United States Patent

[11] 3,554,304

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[45] Patented **Jan. 12, 1971**
[73] Assignee **Christensen Diamond Products Company Salt Lake City, Utah a corporation of Utah**
Continuation-in-part of application Ser. No. 583,263, Sept. 30, 1966, now Patent No. 3,437,159.

[54] **RETRACTABLE DRILL BITS**
21 Claims, 23 Drawing Figs.

[52] **U.S. Cl.** **175/259,** 175/260
[51] **Int. Cl.** **E21b 9/26**
[50] **Field of Search** 175/260, 259, 257

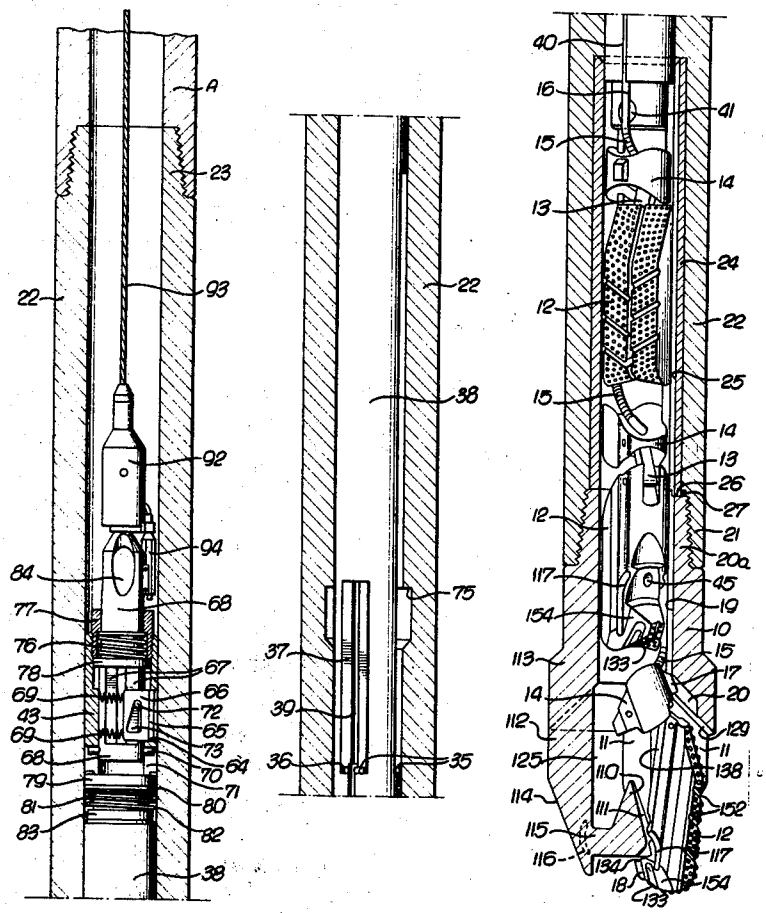
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Primary Examiner—James A. Leppink
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ABSTRACT: A rotary well-drilling bit lowered through drill pipe with cutters in tandem array, the cutters being expanded outwardly and locked to the lower end of the drill pipe to drill upon substantially the full cross-sectional area of the bottom of the well bore. The cutters can be pulled by a wire line device back into the drill pipe and elevated through the drill pipe to the drilling rig for replacement or inspection.



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SHEET 1 OF 8

FIG. 1

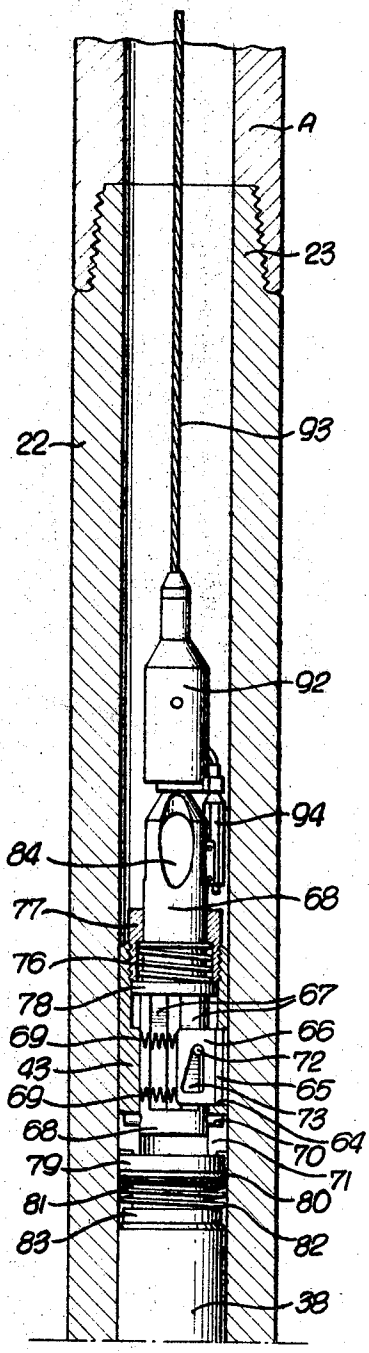


FIG. 1a.

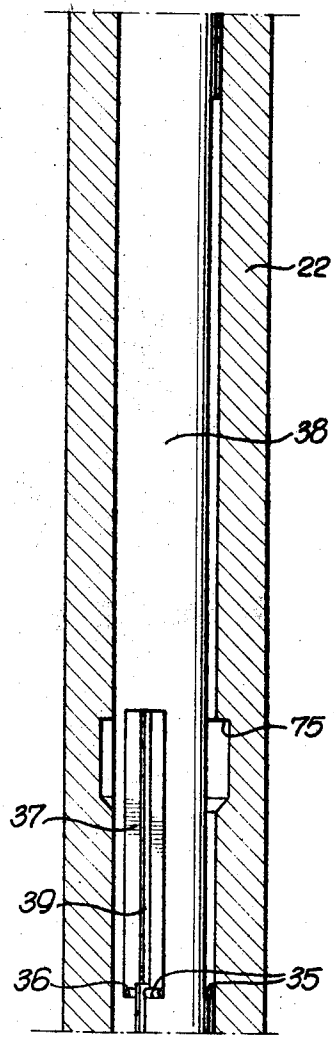
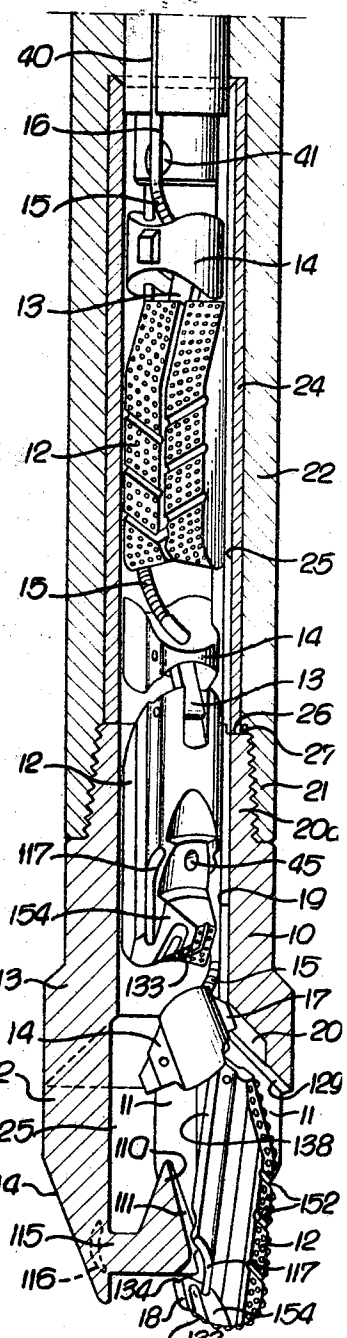


FIG. 1b.



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FIG. 2.

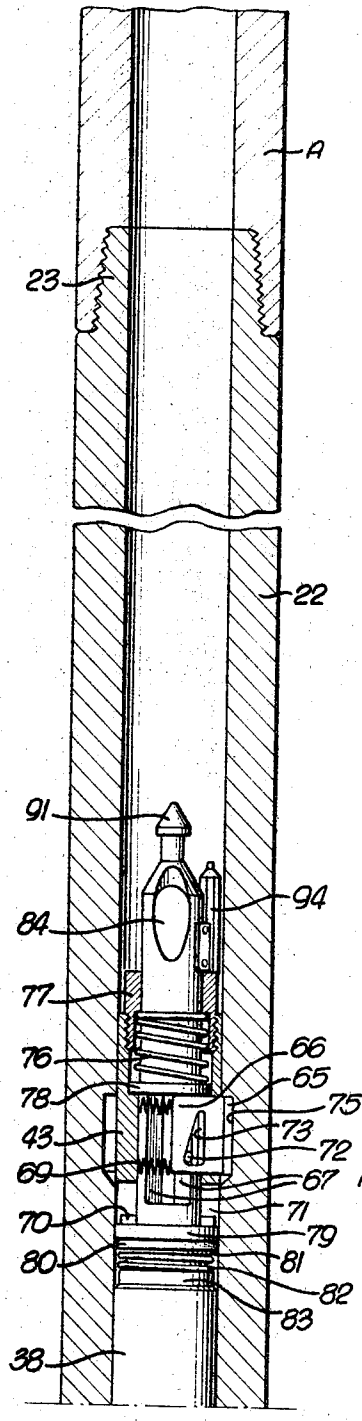


FIG. 2a.

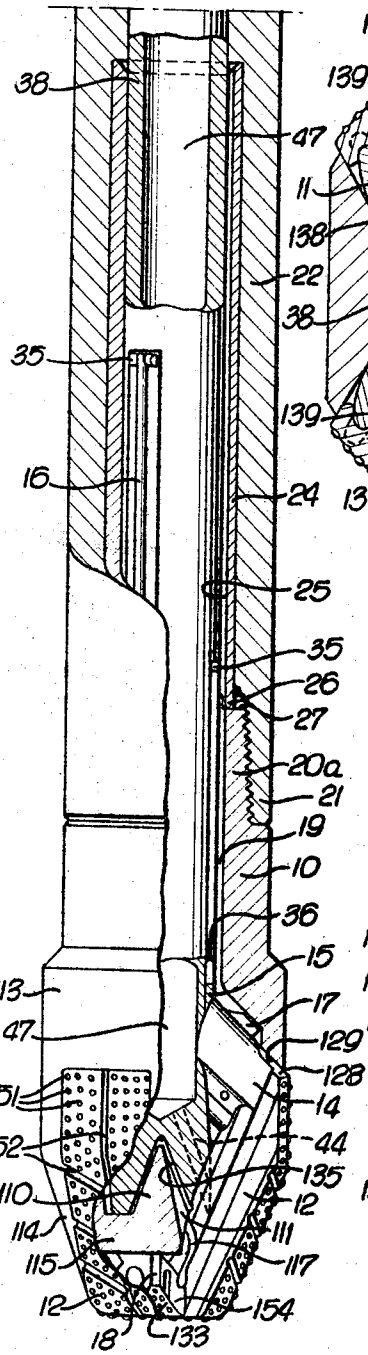


FIG. 8.

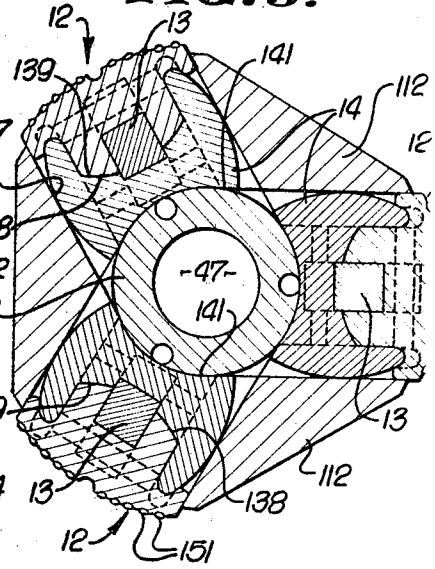
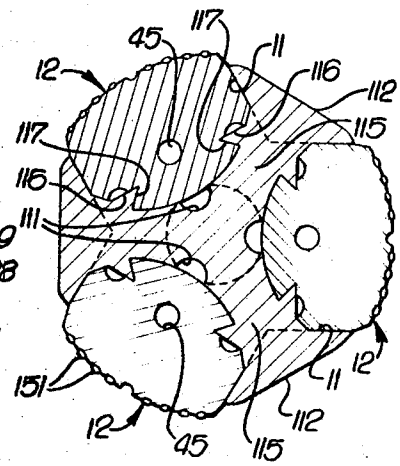


FIG. 9.



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FIG. 3.

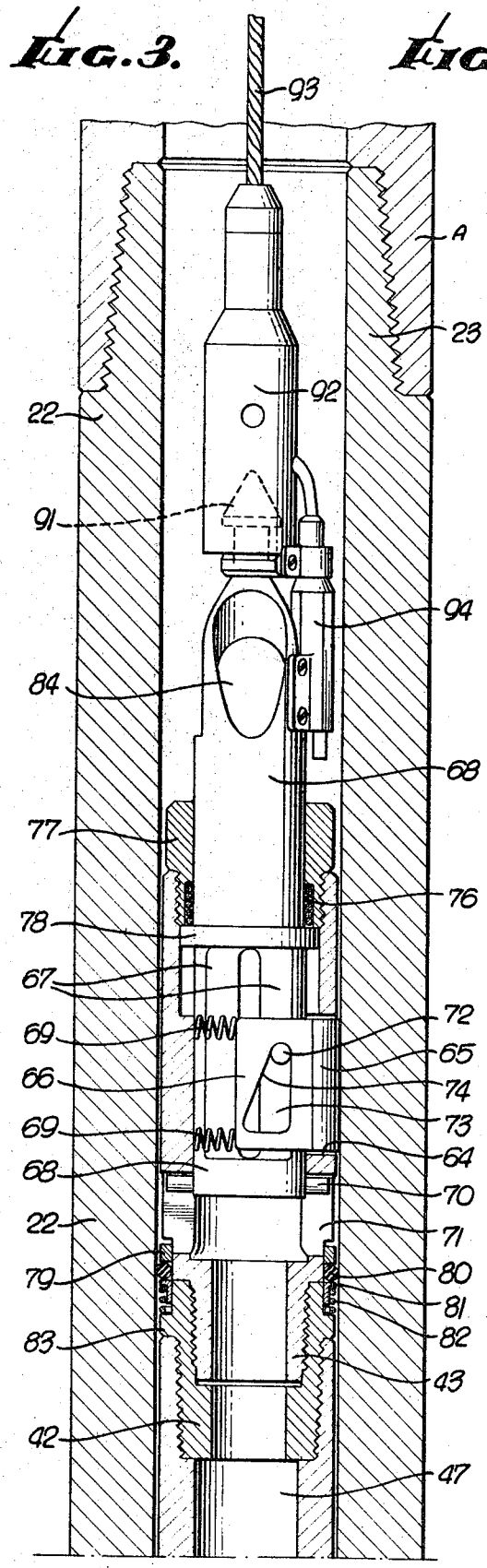
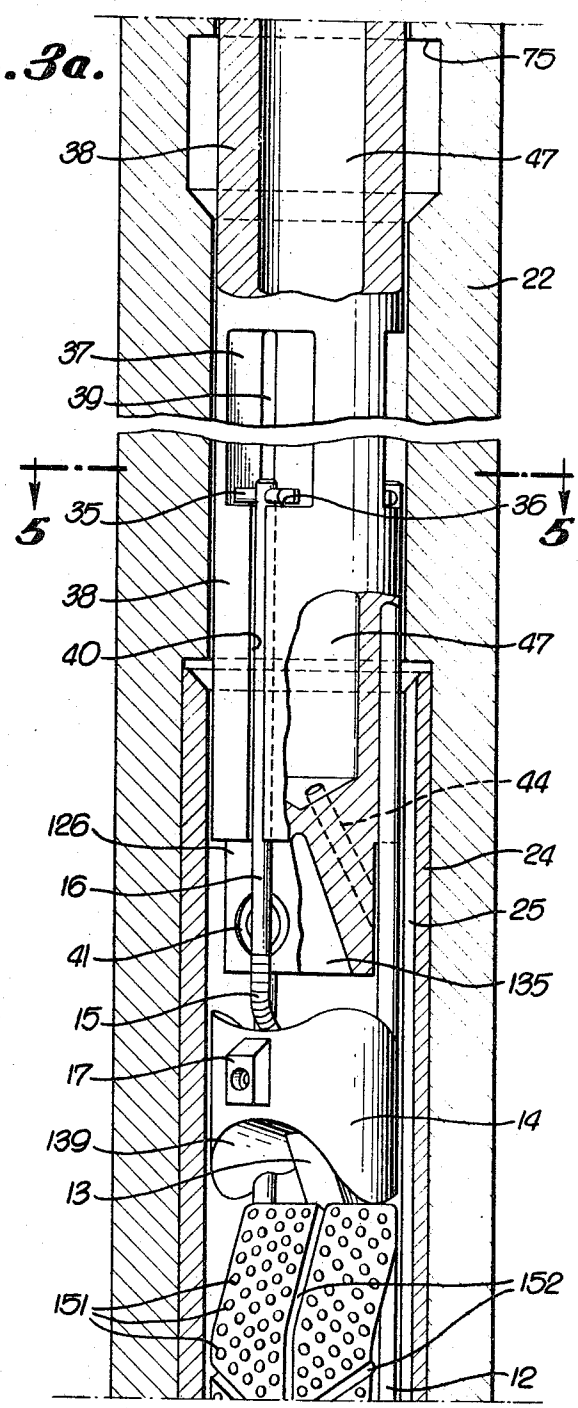


FIG. 3a.



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FIG. 3b.

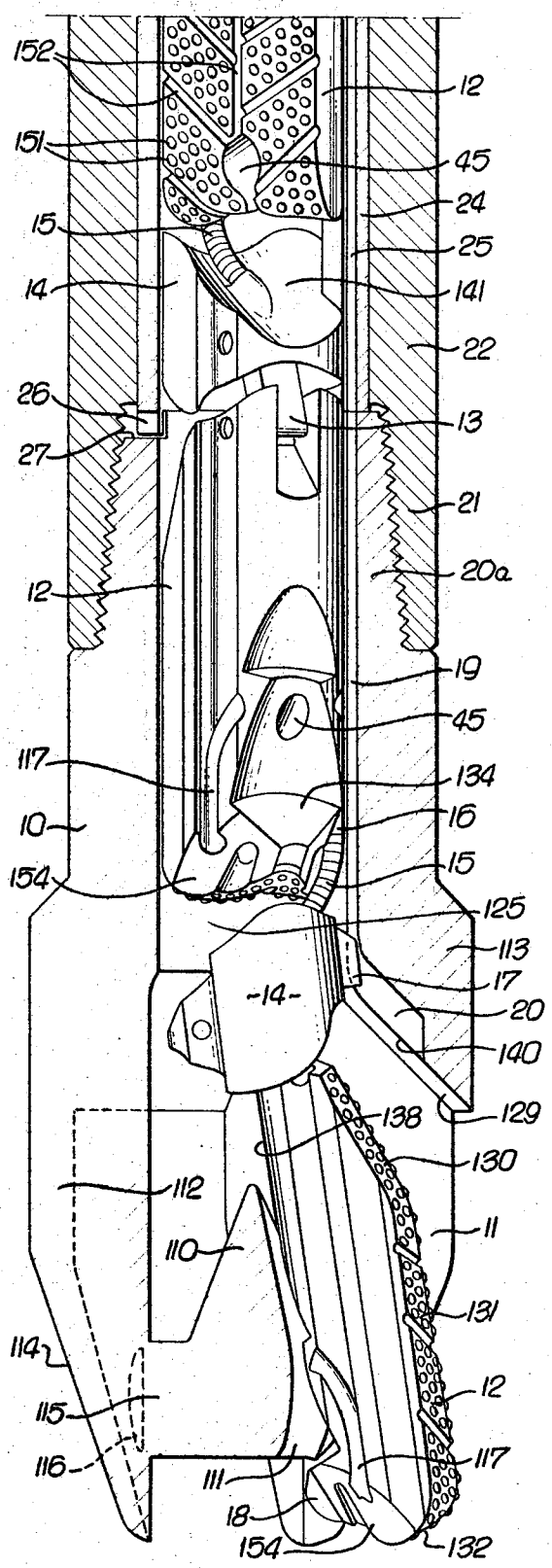


FIG. 5.

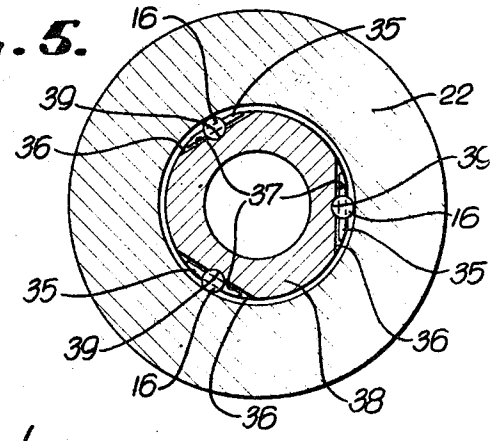


FIG. 6.

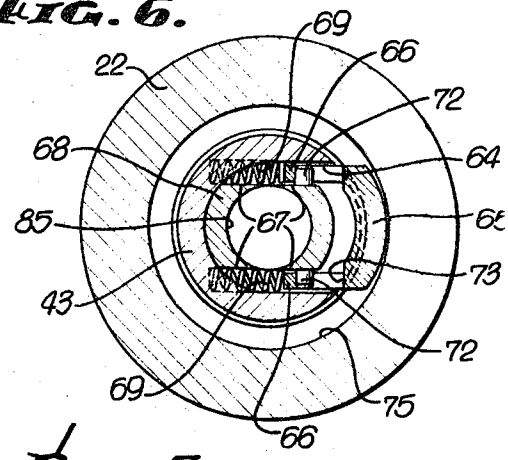
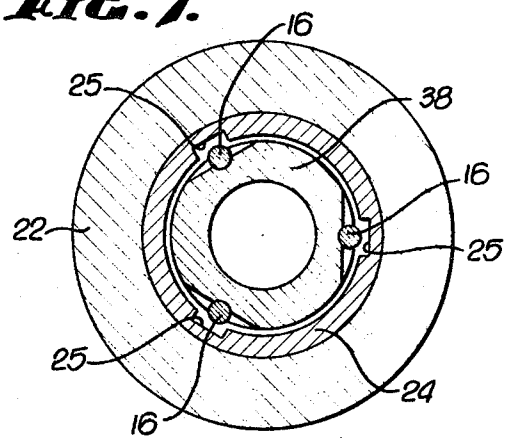


FIG. 7.



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FIG. 4.

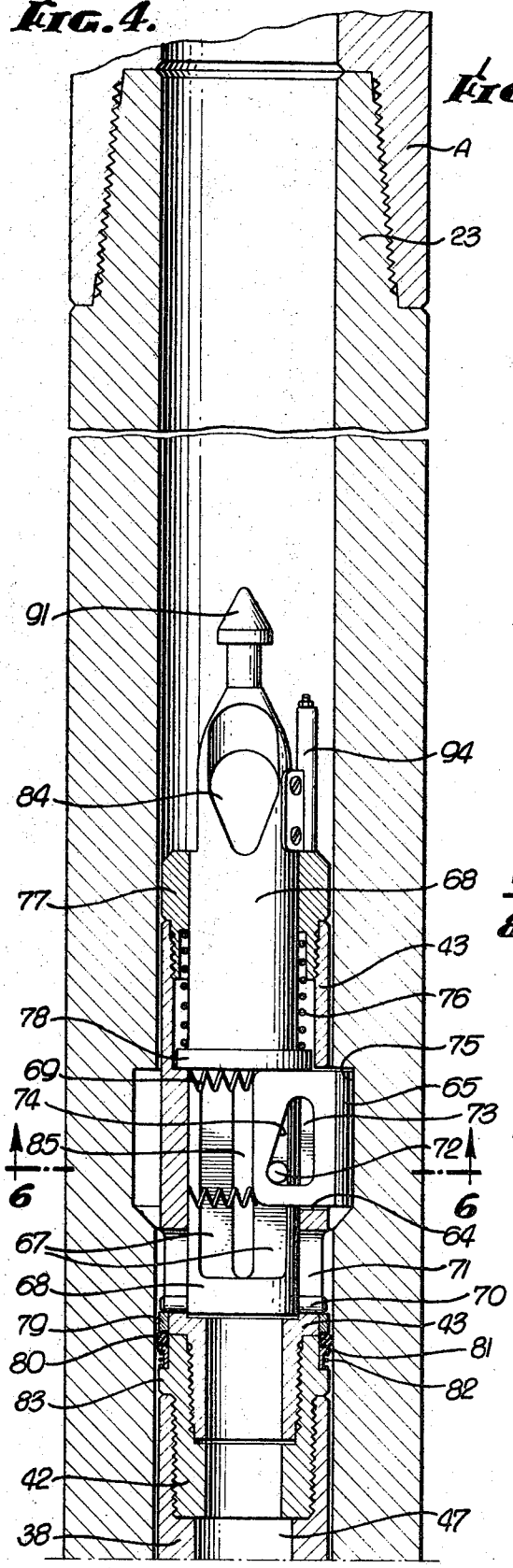
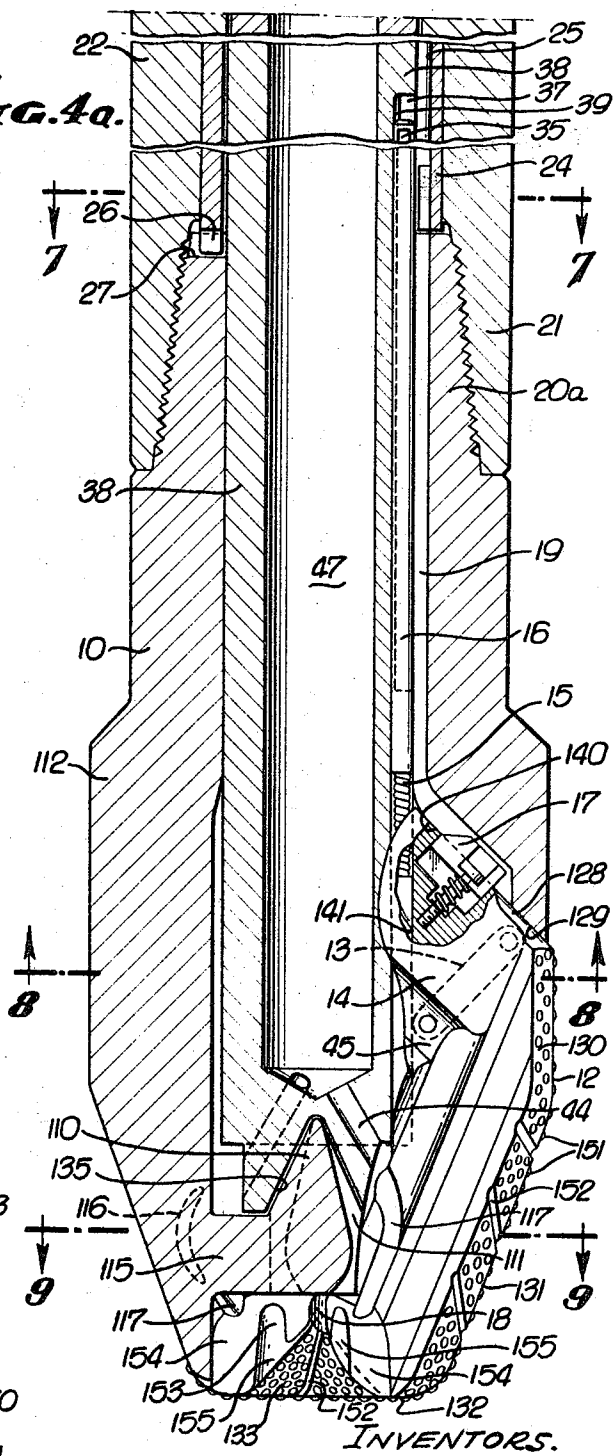


FIG. 4a.



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FIG. 10.

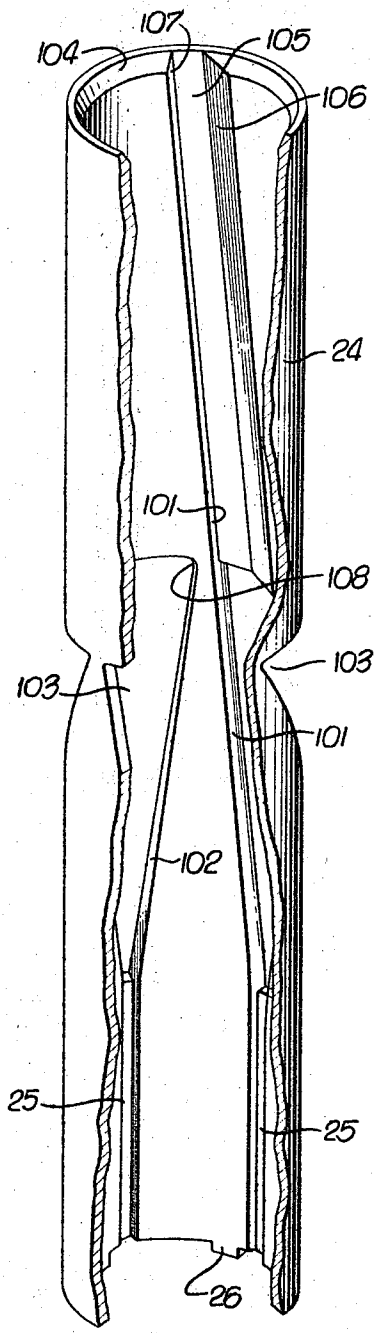


FIG. 11.

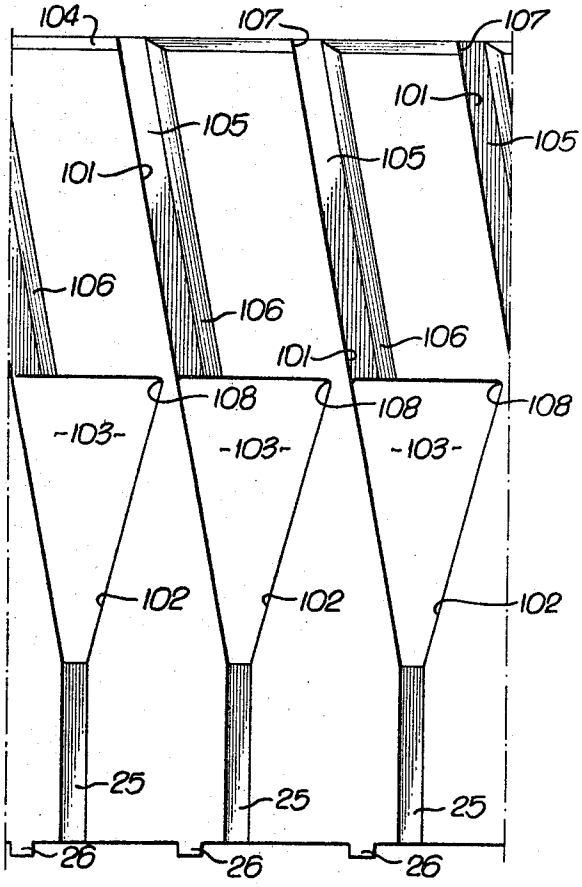
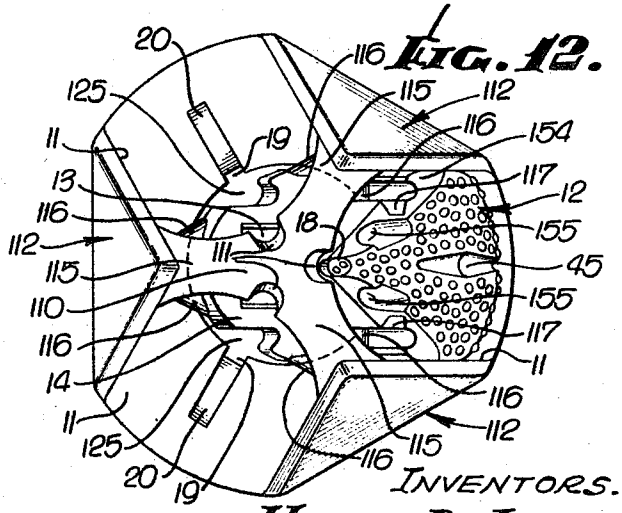


FIG. 12.



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FIG. 14.

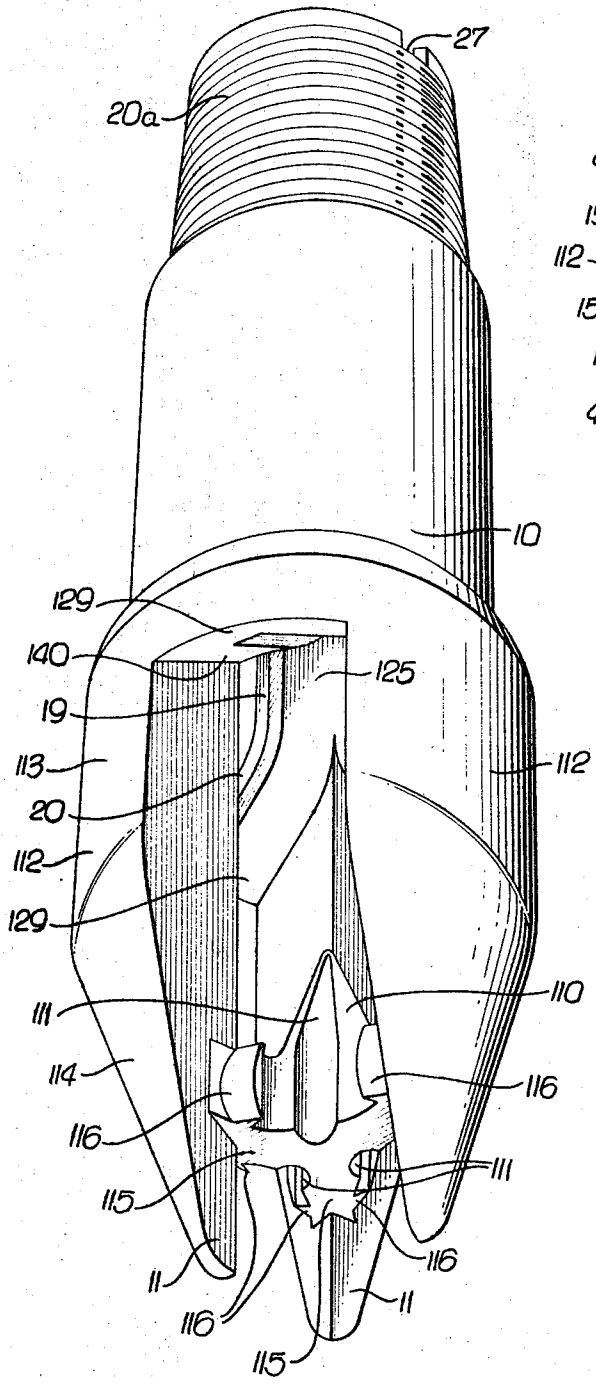


FIG. 13.

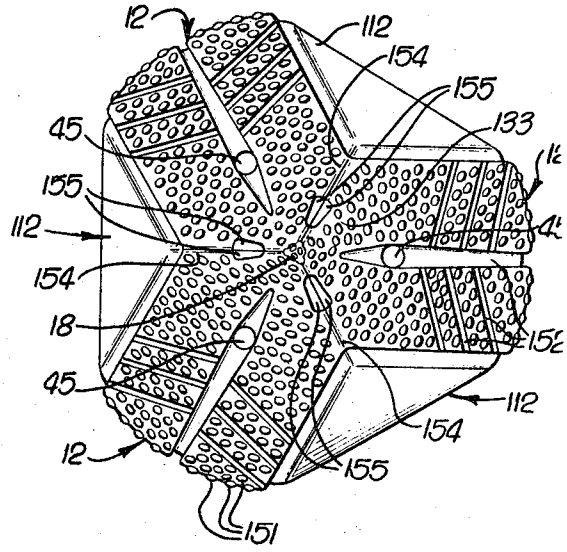
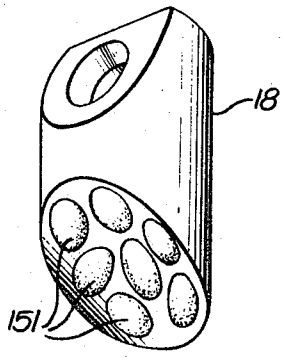


FIG. 15.



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FIG. 16.

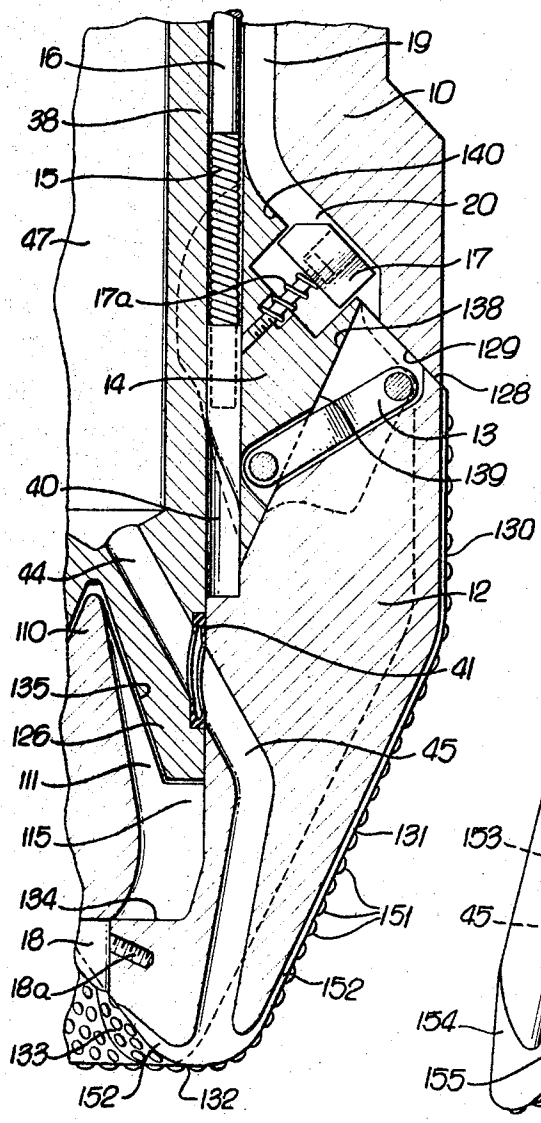
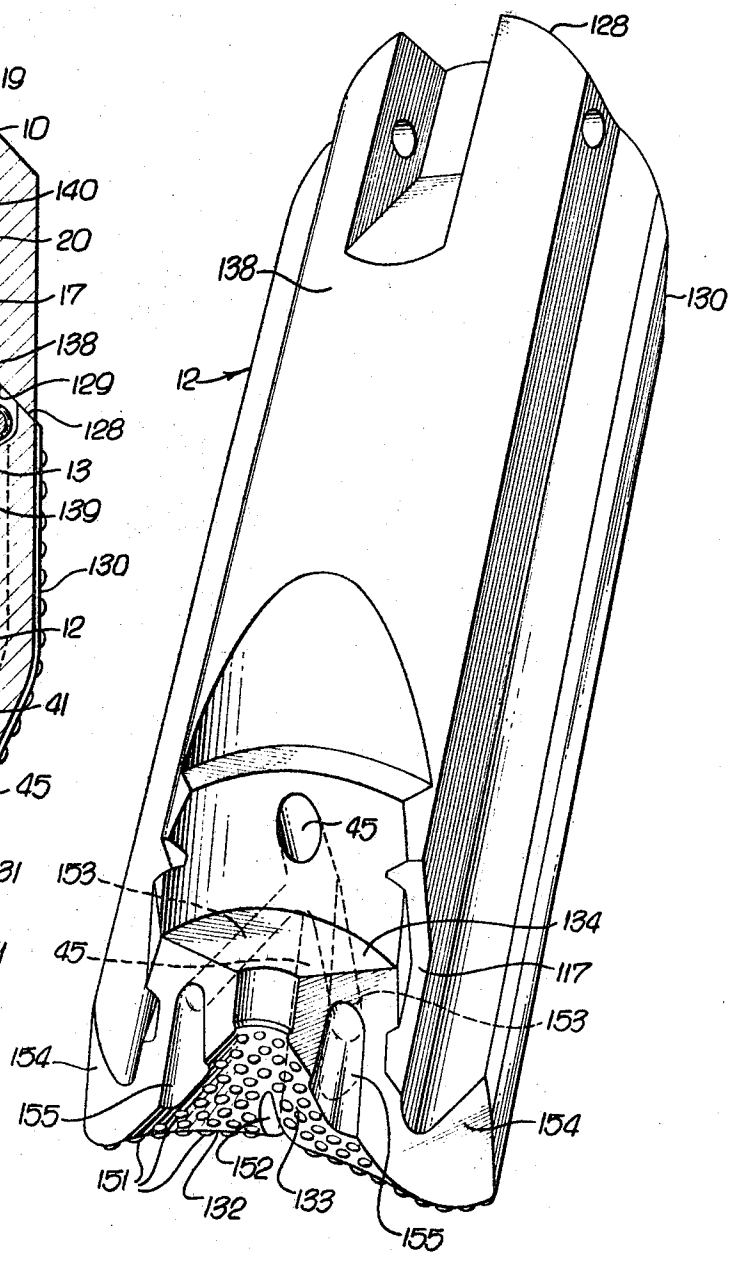


FIG. 17.



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RETRACTABLE DRILL BITS

The present application is a continuation-in-part of our application for "Retractable Drill Bits," Ser. No. 583,263, filed Sept. 30, 1966, now Pat. No. 3,437,159.

The present invention relates to rotary bits for drilling bore holes, and more particularly to rotary bits which are retrievable and replaceable by movement through a string of drill pipe extending to the drilling rig, obviating the need for withdrawing the drill pipe string from the bore hole each time the drill bit is to be removed for replacement or inspection.

In the rotary drilling of well bores, and similar bore holes, the usual practice is to secure a rotary drill bit to the lower end of a string of drill pipe and lower such pipe to the bottom of the bore hole for continued drilling of the hole. Dulling of each bit requires removal of the entire string of drill pipe to the drilling rig, removal of the dull bit, the attaching of another bit to the drill string, and relowering of the latter in the bore hole to its bottom. The necessity for "round tripping" the drill pipe for changing bits is a relatively slow and costly operation in view of the time consumed, the cost increasing as the depth of the hole increases and the string of drill pipe becomes longer. The cost of round tripping is quite considerable in offshore drilling of bore holes, in view of the very high hourly rate of operating a drilling platform, or a drilling vessel or barge floating in the ocean or other body of water.

It has been proposed to avoid the costly round tripping of the drill pipe for the purpose of changing drill bits by providing bits of the type that can be moved through the string of drill pipe, being latched in the lower portion of the latter for the performance of the rotary drilling operation, and being released from the drill pipe when the drill bit is to be replaced. The prior devices have not been successful, since the drill bit cutters are relatively small, placing limitations on the diameter of the hole which they can drill effectively. This is particularly true where the minimum diameter of the passage through the drill pipe string is relatively small.

It is an object of the present invention to provide an improved rotary drill bit of the type capable of being lowered and removed through a string of drill pipe, or other drill string, and which overcomes the above-noted disadvantages, the drill bit being capable of drilling the full cross section of the bore hole.

Another object of the invention is to eliminate the need for slow round trips with the drill pipe to change the drill bits capable of operating upon the entire bottom of the bore hole, thereby reducing considerably the time required for changing drill bits, with resultant major economies in drilling of the bore hole.

Yet another object of the invention is to provide a drill bit mechanism which embodies relatively large bit members movable through the drill pipe, and capable of being positively locked in expanded condition to the rotatable main body or drive mandrel of the bit, to drill the full cross-sectional area of a bore hole substantially greater in diameter than the outside diameter of the drill pipe disposed in the bore hole. As an example, the bit members can pass through a drill pipe string of about 4 inches inside diameter, or through a hollow shaft turbine for rotating the drill bit having an inside diameter of about 4 inches, and be capable of drilling a 9⅞ inch diameter hole when locked to the drive mandrel of the drill bit mechanism.

A further object of the invention is to provide a drill bit mechanism capable of movement through a string of drill pipe and withdrawal therethrough to the drilling rig, capable of drilling the full cross-sectional area of a bore hole more than twice the diameter of the minimum bore through the drill pipe or hollow shaft of a turbine through which the retractable bit members can pass.

Another object of the invention is to provide a rotary drill bit of the type above indicated for drilling upon substantially the entire bottom of the bore hole, in which the individual bit members are properly oriented upon reaching the vicinity of the rotatable drive member at the lower end of the drill string, to insure their correct alignment with the mandrel slots into which they are expandable into appropriate coupled relation to the mandrel, for the transmission of torque and drilling weight between the mandrel and the individual bit members.

Another object of the invention is to positively block or lock the bit cutter members of a full cross section drilling bit in their outwardly expanded condition in the drive mandrel secured to the lower end of the drill string, to prevent horizontal or radial forces incident to the drilling operation, such as drilling weight transmitted through the bit members, from shifting the bit members inwardly. Similarly, drilling weight and drilling torque imposed on the bit members through the drive mandrel cannot effect their inward shifting from their expanded position, the drilling weight and torque being transmitted directly between the drive mandrel and bit members.

Yet a further object of the invention is to provide a bit of the type above indicated, through which adequate drilling fluid can be circulated for removal of cuttings and for maintenance of the bit members in a clean and cool condition.

This invention possesses many other advantages, and has other objects which may be made more clearly apparent from a consideration of a form in which it may be embodied. This form is shown in the drawings accompanying and forming part of the present specification. It will now be described in detail, for the purpose of illustrating the general principles of the invention; but it is to be understood that such detailed description is not to be taken in a limiting sense.

Referring to the drawings:

FIGS. 1, 1*a* and 1*b* together constitute a longitudinal section through the apparatus, with portions shown in side elevation, with parts of the apparatus in condition for movement through its outer portion, FIGS. 1*a* and 1*b* being lower continuations of FIGS. 1 and 1*a*, respectively;

FIGS. 2 and 2*a* are views corresponding to FIGS. 1, 1*a* and 1*b*, showing the parts locked in position within the outer or driving portion of the apparatus, FIG. 2*a* constituting a lower continuation of FIG. 2;

FIGS. 3, 3*a* and 3*b* are views, on an enlarged scale, corresponding to FIGS. 1, 1*a* and 1*b*, FIGS. 3*a* and 3*b* being lower continuations of FIGS. 3 and 3*a*, respectively;

FIGS. 4 and 4*a* are views, on an enlarged scale, corresponding to FIGS. 2 and 2*a*, FIG. 4*a* being a lower continuation of FIG. 4;

FIG. 5 is a cross section taken along the line 5–5 on FIG. 3*a*;

FIG. 6 is a cross section taken along the line 6–6 on FIG. 4;

FIG. 7 is a cross section taken along the line 7–7 on FIG. 4*a*;

FIG. 8 is a cross section taken along the line 8–8 on FIG. 4*a*;

FIG. 9 is a cross section taken along the line 9–9 on FIG. 4*a*;

FIG. 10 is an isometric projection, with parts broken away, of the orienting sleeve;

FIG. 11 is a diagrammatic view in a single plane (not to scale) of the orienting sleeve disclosed in FIG. 10;

FIG. 12 is a plan view as seen from the bottom of FIG. 3*b*;

FIG. 13 is a plan view as seen from the bottom of FIG. 4*a*;

FIG. 14 is an isometric view of the drive mandrel of the bit;

FIG. 15 is an isometric view, on an enlarged scale, of the central plug bit to be secured to one of the bit pads;

FIG. 16 is a fragmentary vertical section, on an enlarged scale, of one of the cutter assemblies locked in position within the drive mandrel; and

FIG. 17 is an enlarged isometric view of one of the bit pads, as seen from the inner side thereof.

The specific retractable drill bit mechanism illustrated in the drawings is capable of drilling a bore hole and is movable as a unit through a string of drill pipe A between the drilling rig and the lower portion of the hole. The drill bit members are movable together through the drill string extending to the drill rig. The drill bit members are secured to the lower portion of the drill string, and the drilling weight and drilling torque are transmitted to it through rotation of the drill string, or, if

desired, of a prime mover mechanism, such as a fluid-operated turbine (not shown), which may be incorporated in the drill string near the lower portion thereof for rotating the drilling mechanism, this fluid-operated turbine having a hollow rotor shaft of an appropriate inside diameter through which the retractable drill bit members can pass in being moved into the lower portion of the drilling apparatus and in being released and retracted therefrom.

As specifically illustrated in the drawings, the drill bit mechanism includes a lower drive mandrel **10** having a plurality of circumferentially spaced slots **11** extending through its wall into which drill bit pads or cutter members **12** are shifted to extend laterally outwardly beyond the periphery of the drive mandrel or main body member **10** of the drill bit. As disclosed in the drawings, there are three slots **11** in the drive mandrel, and three drill bit pads or cutter members, one for each slot, expandable into the slots to be locked to the drive mandrel, and which are also retractable from the slots. Each drill bit member **12** and its associated mechanism described hereinbelow are of a size capable of passing through the inside diameter of the drill string A and through the hollow rotor shaft of a turbine (not shown), if one is employed as the motive power mechanism for rotating the retractable rotary drill bit.

Each drill bit pad or cutter **12** has its upper end pin connected to a link **13**, which, in turn, is pin connected to a pad or cutter follower **14** suitably secured to the lower end of a wire cable **15**, as by silver soldering, the upper end of which is suitably secured, as by silver soldering, to the lower end of a rod **16**, which may be round in cross section and made of steel, extending upwardly within the drive mandrel **10** and adjacent to its inner wall. Each follower **14** has a bar portion **17** loaded by a spring **17***a* to extend outwardly and ride within a longitudinal groove **19** in the inner wall of the drive mandrel to orient each associated pad **12** with a mandrel slot **11**, this groove being wider at its lower end **20** where it is inclined in a downward and outward direction within the drive mandrel and opens into the upper end of the mandrel slot **11**. Since there are a plurality of bit cutters or pads **12** (three in the specific apparatus illustrated in the drawings), there is a link **13**, pad follower **14**, wire cable **15**, round steel rod **16**, bar portion **17**, and spring **17***a* associated with each pad. In other words, there are three sets of pads, links, followers, cables, steel rods, bar portions and springs, the sets being circumferentially spaced from one another about 120°.

A plug bit **18**, FIGS. **15** and **16**, is suitable secured to the inner end cutting portion of one of the drill bit pads **12**, as by use of a bolt **18***a*. This plug bit will be located at the tool axis to fill the opening or space formed by adjoining drill bit pads **12** when they are assembled in the drive mandrel **10**, eliminating the problem of a central core being formed in the formation when drilling.

The drive mandrel has an upper threaded pin **20***a* threadedly secured to a companion box **21** of an elongate drive barrel **22** having an upper pin thread **23** for threaded attachment to the lower end of an adjacent drill string member A, which may either be a drill collar, or the rotor of a turbine secured in the drill string. The rotation of the drill string or turbine A is transmitted through the drive barrel **22** to the drive mandrel **10**, and from the latter to the cutter pads **12** when they are locked in position within the mandrel slots **11**, as described hereinbelow.

Mounted within the lower portion of the drive barrel **22** is an orienting sleeve **24** having a plurality of circumferentially spaced, longitudinal orienting grooves **25** (FIGS. **10**, **11**) therein in alignment with the companion grooves **19** in the drive mandrel. Since three sets of cutter mechanisms are employed to be disposed 120° apart, the orienting sleeve grooves **25** are spaced 120° apart and are aligned with three grooves **19** spaced 120° apart in the drive mandrel. The alignment is obtained by providing downwardly projecting pins **26** on the lower end of the orienting sleeve received within companion sockets **27** in the upper end of the drive mandrel **10**.

The sets of pads **12**, links **13** and pad followers **14** are movable through the string of drill pipe A and drive barrel **22** in tandem or series relation, which will permit the cutter pads, links, and followers to be made of substantial size, being only slightly smaller in maximum transverse dimension than the minimum diameter through the drill string A, orienting sleeve **24** and drive mandrel **10**. To enable such series or tandem movement to take place, the longitudinal supporting rods **16** are made of different lengths, and these rods each have upper heads **35**, such as T-shaped heads, adapted to rest against the lower ends or shoulders **36** of circumferentially spaced elongate grooves **37** formed in the periphery of the carrier barrel **38** of the drilling mechanism, the bottom of each groove being flat and having a half-circular recess **39** therein in which the elongate rod **16** can move, this rod also extending slidably through a companion recess **40** in the lower portion of the carrier barrel **38** below its groove **37**.

Thus, during lowering of the drilling mechanism and the cutter devices through the string of drill pipe A and its elevation therethrough, the T-shaped heads **35** rest upon the carrier barrel shoulders **36**. The uppermost set of a pad **12**, link **13** and pad follower **14** is connected through the wire cable **15** to a rod **16** of relatively short length, the intermediate set to a rod of longer length, so that such set can hang below the uppermost set, the lowermost set being suspended from a steel rod **16** of a substantially greater length than the intermediate rod, so that such set will remain suspended below the intermediate pad **12**. As described hereinbelow, when the pads are expanded outwardly in the drive mandrel slots **11** and are locked in position, the carrier barrel **38** will move downwardly behind the sets of cutter members **12**, **13**, **14**, the carrier barrel **38** sliding downwardly along the rods **16**, the heads **35** of which are free to move relatively upwardly within the longitudinal grooves **37**.

The drill bit mechanism, as stated above, is movable through the drill pipe string A and through the drive barrel **22**. The carrier barrel **38** is threadedly attached to an adapter coupling **42** (FIG. **3**) threadedly secured to a latch body **43** at its upper end, its lower end having ports **44**. Seals **41**, secured to the barrel **38** at the port outlets, are adapted to align with flow passages **45** extending through the drill bit pads **12** to provide a continuation of the fluid passage **47** in the carrier barrel **38** for the drilling fluid used for circulating the cuttings from the bore hole and for cleaning and cooling the bit cutter members, as described hereinbelow.

The drill bit mechanism is releasably latched to the drive barrel **22**. Such releasable latch device includes the latch body **43** previously described, which has a single transverse slot **64** therethrough through which a laterally shiftable latch member **65** is slidable. This latch has inwardly directed parallel side arms **66** extending into side grooves **67** in a retracting rod **68** slidable longitudinally in the latch body **43**, helical compression springs **69** engaging the inner ends of these arms and bearing against the latch body to urge the latch **65** in an outward direction. The retracting rod **68** is prevented from turning within the latch body **43** by a pin **70** shiftable in a longitudinal latch body slot **71**, the retracting rod **68** having retracting pins **72** extending laterally therefrom and received within slots **73** in the latch arms, the inner side of each slot having a tapered or cam face **74** inclined in an upward and outward direction to be engaged by its associated retracting pin **72**, upon upward movement of the retracting rod, to shift the latch **65** inwardly completely from its companion circumferential groove **75** in the drive barrel **22**, thereby to release the drilling mechanism.

The retracting rod **68** is normally urged in a downward direction by a helical compression spring **76** bearing against a cap **77** threadedly secured within the upper end of the latch body **43**, the lower end of the spring bearing against a retracting rod flange **78**. When the retracting rod is in its downward position, its pin **70** bears against a ring **79**, which forces a rubber or rubberlike seal ring **80** against a sleeve **81** encompassing the adapter coupling **42**, the sleeve being urged

against the seal ring by a helical compression spring 82 bearing against the sleeve and against an external shoulder 83 on the adapter coupling. The pliant, elastic seal ring 80 has an unrestrained external diameter slightly less than the internal diameter of the drive barrel 22. However, when the retracting rod 68 is disposed in its lowermost position, with its pin 70 bearing against the ring 79, in order to shift the latter toward the sleeve 81 and compress the seal ring 80, the latter is expanded outwardly into sealed relation against the inner wall of the drive barrel 22 to prevent leakage of fluid along such wall.

The circulating fluid used in drilling can flow through the drill pipe string A and into the upper end of the drive member 22, passing through ports 84 in the retracting rod 68 to its central passage 85, and flowing therefrom through the latch body 43 into the adapter coupling 42, and into the fluid passage 47 or bore of the carrier barrel 38.

The retracting rod 68 has an upper head 91 adapted to be engaged by a suitable overshot 92 secured to a wire line 93, by means of which the entire mechanism is lowered through the drill pipe string A and into the drive member 22 and drive barrel 10, and is also withdrawn therefrom. The lowering will occur until the final latch 65 expands outwardly into its companion groove 75 in the drive barrel 22, at which time a suitable telemeter microswitch 94 on the retracting rod 68 will be closed and convey a signal through the electrically conductive wire line 93 to the drilling rig, advising the operator that the mechanism has been latched in final position. Similarly, elevation of the wire line 93 with its overshot 92 connected to the head 91 will elevate the retracting rod 68 and cause its pins 72 to retract the latch 65 from the groove 75, which will be accompanied by suitable actuation of the telemeter microswitch, advising the operator that the mechanism has been unlatched and is in a condition to be released from the drive mandrel 10 for withdrawal through the string of drill pipe A to the top of the bore hole.

The drill bit members arranged in tandem suspension from the carrier barrel 38 through the agency of the rods 16 are lowered through the passage in the string of drill pipe A and also through the hollow turbine rotor shaft, assuming a turbine is used in the drill string, on the wire line 93. The drill bit pads or members 12 are suspended substantially 120° from one another (since three cutter pads are used in the specific tool shown in the drawings) because of the fact that the suspension rods 16 are disposed 120° from one another, and these pad members 12 are oriented with respect to the slots 11 in the drive mandrel 10 by means of the orienting sleeve 24 and the follower orienting bar 17 serving to achieve the appropriate orienting.

Appropriate inclined guide surfaces 101, 102 are provided on the orienting sleeve for insuring the guiding of the orienting bars 17 into the grooves 25 of the orienting sleeve 24. FIGS. 10 and 11 disclose the orienting sleeve 24, the lower longitudinal grooves 25 of which have a width slightly greater than the width of the orienting bars 17, as described hereinabove. Each of these grooves terminates at a window 103 having sides 101, 102 that diverge in an upward direction. The right side 102, as disclosed in FIG. 10, terminates at the upper end of the window or opening 103; whereas, the left side 101 continues upwardly beyond the window, its inclination continuing to the upper inwardly beveled surface 104 of the orienting sleeve and constituting the left side of an upper groove 105 opening through the upper end of the sleeve. This groove has its left side 106 tapered from the base of the groove to the inner surface of the sleeve 24. It is to be noted that the upper end 107 of the left side 101 of each groove extends circumferentially beyond the upper end 108 of the right side of an adjacent window 103; that is, the upper left side of an inclined guide surface 101 that is associated with one window overlaps the right guide surface 102 of an adjacent window. Thus, the orienting bar 17 of the lowermost set of bit members constituting the cutter pad 12, link 13, and pad follower 14 will engage either the left or right guide surface 101, 102 of one of the windows 103 and grooves 105 in the orienting sleeve 24 as the apparatus is being lowered through the latter, which will turn the drill bit member 38 into a position in which the lowermost pad 12 is in alignment with one of the slots 11. This will substantially orient the several bars 17 with the longitudinal grooves 25 in the orienting sleeve 24. However, if they are angularly displaced from such grooves, they will individually engage either the right or left guide surfaces 102, 101 of the orienting sleeve, which will shift them angularly to a position in which the bars 17 slide into the longitudinal grooves 25, insuring the appropriate alignment of each pad 12 with an individual slot 11 in the drive mandrel, and also into appropriate alignment with an upwardly converging pad deflecting cone 110 integral with and disposed centrally of the drive mandrel 10 at its lower portion, in order to deflect each pad 12 into its individual slot 11. Downward movement of the drilling mechanism can continue until the latch 65 expands outwardly into the latch groove 75 in the drive barrel 22, at which time the carrier barrel 38 will be located behind the sets of pads 12 and followers 14 to lock them in their outward position, as described in detail hereinbelow.

The drive mandrel has circumferentially spaced legs 112 which are defined by the mandrel slots 11, the legs having cylindrical upper portions 113 and downwardly tapering lower portions 114. The lower portions of the legs are interconnected by an annular strut or cutter pad locator support 115, which has the lifting cone or deflecting cone 110 extending into the central passage 125 of the drive mandrel 10, with longitudinal grooves or cutouts 111 in the cone aligned with the center of the mandrel slots 11 to permit the plug bit 18 to pass through any groove 111 into any slot 11 without excess lift of interference of the bit pads 12. Projecting from the sides of the struts 115 into the mandrel slots 11 are retaining guides 116 which are adapted to extend into guide tracks 117 of the bit pads 12 to contain the pads from extending or protruding beyond a controlled condition.

The inside diameter formed by the followers 14 and the upper portion of the bit pads 12 conform to the external diameter of the carrier barrel 38, which firmly supports the follower and bit pad mechanism s while drilling. The inside diameter of the lower portion of the bit pads conforms to the external diameter of the lower portion 126 of the carrier barrel 38 which is reduced in diameter to eliminate the rod retaining grooves 40 and provide a good mating sealing surface for the ports 44 in the carrier barrel to the passages 45 in the bit pads.

Each cutter pad 12, when locked in expanded position within the mandrel slot, has an upper end surface 128 which is tapered to conform with the upper tapered outer end portion 129 of the mandrel slot, an upper surface 130 of the pad extending downwardly from the tapered end surface and parallel to the axis of the drive mandrel, this upper surface being curved circumferentially to conform to the curvature of the diameter of the well bore being drilled. The upper parallel surface 130 of the pad or cutter member merges into a downwardly tapering surface 131 adapted to drill a tapered bore in the bottom of the hole, this tapered surface merging into a lower end face or surface 132 extending inwardly toward the axis of the drive mandrel and merging upwardly into an inner conical surface 133 to help support and stabilize the drill bit on the formation bottom formed by the bit pads or members 12. Each pad has a transverse upwardly facing shoulder 134 adapted to engage the bottom of an annular strut 115, the carrier barrel 38 bottoming on an annular strut 115 with the deflecting cone 110 contained in a suitable conical recess 135 of the barrel 38, and with the latch bar 65 snapping into the latching groove 75 to lock the drilling mechanism firmly in place, which is the final latched position of the drilling mechanism within the drive barrel 22 and mandrel 10.

Each drill bit cutter or pad 12, when locked in expanded position within the drive mandrel 10, also has a downwardly tapering inner surface 138 extending from its upper end, which is engaged by a companion outer surface 139 on its pad follower 14 when the latter is shifted outwardly against the bit

pad 12, the upper end of the pad follower engaging the inner upper tapered surface 140 of the drive mandrel defining the upper end of the slot 11. The inner surface 141 of the back face of the pad follower 14 is concavely curved to conform to the periphery of the carrier mandrel 38, which it will snugly engage, the outer surface or face 139 of the follower also being concavely curved and conforming to a companion convex curvature on the inclined inner surface 138 of the pad 12 (FIG. 8).

Each pad has guide tracks 117 on its inner portion, each of which defines a downwardly opening recess with the main body of the pad and adapted to receive a retaining guide bar 116 of the annular strut or pad locator support 115 extending into the mandrel slot 11. As the pad 12 is being expanded outwardly to its final position, the tracks 117 will move downwardly over the guide portions 116 of the annular strut and the pad will swing outwardly about this strut as a pivot until its upper portion has been swung completely into the slot 11, and with its upper outer surface 130 parallel to the axis of the drive mandrel 10, and with its upper end 128 engaging the upper end 129 of the slot, such as disclosed in FIGS. 2*a*, 4*a* and 16. At this time, the retaining bars 116 extending from the sides of the struts 115 are snugly received within the recesses of the tracks 117, the inner faces of the pads 12 conforming to the shape of the annular strut. When the pad 12 is swung outwardly to its final position, its outer drilling surface 130 is then also extending parallel to the axis of the drive mandrel and at the appropriate radius from such axis, and beyond the periphery of the legs 112, so as to produce the desired diameter in drilling the formation. When in this position, the gasket seals 41 around the ports 44 at the lower end of the outer carrier barrel 38 mate with the drill bit pads 12 on the inner portions of each cutter pad around the passages 45.

Assuming the cutter pads 12 have been expanded outwardly and the barrel 38 has been lowered to its final position, as illustrated in FIGS. 2*a*, 4*a* and 16, the drilling fluid will pass downwardly through the bore 47 of the carrier barrel 38 and then through the ports 44 provided in the lower portion of the carrier barrel, and into the passages 45 of the bit pads 12, discharging around the lower end of the bit pads. Each bit pad has cutting elements 151 mounted in its outer, end, and inner surfaces 130, 131, 132, 133, which are preferably diamonds set in a suitable matrix of which each pad 12 is formed. As specifically disclosed, the diamond cutting elements 151 extend in a desired pattern over the end face 132 of each pad along its inner inclined face 133, over its tapered drilling face 131, and also over its upper gauge face 130. Suitable waterways 152 are provided in each pad to insure the flow of circulating or drilling fluid and the cuttings upwardly around each pad 12, through the annular space between the wall of the bore hole and the drive mandrel 10, the drive mandrel barrel 22, and drill string A, to the drilling rig, the circulating fluid also maintaining the bit pads and diamond matrix portions in a clean and cool condition. An additional or alternate fluid course is illustrated in FIGS. 4*a*, 12, 13, 16 and 17, by extending the passages 45 through the bit pads 12 to the guide tracks 117 or through branching passages 153 below the channels or grooves 155 in the inner pad surfaces 154 that will permit the drilling fluid to discharge at the bit face 133.

Assuming the drill string A, drive mandrel barrel 22 and mandrel 10 are disposed in the well bore near its bottom, without the drill bit mechanism disposed therein, the latter is lowered as a unit on the wire line 93 from the drilling rig through the drill pipe A and through the hollow mandrel of a turbine rotor, if a turbine rotor is used as a source of motive power for rotating the drill mechanism, with the sets of bit pads 12, links 13, and pad followers 14 suspended through the cables 15 and rods 16 from the carrier barrel 38 and arranged in series or tandem fashion. The bit pads 12 can be of substantial size. There need merely be working clearance for them to pass through the minimum diameter passage in the entire drill string A and hollow turbine rotor shaft (if a turbine is used). If, for example, the minimum diameter through which the mechanism must pass is 4 inches, then the bit pads 12 need only be slightly less than 4 inches in maximum transverse dimension, which is also true of the pad follower 14, carrier barrel 38, and apparatus thereabove. The entire string of mechanism is lowered on the overshot 92 and electric wire line 93, the lowermost leading bit pad 12 entering the orienting sleeve 24 and orienting thereto. Lowering of the entire mechanism on the wire line continues, the lowermost bar 17 engaging one guide side 101, 102 or the other of the orienting sleeve 24, which will effect a turning of the carrier barrel 38 and the cutter members suspended therefrom by means of the rods 16, thereby bringing the pads 12 and their bars 17 into substantial alignment with the longitudinal guide grooves 25 in the orienting sleeve 24, which will position and align fully the lowermost bit pad 12 with the pad deflector or cone 110 and mandrel slots 11 into which it is to be expanded. If lowering of the wire line and the entire mechanism continues, the lowermost bit pad 12 will engage the deflecting cone 110, which will deflect its lower portion outwardly to engage the guide tracks 117 of the bit pads with the retaining guides 116 of the drive mandrel 10. Continued lowering will cause the pad follower 14 to shift outwardly, acting through the link 13 to swing the upper portion of the lowermost bit pad outwardly until the follower 14 is also disposed in the slot 11 behind the bit pad.

As lowering of the wire line, latching apparatus and other bit parts continues, the intermediate or second pad 12 then engages the cone 110, and such cone will also deflect and guide the next pad outwardly until its guide portion 117 engages the retaining guides 116 extending into its slot 11, the intermediate follower 14 then acting through the link 13 to swing the upper portion of the intermediate pad outwardly within its slot and to place its follower behind the intermediate pad. As lowering continues, the third or uppermost bit pad 12 will engage the deflecting cone 110, which will guide the last pad outwardly to place its guide grooves 117 over the annular strut portion 116 extending into its companion slot 11, its pad follower 14 then acting through the uppermost link 13 to swing the upper end of the bit pad outwardly, the pad follower also shifting outwardly within the slot behind the uppermost pad.

Lowering of the wire line and drill bit mechanism continues, the lower portion of the carrier barrel 38 moving behind the follower members 14 and the bit pads 12 until it comes to rest upon the annular strut 114, as disclosed in FIGS. 4*a* and 16. The bit pads 12 are now locked in their final position within the slots 11, backed up by the pad followers or blocking elements 14, the pads 12 being snugly hooked to the annular strut portions 116 extending into the mandrel slots 11, and the periphery of the carrier barrel 38 bearing against the pad followers, which, in turn, bear against the inner surfaces of the pads, the upper ends 128 of the latter being held snugly against the drive mandrel defining the upper ends 129 of their slots 11. When in this position, the gasket seals 41 at the lower end of the carrier barrel engage and mate against the bit pads 12 around its fluid passages 45. When the carrier barrel arrives in this final position, the latch 65 is then disposed at the latching groove 75 in the drive barrel 22, the latch expanding outwardly into such groove and locking the entire mechanism in its downward position within the drive mandrel barrel 22 and drive mandrel 10.

As stated above, when the latch snaps into its position within its groove, as permitted by the absence of tension on the retracting rod 68, which permits the spring 76 to shift the rod downwardly and move its retracting pins into the wide portions of the latch slots 73, the telemeter microswitch 94 is actuated by engaging the cap 77, transmitting an appropriate signal through the cable 93 to the top of the hole or drilling rig that the mechanism has been latched in its final position. The overshot 92 is then released, in any suitable manner, from the head 91 of the retracting rod, and the wire line 93 and overshot 92 pulled up through the drill string A to the drilling rig. The drilling operation can now commence.

When the drilling mechanism is lowered through the drill string A toward its position in the drive barrel **22** and mandrel **10**, the lower end of the drive mandrel is preferably several feet off the bottom of the bore hole. When the drill bit parts have been expanded outwardly and the drilling mechanism has been latched in its final position, the wire line **93** and overshot **92** having been removed, rotation of the drilling apparatus can occur either through rotating the entire string of drill pipe from the drilling rig, or through use of the drilling fluid-actuated turbine (not shown) connected thereto. The drill string A is then lowered until the drill bit pads **12**, as well as the plug bit **18** secured to one of the pads, engage the bottom of the hole over its entire area. Appropriate drilling weight is then transmitted from the drill string through the drive mandrel barrel **22** and drive mandrel **10** directly to the cutters **12**, the drilling fluid being pumped through the drill string and discharging from the lower end of the fluid passage **47**, the ports **44** and passages **45** into the bore hole, to carry the cuttings upwardly around the drill pads, which, it is to be noted, are extending laterally outwardly beyond the drive mandrel **10** to a significant extent, the drive mandrel itself performing no drilling action upon the formation. The cuttings produced by the diamond cutting elements **151** are conveyed by the drilling fluid upwardly around the drill bit apparatus and upwardly through the annulus around the drill pipe string A toward the drilling rig, the circulating fluid and cuttings passing upwardly through the waterways **152** and also around the diamond elements **151** themselves, as well as between the bit pads **12**, the diamond cutting elements and the matrix material in which they are embedded being maintained in a clean and cool condition, for most effective penetration of the diamonds into the formation.

To examine the drilling pads, or when the drilling operation is ended, rotation of the drill bit is stopped and the entire drill string raised several feet off bottom. The overshot **92** is then lowered through the drill string on the electric wire line **92** until it engages over the retracting rod head **91**, and upward pull being taken on the wire line and retracting rod **68** to cause the retracting pins **72** to engage the cam faces **74** of the latch **65** and shift the latter inwardly, the retracting rod **68** moving upwardly and informing the operator at the top of the well bore that the latch has been retracted through operation of the telemeter microswitch **94**.

As the wire line **93** is moved upwardly, its upward movement is transmitted through the retracting rod flange **78** to the cap **77** and to the latch body **43**, which is connected through the adapter coupling **42** to the carrier barrel **38**, shifting the carrier barrel upwardly and elevating it above the bit pads **12** and the pad followers **14**. As the carrier barrel **38** moves upwardly, one of its shoulders **36** will engage the T-shaped head **35** of the shortest rod **16** and will pull such rod upwardly. Such upward movement is transmitted through the cable **15** to the follower **14** connected thereto, the follower being pulled inwardly of the drive mandrel **10**, and, through the connecting link **13**, swinging the upper portion of its bit pad **12** inwardly and lifting it and its tracks **117** off the retaining guides **116** of the drive mandrel **10**, pulling the entire bit pad **12** within the drive mandrel passage **125**.

During such upward and inward shifting of the shortest rod **16** and its attached follower **14**, link **13**, and bit pad **12**, the intermediate and the longest rod heads **35** have not as yet been engaged by the shoulders **36** at the lower ends of the carrier barrel grooves **37**. It is only after the bit pad **12** described above has been retracted fully inwardly within the drive mandrel **10** and elevated above the location of the other pad followers **14** and bit pads **12** that the T-shaped head **35** of the intermediate rod **16** will be engaged by its shoulder **36** at the lower end of the groove **37** in which it lies, exerting an upward pull on the rod **16** of intermediate length, the continued elevation of the carrier barrel **38** by the wire line **93** then pulling the intermediate pad follower **14**, its link **13**, and its bit pad **12** first inwardly of its slot **11** and then completely within the drive mandrel passage, the uppermost follower, link and bit pad shifting upwardly of the drive barrel ahead of the intermediate parts.

When the intermediate pad **12** has been elevated above the remaining bit pad and its follower mechanism, the T-shaped head **35** of the longest rod **16** will be engaged by the carrier barrel shoulder **36** at the end of its groove **37**, which will exert an upward pull on such rod, which acts through its cable **15** to pull the remaining follower **14** inwardly, and acting through the link **13** to pull the remaining bit pad **12** inwardly of the mandrel slot **11** into the central passage of the mandrel **10**. The entire mechanism has now been fully retracted. Elevation of the wire line **93** will remove the entire drilling mechanism and the entire bit mechanism in tandem array through the drive barrel **22** and the drill string A to the drilling rig, where the various bit parts may be inspected and replaced, if necessary.

After the parts have been examined and replaced, if required, they are again assembled and related to the drilling mechanism and the latter appropriately secured to the tandem arrangement of drill bit mechanism, this combination can again be lowered from the drilling rig through the drill string A to the drive member **22** and the drive mandrel **10**, the orienting sleeve **24** again appropriately orienting the several parts so that the bit pads **12** are appropriately oriented with respect to their mandrel slots **11** and deflector cone **110**. The foregoing cycle of operation is repeated to effect the progressive outward shifting of the bit pads **12**, links **13** and followers **14** within the drive mandrel **10**, and the final latching of the drilling mechanism in position behind the bit pads and followers, the wire line mechanism being released from the head **91** of the retracting rod **68** and removed from the drill string. The apparatus is again lowered until the bit pads **12** are bearing against the bottom of the hole, and the drilling operation can continue as before.

The operation of running the mechanism on a wire line through the drill string and shifting the several parts to their final position is a continuous one. Lowering of the wire line **93** proceeds without hesitation, with the orienting sleeve **24** and the pad members **17** appropriately turning the carrier barrel **38** and the bit mechanisms supported thereby in oriented relation into aligned position with the deflector cone **110** and mandrel slots **11**, with the alignment occurring automatically by virtue of the orienting bars **17** on the followers **14** engaging the guide surface **101** or **102** of the orienting sleeve **24**. Lowering of the wire line, as stated above, is continuous until an appropriate signal is given at the drilling rig advising the operator that the mechanism has been latched in appropriate position. Similarly, retraction and retrieval of the mechanism from the drive mandrel **10** and drive barrel **22**, and through the drill string A is a continuous operation. The engagement of the overshot **92** with the retracting plunger head **91** and partial raising of the rod **68** will provide a signal to the operator at the top of the well bore, transmitted through the electric cable, that the latch **65** has been retracted; whereupon, the wire line is moved upwardly without interruption to elevate the drill bit mechanism above the bit portions of the apparatus, followed by successive retraction of the sets of followers **14**, links **13** and bit pads **12** from their positions within the drive mandrel slots **11**, replacing them in tandem array, the elevation of the wire line continuing, to withdraw the entire mechanism through the drill pipe A to the drilling rig.

The pad followers **14** are locked in their position behind the pads **12** by the carrier barrel **38**. As a result, the horizontal, radial forces incident to drilling are transmitted from each pad directly back to the stiff carrier barrel **38**, insuring the retention of each bit pad **12** in its outwardly expanded position. The downward drilling weight imposed on the bit pads **12** is transmitted directly from the drive mandrel **10** thereto, relieving the follower and link mechanisms of such load. The same is true of the drilling torque which is transmitted directly from the sides of the mandrel slots **11** to the bit pads.

The drill bit disclosed has maximum lateral stability to prevent drill collar wobble, the drill collars forming the lower

portion of the drilling string A, and which are attached to the drive mandrel barrel **22** or to a turbine, if a turbine is used to supply the motive power for rotating the drill bit. Both the vertical gauge surfaces **130** and the tapered wedging surfaces **131** on the bit pads provide for such stability. The tapered drilling surfaces **131** permit appropriate sizes, numbers and patterns of diamonds **151** to be plotted, insuring the presence of appropriate diamonds to maintain a maximum drilling rate without causing the diamonds to be locally overloaded, that would result in their failure, and consequent shortening of the effective life of the drill bit pads **12** and of the drill bit itself, requiring premature retracting and removal of the parts to the drilling rig for replacement of parts. It is found that satisfactory diamond coverage is obtained, while stability is improved to prevent drill collar wobble, by making the angle of the tapered surfaces **131** of the bit pads about 70° from the horizontal, and preferably greater than 70°; that is to say, the tapered surfaces of the bit pads make an angle of preferably less than 30° with respect to the axis of the drive mandrel **10**. Despite the existence of such relatively steep taper, it is found that excessive torques are not required to rotate the bit, the angle of the cone surface **131** being a safe one.

It is found that the bit pads **12** can be made entirely of matrix material, with the diamonds **151** molded therewithin. There is no necessity for providing a steel core and bonding the matrix material thereto. In the past, the provision of a steel core has increased the chance of bond failure, since the matrix and the steel core are of basically dissimilar materials having different physical properties. The provision of an all matrix and diamond bit pad increases the strength of the parts and their reliability under high stress.

The drill bit of the type disclosed enables the bit pads **12** to be made of relatively large size for the minimum diameter passage through which they must pass, and yet permits them to drill a bore hole of a diameter which is more than twice the diameter of the minimum passage through which the bit cutter members **12** can pass. By way of example, bit pads **12** capable of passing through a minimum passage of 4 inches in diameter can be expanded outwardly of the drive mandrel **10** and locked therewithin to drill a hole of 9⅞ inches in diameter, or more than twice the diameter of the minimum passage through which the parts must pass.

The net result of all of the foregoing is the elimination of slow round trips with the drilling string A for the purpose of changing bits, thereby reducing considerably rig time consumed in connection with bit changes, with attendant major reductions in the cost of drilling the hole.

We claim:

1. In an expansible and retractable drill bit for drilling a bore hole: tubular drive means attachable to the lower portion of a tubular drilling string; deflector means extending across the passage of said drive means; cutter means movable downwardly through the passage of said drive means and into engagement with said deflector means to be expanded thereby into driving relation to said tubular drive means and to a position extending laterally outwardly beyond the exterior of said drive means; said cutter means being constructed and arranged to extend from a location closely adjacent to the axis of said tubular drive means to said extended position beyond said drive means to drill upon substantially the full cross-sectional area of the bottom of the bore hole upon being expanded into driving relation to said tubular drive means; and means for turning said cutter means within said drive means in response to downward movement of said cutter means in said drive means to orient said cutter means relative to said deflector means.

2. In a drill bit as defined in claim **1**; and holding means in said drive means for retaining said cutter means in its outwardly expanded position.

3. In an expansible and retractable drill bit for drilling a bore hole: tubular drive means attachable to the lower portion of a tubular drilling string; deflector means extending across the passage of said drive means; cutter means movable downwardly through the passage of said drive means and into engagement with said deflector means to be expanded thereby into driving relation to said tubular drive means and to a position extending laterally outwardly beyond the exterior of said drive means; said tubular drive means having a plurality of circumferentially spaced slots; said cutter means comprising a plurality of cutter members movable in tandem through the passage of said drive means and successively into engagement with said deflector means to be deflected thereby successively laterally into said slots and into coupling relation to said drive means; said cutter means being constructed and arranged to extend from a location closely adjacent to the axis of said tubular drive means to said extended position beyond said drive means to drill upon substantially the full cross-sectional area of the bottom of the bore hole upon being expanded into driving relation to said tubular drive means.

4. In a drill bit as defined in claim **3**; and a plug bit secured to the inner portion of one of said cutter members for drilling the axial portion of the bottom of the bore hole.

5. In a drill bit as defined in claim **3**; and holding means movable downwardly in said drive means passage behind said cutter means to retain said cutter means within said slots in their outwardly expanded position.

6. In a drill bit as defined in claim **3**; and orienting means for aligning said cutter means with said slots to insure their outward deflection thereinto.

7. In a drill bit as defined in claim **3**; orienting means for aligning said cutter means with said slots to insure their outward deflection thereinto; and holding means movable downwardly in said drive means passage behind said cutter means to retain said cutter means within said slots in their outwardly expanded position.

8. In a retractable and expansible drill bit: tubular drive means attachable to the lower portion of a tubular drilling string; deflector means rigidly fixed to said drive means and extending across the passage of said drive means; and cutter means movable downwardly through the passage of said drive means from a position completely above said deflector means and into engagement with said deflector means to be expanded thereby into driving relation to said tubular drive means and to a position extending laterally outwardly beyond the exterior of said drive means.

9. In a drill bit as defined in claim **8**; said cutter means being constructed and arranged to extend from a location closely adjacent to the axis of said tubular drive means to said extended position beyond said drive means to drill upon substantially the full cross-sectional area of the bottom of the bore hole upon being expanded into driving relation to said tubular drive means.

10. In a drill bit as defined in claim **8**; said tubular drive means having a plurality of circumferentially spaced slots; said cutter means comprising a plurality of cutter members movable in tandem through the passage of said drive means and successively into engagement with said deflector means to be deflected thereby successively laterally into said slots and into coupling relation to said drive means.

11. In a drill bit as defined in claim **8**; said tubular drive means having a plurality of circumferentially spaced slots; said cutter means comprising a plurality of cutter members movable in tandem through the passage of said drive means and successively into engagement with said deflector means to be deflected thereby successively laterally into said slots and into coupling relation to said drive means; said cutter means being constructed and arranged to extend from a location closely adjacent to the axis of said tubular drive means to said extended position beyond said drive means to drill upon substantially the full cross-sectional area of the bottom of the bore hole upon being expanded into said slots and into coupling relation to said drive means.

12. In a drill bit as defined in claim **8**; said tubular drive means having a plurality of circumferentially spaced slots; said cutter means comprising a plurality of cutter members movable in tandem through the passage of said drive means and

successively into engagement with said deflector means to be deflected thereby successively laterally into said slots and into coupling relation to said drive means; said cutter members being constructed and arranged to extend from a location closely adjacent to the axis of said tubular drive means to said extended position beyond said drive means to drill upon substantially the full cross-sectional area of the bottom of the bore hole upon being expanded into said slots and into coupling relation to said drive means; and a plug bit secured to the inner portion of one of said cutter members for drilling the axial portion of the bottom of the bore hole.

13. In a retractable and expansible drill bit for drilling a bore hole: tubular drive means attachable to the lower portion of a tubular drilling string, said tubular drive means having a plurality of circumferentially spaced slots; deflector means rigidly fixed to said drive means and extending across the passage of said drive means, said deflector means being disposed adjacent said slots; carrier means adapted to be lowered and elevated through the drilling string on a wire line; cutter means carried by said carrier means and comprising a plurality of cutter members movable in tandem through the drilling string and drive means passage and successively into engagement with said deflector means to be expanded thereby successively laterally into said slots to extend beyond said drive means in coupling relation to said drive means; said carrier means being movable downwardly in said drive means passage behind said cutter means to retain said cutter members in coupling relation to said drive means.

14. In a drill bit as defined in claim 13; said cutter members having fluid passages therein for discharging drilling fluid toward the bottom of the bore hole; said carrier means having a central fluid passage communicating with said fluid passages when said carrier means is behind said cutter means.

15. In a drill bit as defined in claim 13; said cutter members having portions underlying and engaging said deflector means when said cutter members are coupled to said drive means.

16. In a drill bit as defined in claim 13; said cutter members having portions underlying and engaging said deflector means when said cutter members are coupled to said drive means; said cutter members having fluid passages therein for discharging drilling fluid toward the bottom of the bore hole; said carrier means having a central fluid passage communicating with said fluid passages when said carrier means is behind said cutter means.

17. In a drill bit as defined in claim 13; and orienting means within said drive means for aligning said cutter members with said slots to insure their outward expansion thereinto.

18. In a drill bit as defined in claim 13; said cutter members being constructed and arranged to extend from a location closely adjacent to the axis of said tubular drive means to said extended position beyond said drive means to drill upon substantially the full cross-sectional area of the bottom of the bore hole upon being expanded into driving relation to said tubular drive means.

19. In a drill bit as defined in claim 13; said cutter members being constructed and arranged to extend from a location closely adjacent to the axis of said tubular drive means to said extended position beyond said drive means to drill upon substantially the full cross-sectional area of the bottom of the bore hole upon being expanded into driving relation to said tubular drive means; and a plug bit secured to the inner portion of one of said cutter members for drilling the axial portion of the bottom of the bore hole.

20. In a drill bit as defined in claim 13; said cutter members being constructed and arranged to extend from a location closely adjacent to the axis of said tubular drive means to said extended position beyond said drive means to drill upon substantially the full cross-sectional area of the bottom of the bore hole upon being expanded into driving relation to said tubular drive means; said cutter members having fluid passages therein for discharging drilling fluid toward the bottom of the bore hole; said carrier means having a fluid passage communicating with said fluid passages when said carrier means is behind said cutter means.

21. In a drill bit as defined in claim 13; said cutter members being constructed and arranged to extend from a location closely adjacent to the axis of said tubular drive means to said extended position beyond said drive means to drill upon substantially the full cross-sectional area of the bottom of the bore hole upon being expanded into driving relation to said tubular drive means; said cutter members having fluid passages therein for discharging drilling fluid toward the bottom of the bore hole; said carrier means having a fluid passage communicating with said fluid passages when said carrier means is behind said cutter means; said cutter members having portions underlying and engaging said deflector means when said cutter members are coupled to said drive means.