at 90° intervals around the said second annular drill head member; a suitable recession formed in the lower tip of said second lower outer drill head section to accommodate loosely the aforesaid rolling cutter mounted on an axle pin fixedly attached by suitable means to the lower tip of the smaller diameter lower section of the upper annular drill head member; a second axle pin having its longitudinal axis substantially in the same vertical plane containing the first said rolling-cutter axle pin fixedly attached to the lower tip of the upper said annular drill head member, but with the second said axle pin, suitably mounting rotationally a second suitable rolling cutter, being mounted in the lower tip of the lower and outer second said annular drill head member almost member, almost through which, at the midpoint plane of one of the outward arcuate extensions thereof, the threaded hole mounting the threaded tip of said second axle pin extends, the axis of said second rolling-cutter axle pin, mounting a suitable antifriction bearing thereon, being disposed at a smaller angle than the first said rolling-cutter axle pin with respect to the horizon, and the rolling cutter, provided with suitable teeth on a slightly conical face of smaller maximum diameter than the diameter of the first said rolling cutter having a substantially cylindrical outer face for the teeth thereof, describing an annular almost horizontal cutting path on the bottom of the hole larger than the annular rotational path of the first said cutter by virtue of the suitable cylindrical cavity milled in the lower outer second said annular drill head member for rotational accommodation of the second said rolling cutter, for the rotational accommodation of which a suitable cavity also is cut in the adjacent outer wall of the telescoped lower segment of the inner upper first said annular drill head member; a pair of diametrically disposed axle pins, mounted in a vertical plane passing through the rotational axis of the two telescoping annular drill head members perpendicular to the vertical plane including the axes of the two previously mentioned rolling-cutter axle pins, mounted at suitable equal angles with respect to the horizon in suitable cylindrical cavities milled in the lower inner tip of the outer lower said annular drill head member, there being corresponding cavities milled in the outer wall of the inner said telescoped second said annular drill head member rotationally accommodating the upper faces of the two rolling cutters mounted on said pair of axle pins provided with suitable antifriction bearings for said substantially duplicate rolling cutters having suitable teeth in conical faces, which describe an annular path disintegrating the rock formation and thereby cutting a hole of slightly greater diameter than the diameter of the lower outer annular drill head member through the respective outward vertical extensions thereof, between which the rock cuttings are carried upward by the circulating drill fluid, for the downward passage of which through the pair of annular drill head members multiple suitable small holes are provided therethrough at least almost vertically.

11. A pilot hole drilling and coring mechanism consisting of a novel modified annular female "box" segment of a tool-joint screwed onto the lower "pin" segment of a conventional "internal upset" flashwelded joint of drill pipe with said annular "box" being modified to achieve the following construction: (1) to a distance of 1 inches below the lower end of the above-mentioned "pin" segment of said conventional joint of drill pipe above it, said "box" is bored out internally to form a cylindrical canal of suitable diameter, below which said vertical canal becomes conical, at an angle of 30° from vertical, until it reaches the original conventional cylindrical canal through said "box" segment of the tool-joint; (2) at a level one-quarter inch below said conical section of the canal, an annular shoulder is created by boring that conventional cylindrical canal out downwardly to an internal diameter one-eighth inch greater than above said shoulder, thereby forming a cylindrical cavity in which in due time is installed from beneath and fixedly therein a generally cylindrical insert about 1¼ inches high having **12** vertical grooves about three-sixteenth inch deep cut vertically out of the internal surface, remaining after the upper inner tip of said insert is bored out conically to continue the conical downward slope of the canal above said insert in said annular "box," of said insert, on which internal arcuate surface between said vertical grooves are mounted multiple industrial diamonds, by a sintering process well-known to the art, for reaming around a rock core remaining after the annular groove in the rock formation has been cut around said cylindrical core by rotation of said "box"; (3) 12 vertical grooves provided in the inner wall of said "box" and extending outwardly with their respective outer walls being downward extensions of the outer wall of the vertical canal having maximum diameter in said annular "box" member, each of said 12 grooves being disposed radially in said box with respect to the corresponding **12** grooves in the inner cylindrical wall of the generally cylindrical insert, which is provided with very slight ribs inserted in the respective said grooves in the surrounding "box" member to keep said "box" from rotating with respect to the generally cylindrical insert, which also forms a small vertical canal, through which drilling fluid is transmitted downward under pressure from the canal in the drill pipe, in conjunction with each of the grooves in said annular "box" member, in which those vertical canals extend downward to the lower annular tip thereof, which is formed with a hemispherical vertical cross section; (4) 12 grooves formed in said annular lower tip of said annular "box" member fixedly accommodating 12 J-shaped steel segments fixedly attached thereto by multiple bolts and other means permitting easy removal therefrom to conveniently replace any of the multiple industrial diamonds installed on the drilling face of each of said 12 J-shaped steel mounting segments individually without having to install diamonds in all of the drill bit.

12. A pilot hole drilling and coring mechanism specified in claim **11** in which is installed from above through said conventional internal-upset flashwelded joint of drill pipe an inner nonrotating tubular cylindrical core barrel having fixedly, but removably, attached to the lower tip thereof a tubular cylindrical core-catching device, having an outside diameter easily slidable through said conventional joint of drill pipe and having a lower tip that fits the upper inner face of the generally cylindrical insert around the rock core, which travels upward relatively with respect to said nonrotating core barrel and into its telescoped smaller vertically slit inner segment, in which said core is retained by a lower suitable collet provided with a suitable conical seat in said tubular cylindrical member fixedly attached to the lower tip of the outer said nonrotating core barrel.