April 11, 1961 J. E. ECKEL ET AL 2,979,144

RETRACTABLE DRILL

Filed Aug. 22, 1957 3 Sheets-Sheet 1

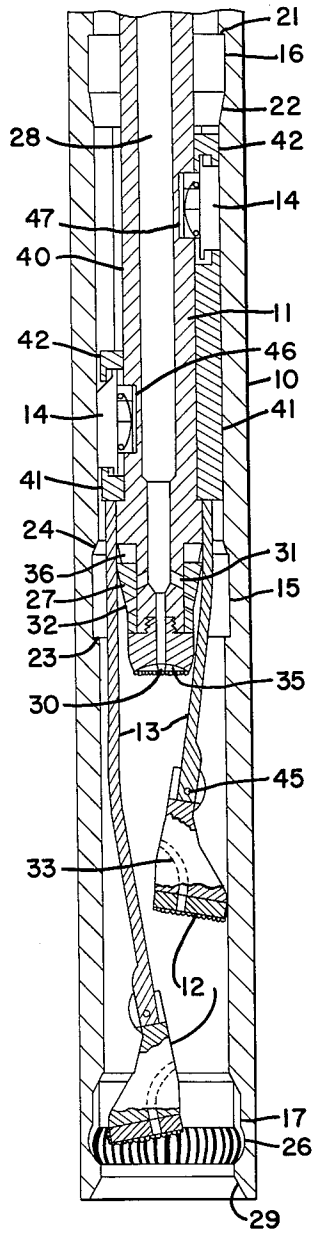


FIG.-1(A)

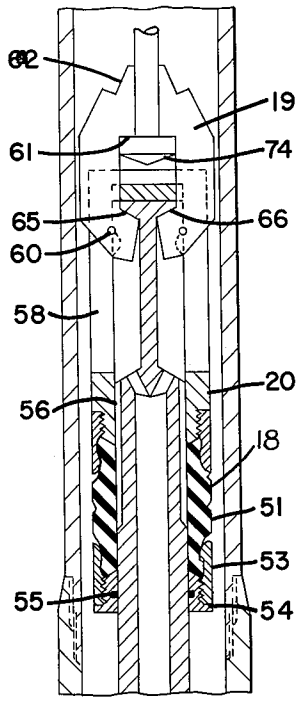


FIG.-1(B)

John M. Camp
John E. Eckel Inventors

By James A. Reilly Attorney

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RETRACTABLE DRILL

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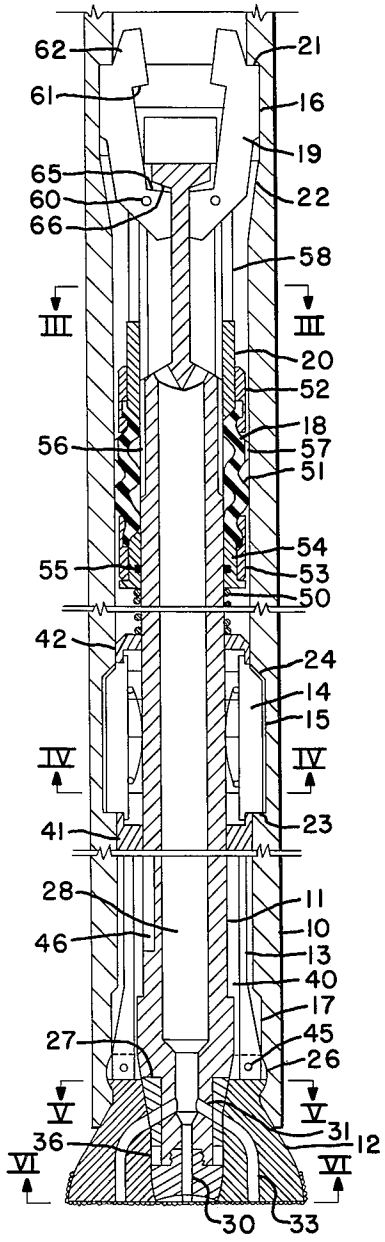


FIG.-2

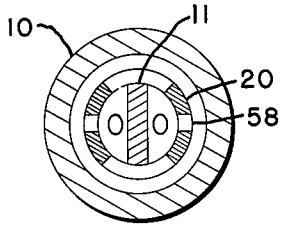


FIG.-3

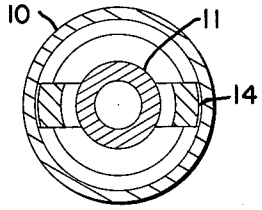


FIG.-4

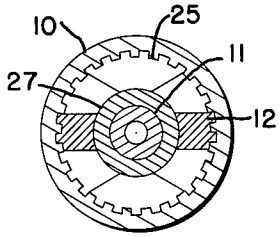


FIG.-5

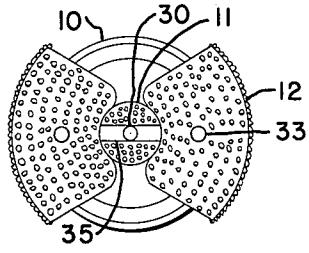


FIG.-6

John M. Camp
John E. Eckel Inventors

By James A. Reilly Attorney

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RETRACTABLE DRILL

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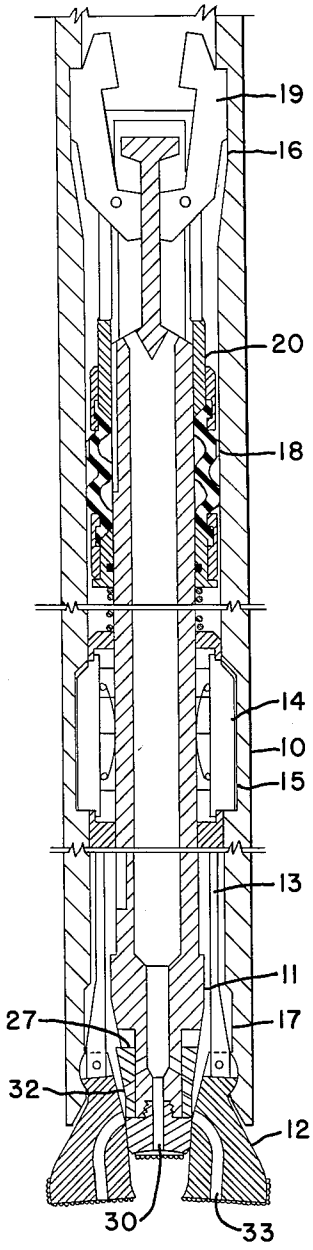


FIG.- 7

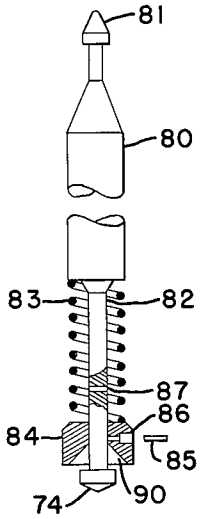


FIG.-8

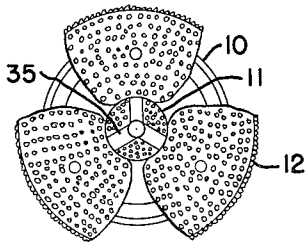


FIG.-9

John M. Camp
John E. Eckel
Inventors

By James A. Reilly Attorney

United States Patent Office 2,979,144
Patented Apr. 11, 1961

2,979,144

RETRACTABLE DRILL

John Edward Eckel and John M. Camp, Tulsa, Okla., assignors, by mesne assignments, to Jersey Production Research Company

Filed Aug. 22, 1957, Ser. No. 679,652

12 Claims. (Cl. 175—232)

This invention pertains generally to borehole drilling and more particularly to an improved type of retractable drill and bit. The invention especially pertains to a form of retractable drill which is particularly flexible in that it is suitable for drilling not only large-diameter holes but also small-diameter ones.

A very large portion of the expenditures that are made each year by the petroleum industry in its quest for oil is concerned with drilling boreholes. In view of this fact, there has been a continuing effort on the part of the petroleum industry to reduce the high costs that are associated with drilling. Much progress has been made over the years in this direction, but there is still much room for improvement. Improved drill bits, less expensive rig designs, improved drilling fluids, etc., have contributed much to less expensive and more efficient drilling; but these gains are being offset to a considerable degree by the increasing difficulty in finding and producing oil. For example, it is becoming necessary to drill to progressively greater depths in order to find new oil reserves; and these greater depths are directly reflected in greater drilling expenses.

Rotary drilling is the most generally employed system of drilling in use today; and, accordingly, most efforts at improving drilling efficiency have been directed toward this particular technique. In this system of drilling, a multi-cutter bit is attached to the lower end of a string of pipe; and the entire assembly is rotated so as to crush and pulverize the earth underlying the bit. A drilling fluid in the form of drilling mud, water, air, or the like is circulated past the cutters via the drill pipe and the annulus between the pipe and the borehole so as to flush cuttings from the hole.

A serious and expensive disadvantage of the rotary drilling technique lies in the fact that the entire length of drill pipe must be removed from a borehole in order to replace a worn-out drill bit. This is an operation which necessarily requires considerable time and money; and repeated efforts have been made to avoid it. One of the most attractive solutions to this problem is a recently developed retractable drill whose bit can be lowered through a well pipe, assembled and expanded in position at the bottom of the pipe, and thereafter retracted and withdrawn from the pipe as desired. A particularly effective drill of this character is described in United States Patent No. 2,764,388—J. M. Camp. This particular drill makes use of a special sub which is attached to the lower end of a drill string and which is adapted to receive a mandrel or body member carrying a plurality of cutter elements. Suitable interlocking or interengaging means cooperate with the sub and the mandrel to assemble the elements as an integral bit at the lower end of the sub. No particular orientation of the mandrel or cutter elements relative to the sub is required to expand or retract the bit. Retractable interengaging or locking means hold the mandrel within the sub, and a packer seals the annulus between the mandrel and the sub.

Another attractive form of retractable drill is set forth in U.S. Patent No. 2,771,275—J. E. Ortloff; and still another type is shown in U.S. 2,208,457—W. G. Hurley. All of these drills vary in material respects, but they still resemble one another in that each one uses a mandrel carrying a plurality of cutters which enters and cooperates with a sub to form an integral drill bit which is retractable in character.

In spite of their obvious advantages, the adoption of retractable drills by the petroleum industry has been relatively slow—partially because of certain mechanical limitations, and partially because of recent trends in the drilling art. For example, mechanical limitations of presently known retractable drills have been major deterrents in their application to the drilling technique popularly known as "slim-hole drilling." Slim-hole drilling—as its name implies—consists essentially in drilling smaller diameter holes than usual; and it is a technique that is rapidly growing in favor, since it constitutes a relatively inexpensive procedure for drilling to great depths. Its lower cost makes it attractive not only for regular production purposes but also for exploration purposes. It has further interesting possibilities in connection with a recently developed method of permanent well completion.

While the advantages of both "slim-hole" drilling and retractable drills have heretofore been recognized in the art, the two techniques have been incompatible for the reason that retractable drills have heretofore not been available or feasible in small sizes. Small-diameter retractable drills tend to have shorter lives than conventional non-retractable bits of equivalent size; and they are also quite sensitive to variations in hole size. Thus, in some instances where a retractable bit has been removed from a borehole because of wear, difficulty has been experienced in replacing the bit with a new member by virtue of the fact that the new bit—being somewhat larger than the old bit—could not be sufficiently expanded within the narrow hole cut by the previous bit.

Another difficulty that has beset retractable drills—and especially small-diameter drills—has centered about the bearings that are used with conical-type cutters. Thus, in spite of the fact that both slim-hole drilling and retractable drills have been known to possess marked advantages, no satisfactory solution has been advanced or suggested to date for combining these two ideas.

Accordingly, it is an object of the present invention to improve upon the structure and use of retractable drills and bits. It is a further object of the invention to render retractable drills and bits more practical and attractive for general use, and especially for use in slim-hole drilling. It is an especial object of the invention to overcome the difficulties that have been experienced with retractable drills and bits resulting from variations in drill hole size.

It is a general object of the invention to reduce the costs of drilling boreholes so as to render this technique more satisfactory, not only for petroleum production purposes, but also for straight exploration purposes. Numerous advances in geological and geophysical research have been made in recent years to aid in the discovery of new oil reserves; but the only completely certain method of establishing the existence of a subterranean oil deposit is to drill through the earth's crust to the actual deposit itself. It is therefore an object of this invention to make drilling sufficiently inexpensive such that it may be used more extensively for sheer exploration purposes.

These and related objects of the invention, which will be expressly discussed or readily apparent in the fol-

lowing description, are realized by the use of an improved type of drilling design.

The present invention, in essence, relates to improvements in the types of retractable drills and bits generally described in the aforementioned patents. Thus, like those patents, it concerns a drill which includes a mandrel and a tubular member or drive sub. The sub is attachable to the lower end of a string or well pipe, and it is adapted to receive the mandrel. The latter member, which carries a plurality of bit or cutter elements, is adapted to be manipulated as by means of a wire line within the well pipe; and it is further adapted to fit within and engage with the drive sub in a retractable manner. Each bit element is suspended from the mandrel by means of a support member which includes at its upper end a latching device, dog, or equivalent means for alternately engaging sets of locking means disposed within the mandrel and the drive sub. When the cutter support members are locked to the mandrel, the cutter elements are preferably arranged in a vertically spaced, nested relationship so as to occupy a minimum lateral dimension when being manipulated within a drill string. Alternately, when the cutter support members are locked to the drive sub, the cutter or bit elements are positioned on the same lateral plane and immediately below and in engagement with the lower portion of the drive sub. Furthermore, when the locking devices have engaged the cutter support members with the drive sub, the mandrel is adapted to move downward against the cutter elements and to wedge them into engagement with the lower end of the sub.

In this invention, each cutter or bit element as well as the lower end or surface of the mandrel is provided with an abrasive-type cutting surface. When expanded into drilling position, the cutting surfaces combine to form an integral cutting surface which drills against the entire bottom of a borehole. A central or main drilling-fluid passageway is provided throughout the length of the mandrel, and branch passageways connecting with the central mandrel passageway and extending through each cutter element are provided for the circulation of a drilling fluid. Packing means are provided on the mandrel to seal the annulus between the mandrel and the sub so as to require a drilling fluid to pass down through the mandrel and thence through the annulus between the drill string and the wall of the borehole.

The bit elements may rely upon sheer frictional forces to maintain them in positive engagement with the drive sub; but they and the sub are preferably equipped with matching splines or other positive-type interengaging means so that a completely positive driving arrangement may be assured.

In a preferred version of the invention, the lower end of the sub and each bit element is designed so as to define a movable joint therebetween which enables the elements to move in a longitudinal (i.e., normally vertical) plane when in engagement with the drive sub. Thus, as the mandrel travels downward within the sub and urges the bit elements radially outward from the mandrel, the elements are capable of a somewhat pendulum-like movement as they swing around the end of the sub into drilling position. This articulated action of the bit elements enables them to be held in a firm manner between the mandrel and the drive sub even though they may not fully expand into their normal drilling position.

Once the mandrel has entered within the drive sub and the cutter support members have engaged the drive sub, the mandrel is maintained within the drive sub through the use of suitable interengaging means of a retractable type. A lost-motion device or equivalent means is preferably included in the apparatus so that the mandrel is capable of longitudinal movement within the drive sub after the interengaging means has locked the mandrel within the drive sub. The lost motion is desirable from the standpoint of setting a packer or enabling the mandrel to expand the bit elements into drilling position.

In a preferred version of the invention, the drilling-fluid passageway in each bit element is constructed so as to be in fluid communication with the central drilling-fluid passageway in the mandrel only when the mandrel and the bit elements are in their fully expanded normal drilling position. Otherwise, the drilling fluid flows in a restricted manner solely through the mandrel, with the result that a fluid force is exerted against the mandrel, continually urging the mandrel into its normal drilling position.

In a still further preferred version of the invention, each bit element is pivotally mounted on its support member so that expansion and retraction of the element is facilitated.

Having generally outlined the major components and features of the present invention, attention is now directed to the figures for a more complete and clearer understanding of the invention. The figures illustrate an apparatus constituting a preferred embodiment of the invention which is contemplated to be the best mode for practicing the invention.

Figure 1 illustrates an apparatus of the invention in vertical cross section, as the apparatus appears with its bit elements in a retracted position for movement within a string of well pipe. Figure 1(*a*) illustrates a lower portion of the apparatus and Figure 1(*b*) an upper portion thereof.

Figure 2 illustrates the apparatus of Figure 1, again in cross section, as the apparatus appears with its bit elements and mandrel completely expanded into normal drilling position.

Figure 3 is a section view taken along the line III—III of Figure 2.

Figure 4 is a section view taken along the line IV—IV of Figure 2.

Figure 5 is a section view taken along the line V—V of Figure 2.

Figure 6 is a bottom view of the apparatus shown in Figure 2 depicting the orientation of the mandrel and the cutter elements when in a fully expanded drilling position.

Figure 7 is a section view of the same apparatus shown in Figure 1, but with the bit elements and mandrel incompletely expanded.

Figure 8 is a partially sectioned view of a tool suitable for expanding or retracting the apparatus of Figures 1–7.

Figure 9 is a bottom view similar to Figure 6 but showing the fully expanded arrangement of a bit comprising a mandrel and three bit elements.

In referring to the figures, it will be observed that the same legends are used throughout the figures to identify identical parts or components. Thus, the major structural components shown in the various figures include tubular member or drive sub **10**, mandrel **11**, bit elements **12**, cutter supports **13** including locking devices or dogs **14**, intermediate sub recess **15**, upper sub recess **16**, packer **18**, retractable interengaging means **19**, and sleeve **20**.

Referring first in detail to the drive sub **10**, it may be seen that this member is essentially an elongated tubular member, not unlike a conventional drill collar modified to serve the purposes of this invention. The sub is adapted at its upper end to be attached to the lower end of a string of drill pipe; and it preferably has an inner diameter corresponding to the inner diameter of the pipe. The outer diameter of the sub may be somewhat larger than the drill pipe in order to provide the sub with added strength and rigidity.

Near the upper end and interiorly of drive sub **10** is a circumferential groove or recess **16** which possesses a downward-facing upper shoulder **21** and a tapered upward-facing lower shoulder **22**. The second peripheral

recess 15 within drive sub 10 is positioned at a point intermediate the ends of the sub. This recess possesses an upward-facing lower shoulder 23 and a tapered downward-facing upper shoulder 24. The extreme lower end of the drive sub terminates in an inwardly tapered and downward-facing shoulder 29, the angle of taper being preselected in a manner to be described later in this discussion.

Spaced slightly above shoulder 29 is a recess 17 which includes a curved spline section 26 comprising a plurality of longitudinally disposed and arcually spaced splines 25. As will be brought out later in this description, these splines coact with mating splines on each one of the bit elements 12 to effect a positive drive relationship between the sub and the bit elements. The upper end of recess 17 is preferably tapered so that the splines on the bit elements freely engage the splines on the sub. The spline section 26 is grooved or curved to define a movable joint or bearing surface with a mating portion of each cutter element. Conveniently, the groove 26 is rounded or circular in profile for this purpose.

Adapted to fit within drill sub 10 is mandrel 11 which carries with it bit elements 12, packer 18, lower retractable interengaging or latching devices 14, upper interengaging means or latches 19, sleeve 20, and sleeve valve 27. A central passageway 28 extends longitudinally throughout the mandrel and provides means for conveying drilling mud or other drilling fluid from the interior of the string of well pipe to the various elements of the bit. The lower end of this passageway terminates preferably in a jet 30 adapted to direct drilling fluid vertically downward from the mandrel. A plurality of branch passageways 31 interconnect the central passageway above the jet with ports 32 in sleeve valve 27 and fluid passageways 33 in each bit element 12.

The lower end of the mandrel 11 is covered with an abrasive-type cutting surface (preferably diamonds); and radially extending grooves 35 are preferably provided to conduct drilling fluid from the jet 30 toward adjoining surfaces of the cutter elements 12. It has been found in practice that drill cuttings tends to collect in the regions between the bit elements with adverse drilling results, and this condition is greatly relieved by the use of these grooves. It will be recognized, of course, that other passageway and groove configurations may be used as desired.

Immediately above the lower end of the mandrel 11 is a peripheral recess 36 which acts somewhat as a valve guide or seat for the sleeve valve 27. This recess is somewhat longer than the valve in order that a degree of longitudinal movement of the valve along the mandrel is possible.

The outer surface of the valve 27—as well as the adjoining surface of the mandrel 11—is tapered to enable the mandrel to apply a wedging action against the inner surface portions of the bit elements 12 when the bit elements are expanded into a drilling position and placed in engagement wtih the drive sub 10. Additionally, the ports 32 in the valve 27 are positoned so that the ports are: (1) in direct alignment with the branch passageways 31 and the bit element passageways 33 when the valve is in its uppermost longitudinal position and the bit elements and mandrel are in a fully expanded drilling position, and (2) out of alignment with the passageways 31 and 33 when the valve 27 is in a position other than its upper most position and the bit elements are in an incompletely expanded condition.

Disposed above the lower tapered portion of the mandrel 11 and extending along the length of the mandrel are elongated grooves or slots 40 which provide runways for movement of the latch assemblies 41. Each latch assembly includes a device in the nature of a dog 14 and a holder 42 adapted to receive the dog and to slidably engage the mandrel 11 in a groove 40. Each dog, it will be noted, is spring-loaded within its respective holder 42 so that it is normally urged outward from the holder. Each dog is also provided with a lower shoulder adapted to engage the shoulder 23 of the drive sub and with a tapered upper shoulder matching the shoulder 24 of the drive sub. Furthermore, each dog is made of a sufficient length and is preferably rounded off so that it may move freely within a string of well pipe without obstruction by the pipe joints.

Secured to the lower ends of the latch assemblies 41 and integral therewith are elongated bit element supports 13. The lower end of each support is attached to an upper portion of a bit element 12—preferably in a pivotal or otherwise articulated manner. Thus, as illustrated in the drawing, each support 13 is attached to its respective bit element by means of a pin 45. The connection between each support and each bit element may be rigid if so desired, but the support must then be sufficiently flexible to enable free movement of the bit elements to and from their drilling position.

Vertically spaced dog recesses 46 and 47 are positioned along the mandrel 11, each recess being in alignment with one of the grooves or slots 40. Each such recess is adapted to receive one of the dogs or locking devices 14 when the bit elements are in a retracted position for manipulation within a string of well pipe.

At this point, it will be noted that the bit elements 12 in a retracted position should occupy a smaller lateral cross-section area than they do when in an expanded drilling position—otherwise, it would be difficult to manipulate the mandrel and its associated bit elements conveniently to and from a drilling position. This condition is most conveniently met by simply spacing the recesses 46 and 47 along the length of the mandrel 11 and by varying the lengths of the support members 13. Thus, in a retracted condition, the bit elements 12 are staggered vertically in a nested relationship; while, in an expanded drilling position, the bit elements are all on the same lateral plane.

At this point, it will further be noted that the apparatus shown in the drawing is depicted as possessing two bit elements. An apparatus with merely two bit elements has been chosen to lilustrate and explain the invention, since the description of an apparatus of this type is relatively straightforward and readily understood. It should be pointed out, however, that an apparatus employing more than two cutters or elements—preferably three cutters—is actually more desirable for the purposes of the invention. When using three bit elements, the elements and their respective dogs and supports are spaced 120° apart around the mandrel. When two bit elements are employed, the spacing is 180°, as shown in the drawing. A three-element or cutter bit is shown in Figure 9.

Positioned above the dog holders 42 and separated therefrom, preferably as by means of a spring 50, is a packer 18 which comprises an elastic deformable sleeve 51, upper and lower rings 52 and 53, respectively, and bushing 54. The bushing 54 is the component of the packer which actually rests upon the spring 50 and is slidable longitudinally along the mandrel 11. Sealing means in the form of packing or the like 55 is preferably provided on the inner surface of bushing 54 in order to effect a fluid-tight seal against the mandrel.

The lower end of the sleeve 51 is secured between the bushing 54 and ring 53, and the upper end of the sleeve is similarly secured between ring 52 and the lower end of sleeve 20. The sleeve—preferably made of natural or synthetic rubber—is preferably pleated in the manner shown to resemble a bellows or accordion-like member. Conventional sleeve-type packers may be used with the invention, but it has been found by experience that a pleated-type packer such as just mentioned is far more effective in maintaining an effective fluid-tight seal. The sleeve in an unset condition should be less than the diameter of the well pipe and drive sub in which the packer is to be manipulated. When set, however, the packer

should be capable of expanding against and contacting the inner wall surface of the drive sub.

The sleeve **20** and the upper packer ring **52** are conveniently threaded or otherwise adapted to be connected to one another. The bushing **54** and the lower ring **53** are similarly threaded or otherwise adapted to be assembled.

With further reference to the sleeve **51**, it will be noted that only one of the bellows elements in the sleeve preferably actually seals against the inner wall of the sub **10**. Only one bellows element is required for this purpose, the other bellows elements being present primarily to enable the sleeve **51** to be contracted longitudinally a substantial amount. A longitudinal groove or passageway **56** is preferably provided along the upper portion of the mandrel **11**, the purpose of this groove being to vent the inner portions of the bellows elements of the packer sleeve **51**. A similar groove **57** is provided to vent outer portions of the bellows elements of the packer sleeve. Any liquid entrapped within the bellows elements is therefore able to escape from the bellows elements, thereby enabling the packer to be set with relatively low loadings.

Sleeve **20** extends up beyond the end of the mandrel **11** and is provided with ports **58** through which the upper dogs, latches, or equivalent interengaging means **19** may pivot. Thus, in the drawing, both dogs **19** are pivotally mounted on pins **60**; and the pins in turn are mounted within the sleeve **20**. Each dog is provided with an upper shoulder adapted to engage the shoulder **21** of the sub **10**, and the dogs are further provided with tapered lower shoulders. The upper ends of the dogs **19** are further provided with downward-facing shoulders **61** which are adapted to engage the spearhead of a tool for raising or lowering the mandrel and its associated components. A suitable such tool is one shown in Figure 8, the spearhead of this tool being identified by the legend **74**.

It will be noted that the upper dogs or latches **19** are normally urged outward from the mandrel as by means of suitable springs or other resilient elements not shown. The uppermost portion of each latch or dog **19** terminates in a tapered section **62**, the purpose of this section being to cooperate with a suitable tool so as to urge the dogs inward when it is desired to retract the drill and manipulate it within a drill string or the drive sub. As mentioned earlier, a suitable tool for this purpose is shown in Figure 8 and includes sinker bar **80**, upper spearhead **81**, stem **82**, spring **83**, retracting sleeve **84**, the lower spearhead **74**, and pin **85**. Sleeve **84** is slidably movable along stem **82** and is normally urged downward or away from the sinker bar **80** by means of spring **83**. The tool is illustrated in Figure 8 with the spring **83** in its expanded position, this being the condition of the spring when the tool is employed to retract the drill assembly. The pin **85** is not inserted in the tool during this phase of operation. Lifting of the drill by the tool is actually effected when the inner shoulders **65** of the dogs **19** engage the shoulders **66** located near the top of the mandrel.

When the tool in Figure 8 is used to lower a drill into a borehole, spring **83** is compressed; and pin **85** is inserted in the matching holes **86** of the sleeve **84** and hole **87** of the stem **82**. The pin thereby holds the spring in its compressed position. Sleeve **84** is provided with a conical recess at its lower end to enable the sleeve to retract dogs **19** by bearing down upon the shoulders **62**. Upper spearhead **81** is attachable to a wire line or equivalent means for raising and lowering or otherwise manipulating the retracting tool.

Referring next to the bit or cutter elements **12**, it will first be noted that the cutting surfaces of these elements are hard abrasive particles. Diamonds are preferred, but other materials such as carborundum, tungsten carbide, etc., may also be used if so desired. The cutting surface embraces the entire lower areal portion of each bit element as well as a portion of the sidewall surface thereof. Furthermore, areal configurations of the bit elements and the lower portion of the mandrel are preselected so that the cutting surfaces generate a cutting action on the entire bottom of a borehole when the bit is in a fully expanded condition.

The interior surface of each bit element is tapered to receive the lower portion of the mandrel **11**, and the outer upper surface of each bit element is similarly tapered to match the lowermost shoulder **29** of the sub **10**. The upper outer surface of each bit element **12** is also profiled to mate with the splined portion **26** of the drive sub in a movably articulated manner as described earlier in this presentation. Thus, where the splined section of the drive sub has a curved or rounded profile **26**, the outer upper portion of each bit element is similarly splined and contoured to move within this portion of the drive sub.

With respect to the tapered outer portion of each cutter element which engages the shoulder **29** of the drive sub, it is preferred that a taper angle with a vertical of about 35° to 40° be used. It has been found that angles within this range provide a uniquely advantageous distribution of thrust and space for the expansion and retraction of the cutter elements.

Referring again to the splined portion of the drive sub and to the corresponding splined portion of each cutter element, it will be noted that sharp edges should be avoided with these portions in order that the splines may readily engage and disengage.

In order that the cutter elements be fully capable of entering within the drive sub without requiring any substantial orientation, it is desirable that a sufficient number of splines be used on the drive sub. It is further preferred that the number of splines in the sub be evenly divisible by the number of bit telements. For example, sixty splines would be suitable for use with bits containing anywhere from two to six bit elements. It has been ascertained that engagement of the splines of the bit elements with the matching splines in the drill sub are greatly facilitated when this condition is observed.

Having thus described in some detail the various parts of the apparatus shown in the drawing, attention is now directed toward the manner in which the apparatus is best operated. For this purpose, it will be assumed that the apparatus is first in a condition to be lowered within a string of drill pipe.

Referring to Figure 1, the apparatus of the invention is there illustrated in the condition required to enable it to be lowered within a string of drill pipe. The spearhead **74** of the lowering tool illustrated specifically in Figure 8 is engaged with the shoulders **61** of the upper interengaging means or dogs **19**, and the entire mandrel and bit assembly is suspended from the spearhead. The dogs are thereby maintained in a fully retracted condition; and, since the packer **18** is under no compressive loading, it is also in a retracted condition. The bit elements **12** are in a retracted, vertically nested condition, the latch assembly **41** being secured to the mandrel **11** by virtue of dogs **14** being positioned in recesses **46** and **47**. Sleeve valve **27** rests against the lower shoulder of the valve guide or recess **36**, so that the passageways **31** and the valve ports **32** are out of alignment. At this point, it should be noted that the sleeve valve **27** and the mandrel are preferably splined, keyed, or otherwise adapted to be maintained in longitudinal alignment with one another at all times.

When the mandrel and its associated parts are lowered within the drive sub, the following sequence of operations takes place. First, the lower one of the two dogs **14** reaches groove **15**, with the result that it pops out into the groove from its recess **46**. Since the lower dog is automatically clear of the mandrel when it engages groove **15**, the mandrel remains free to move vertically downward relative to this dog and the drive sub.

Simultaneously with the entry of the lower dog into

groove 15, lower bit element associated with or suspended from the lower dog tends to expand into a drilling position immediately below the lower end of the drive sub. In other words, the tapered outer surface of the bit element approaches the shoulder 29 of the drive sub; and the curved splined portion of the bit element tends to engage the curved splined portion of the drive sub.

Following engagement of the lower of the two bit elements with the drive sub, mandrel 11 continues vertically downward with its remaining dog and cutter—i.e., the upper of the dogs 14 and the upper of the cutter elements 12. When the remaining dog reaches groove 15, it—like the first dog—disengages itself from the mandrel and enters the groove. Simultaneously, its bit element tends to expand into a drilling position radially opposite the first cutter. Then, mandrel 11—being free of both locking dogs—continues to move downward relative to the drive sub and the bit elements until its lower wedging surface bears against the inner tapered surface of the bit elements. This action on the part of the mandrel tends to wedge the cutters apart and to force them firmly into drilling position within the drive sub. If the outer diameter of the bit—as defined by bit elements—is no greater than the diameter of the borehole, the mandrel and the bit elements assume the position shown in Figure 2. Furthermore, the sleeve valve—due to its tapered outer surface—engages the inner tapered surface of the bit elements and rides upwardly within the valve guide or recess 36. As a result of the sleeve valve action, the valve ports are in mutual alignment with the branch passageways 31 and the bit element passageways 33.

At this point, it is well to note that it is generally necessary to employ a sinker bar or other equivalent means for applying a load on the mandrel 11 which is sufficient to wedge the bit elements into their drilling position. As shown in Figure 8, a suitable sinker bar 80 may be incorporated directly as a component of the tool which is used to raise and lower the drill assembly.

Once the bit elements have been wedged into their drilling position, expansion of the packer 18 is the next necessary step in the operating sequence. To effect expansion of the packer, the sinker bar 80 of Figure 8 exerts a downward thrust through spearhead 74 and the upper end of sleeve 20—the thrust being sufficient to drive the sleeve 20 downward along with the attached upper packer ring 52 and the rubber sleeve 51. Since the lower end of the sleeve 51 is supported by the lower packer ring 53 and the bushing 54, and since the bushing and lower ring in turn are supported through spring 50 from the holders 42, longitudinal compression and radial expansion of the sleeve 51 results. Any liquid or pressure entrapped within the inner portions of the bellows elements of the sleeve 51 is relieved through the grooves 56 and 57 in mandrel 11. The packer sleeve 51 forms a peripheral seal between the mandrel and the inner wall surface of the drive sub. The degree of compression and the degree of sealing may be readily controlled by the amount of force which is applied by means of the sinker bar.

Concurrently with the setting of the packer, upper dogs or latches 19 spring outwardly until they enter the groove or recess 16 in the drive sub. Since the spearhead 74 is bearing directly against the sleeve 20, it follows that the dogs 19 are free to expand and ride along the inner surface of a string of drill pipe and the drive sub 10 until they reach this groove or recess.

Once the dogs 19 have engaged the recess 16 and the packer has set, and the bit components have expanded into drilling position, the drill is arranged as shown in Figure 2 and is ready for drilling. At this point, spearhead 74 may be raised vertically from the apparatus and removed from the borehole, since the dogs 19 cannot escape or retract without the application of a suitable tool as mentioned earlier.

Actual drilling with the apparatus of Figure 2 is attained by lowering the drive sub and the attached well pipe above the sub until the cutter elements (i.e., the assembled bit) reach the bottom of the borehole. Rotation of the bit, the drive sub, and the well pipe may be obtained conveniently by the use of conventional surface rotary equipment; and loading of the bit may likewise be readily controlled by the use of conventional surface apparatus.

During the operation of the drill in a drilling sequence, drilling fluid—preferably drilling mud, air, or the like—is passed down through the well pipe and thence through the passageway 28 to the jet 30 and the passageways 33 in the various cutter elements. The drilling fluid aids materially in the drilling operation—as in conventional operations of this type—by removing cuttings from the borehole, lubricating the bit, etc.

When a drilling operation is interrupted and it is desired to remove a drill bit from a borehole, the following sequence of operations is employed. First, the drill pipe and the drive sub 10 are lifted from the bottom of the borehole; and rotation of the equipment is stopped. A tool such as that shown in Figure 8 (with pin 85 removed) is then lowered through the pipe and the drive sub until the inner conical surface 90 of the tool engages the upper ends of latches 19 and forces them together so as to disengage them from the drive sub. An upward pull on the tool then causes the upper surface of the spearhead 74 to engage the shoulders 61 of the dogs 19, with the initial result that the packer 18 is released.

Continued upward pull of the tool lifts the mandrel 11. As a further result, the bit elements 12 are retracted from their drilling position and lifted within the drive sub in a sequence which is substantially opposite to or the reverse of the sequence by which they were expanded into drilling position. Thus, the right-hand bit element in Figure 2 is the first of the cutters to be retracted and withdrawn; and the left-hand cutter then follows.

Concurrently with retraction of the bit elements, upward pull of the mandrel 11 causes the latch assemblies to be sequentially engaged and lifted with respect to the drive sub. As the grooves 40 in mandrel 11 move upward, their lower shoulders engage latch assembly 41. The dogs 14 are retracted from the groove or recess 15, and they then enter the recesses 46 and 47 in the mandrel. When this occurs, the drill is in a fully retracted position and may be lifted to the surface of the earth.

As mentioned earlier in this description, it is a particular characteristic of the drill of this invention that it may drill even though it may not be in a completely expanded drilling position. This feature or characteristic of the invention is shown particularly well in Figure 7. Referring to that figure, the bit elements 12 are depicted there as they would appear in attempting to expand within an under-sized hole. The bit is capable of being rotated in the hole, but it cannot expand to its full drilling diameter. It will be noted, however, that compensating factors within the apparatus are operative in the figure to gradually expand the bit into the fully expanded condition. Thus, the sleeve valve 27 is resting on the lower shoulder of the valve guide portion 36 of the mandrel; and the valve ports 32 are therefore out of alignment with the branch passageways 31. It will be apparent, then, that drilling fluid in passing down through central passageway 28 is unable to follow its usual course through the bit elements 12. Instead, it must travel entirely through the jet 30, with the result that an extraordinary amount of hydraulic force is exerted on the mandrel so as to urge it vertically downward. There is, therefore, a continuous effort on the part of the over-all drilling ssytem to urge the bit elements 12 into their expanded position; and this effort is continuous until this objective is realized.

Also of particular interest in Figure 7 is the fact that the mating curved spline portions of the cutter elements

and the drive sub enable the cutter elements to articulate relative to the drive sub during the entire time that the mandrel 11 is urging them into an expanded position. This feature is an especially desirable one in that the bit can be expanded in a hole smaller than one the nominal gage of the bit. Such holes are frequently encountered as a result of wear of the outer diamonds of the preceding bit. Thus, the borehole is quickly restored to its nominal gage, providing for easy insertion of a large size of oil well casing after the well is drilled.

The foregoing description has been limited to an apparatus which is contemplated to be the best mode of practicing the invention. However, it will be recognized that numerous variations and modifications are possible without departing from the spirit or scope of the invention. For example, it is contemplated that the center mandrel need not always have an abrasive cutting surface as where the drill is used for reaming purposes.

The invention claimed is:

1. In a retractable and expansible drill including a mandrel, a plurality of bit elements movably supported from the mandrel by means of elongated support members, and a tubular member adapted to receive the mandrel and the bit elements in a manner to assemble the bit elements adjacent one end of the tubular member after passage therethrough, said mandrel being adapted further to move longitudinally relative to the assembled bit elements and to wedge said bit elements against the tubular element, the improvement which comprises an abrasive-type cutting surface covering each bit element and the wedge-end portion of the mandrel, said mandrel being coextensive with said bit elements when completely wedged and expanded so as to integrate the various cutting surfaces, positive-type mating means on each bit element and said tubular member to resist lateral peripheral movement between the expanded bit elements and the tubular member, a central fluid passageway extending longitudinally throughout said mandrel, a separate branch fluid passageway intersecting said central fluid passageway and extending toward each bit element, a separate fluid passageway extending through each bit element, and valve means on said mandrel adapted to interconnect each branch passageway with a bit passageway when the bit elements are fully expanded.

2. An apparatus as defined in claim 1 in which the valve means is a sleeve valve movable along the mandrel.

3. In a retractable and expansible drill including a tubular sub attachable to the lower end of a string of drill pipe, a mandrel insertable into the sub from the drill pipe, a plurality of bit cutter elements, a separate support member connected to each bit element and in turn supported in a longitudinally movable relation by the mandrel, said sub upon insertion of said mandrel being cooperable therewith to assemble said cutter elements adjacent the lower end of the sub, a packer supported around said mandrel and operable to seal the annular space between the mandrel and the sub, said mandrel upon assembly of said cutter elements being adapted to wedge said cutter elements against said sub, the improvement which comprises an abrasive cutting surface on the lower end of said mandrel and on the lower and outer surfaces of each cutter element, all lower cutting surfaces defining a coextensive integral cutting surface upon complete expansion of the cutter elements, positive-type interengaging means on each cutter element and said sub to resist rotational movement between said cutter elements and said sub, each cutter element being pivotally connected to its respective support member, said interengaging means defining a curved bearing section to facilitate expansion and retraction of said cutter elements, a main fluid passageway extending throughout the length of said mandrel, a separate fluid passageway in each cutter element, and normally closed valve means on said mandrel operable upon complete expansion of the cutter elements to interconnect the main passageway with the cutter element passageways.

4. An apparatus as defined in claim 3 in which the abrasive cutting surfaces are diamond surfaces.

5. An apparatus as defined in claim 3 in which the interengaging means are mating longitudinally disposed splines on each cutter element and said sub.

6. A retractable drill comprising a conduit-like elongated drive sub attachable to the lower end of a string of well pipe, an elongated mandrel lowerable within said sub, a plurality of bit element supports spaced around said mandrel, each support being retractably mounted at its upper end to said mandrel and terminating at its lower end below said mandrel, an abrasive-type bit element pivotally attached to the lower end of each cutter support, a plurality of longitudinally disposed splines spaced around the inner periphery of and near the lower end of said sub, each bit element having a splined outer portion adapted to engage the said sub splines, said bit element splines and said sub splines having rounded matching profiles to enable said cutters to pivot within said sub, means associated with said sub to retract the upper end of said cutter supports from said mandrel when said cutter splines and said sub splines are in lateral alignment thereby enabling said mandrel to move downward relative to said cutters, the lower end of said mandrel terminating in an abrasive cutting surface and adapted to urge said bit elements outward thereby engaging said bit element splines with said sub splines, retractable interengaging means between said mandrel and said sub to lock said mandrel within said sub, lost-motion means between said retractable latching means and said mandrel to enable limited longitudinal movement between said mandrel and said sub, a packer mounted exteriorly of said mandrel and adapted to effect a fluid-tight seal between said mandrel and said sub, a central drilling fluid passageway extending throughout the length of said mandrel, drilling fluid passageways in said bit elements, and branch drilling fluid passageways in said mandrel interconnecting said central passageway and said bit element passageways when the lower surfaces of all abrasive cutter elements are laterally flush with one another.

7. A retractable drill comprising a tubular sub adapted to be attached to the lower end of a string of drill pipe, a mandrel adapted to be lowered within said sub, a plurality of bit element supports spaced around said mandrel, the upper end of each bit element support terminating in a dog retractably mounted within said mandrel, the lower end of each bit element support terminating in a diamond-type bit element depending below said mandrel, a plurality of vertically disposed splines extending around the inner surface of said sub near the lower end thereof, a splined outer portion on each bit element adapted to engage the splines of said sub after the cutting surfaces of the bit elements have passed through said sub, the splined portion of each bit element and the splines of said sub having a rounded profile to enable a pivotal-type motion of said bit elements relative to said sub, means within said sub adapted to retract and receive said dogs from said mandrel substantially concurrently with the engagement of said bit element splines and said sub splines, the lower end of said mandrel terminating in a diamond cutting surface and shaped to urge said bit elements radially outward from said mandrel so as to engage said bit element splines and said sub splines, combination lost-motion means and retractable latching means to retain said mandrel within said sub, a central drilling fluid passageway extending throughout the length of said mandrel, at least one drilling fluid passageway in each said bit element, a plurality of branch drilling fluid passageways in said mandrel interconnecting said central passageway with said bit element passageways when the lower surfaces of said mandrel and each bit element are laterally flush with one an-

other, and a packer on the outer surface of said mandrel adapted to seal the annular space between said mandrel and said sub.

8. In a retractable and expansible drill including a mandrel carrying a plurality of bit elements and a tubular member adapted to receive the mandrel and bit elements and cooperable therewith to expand the bit elements at one end of the tubular member after passage therethrough, the improvement which comprises means to wedge said mandrel between the expanded bit elements and to urge the bit elements into contact with the tubular member, interengaging means provided upon contacting portions of each bit element and said tubular member to resist rotational movement therebetween, an abrasive cutting surface on each bit element, contacting portions of each bit element and said tubular member being shaped to define curved bearing surfaces to enable the bit element to pivot relative to said tubular member upon expansion and retraction of the drill.

9. In a retractable and expansible drill of the type described including a tubular member adapted to be attached at its upper end to the lower end of a string of drill pipe, a mandrel and a plurality of abrasive-type bit elements dependent therefrom adapted to be lowered within the sub and cooperable therewith to expand the bit elements into a positive-type engagement against the lower end of said tubular member, the improvement which comprises fluid passageways in each bit element and said mandrel for the flow of drilling fluid therethrough, the passageways in said bit elments being alignable with passageways in said mandrel when the drill is in an expanded position, means to restrict the discharge of drilling fluid from passageways in said mandrel except when said drill is in an expanded position, contacting portions of said bit elements and said tubular member being shaped to define an arcuate race joint enabling the bit elements to pivot relative to the tubular member upon expansion and retraction of said drill.

10. In a retractable and expansible drill including a mandrel, a plurality of bit elements movably supported from the mandrel by means of elongated support members, and a tubular member adapted to receive the mandrel and the bit elements in a manner to assemble the bit elements adjacent one end of the tubular member after passage therethrough, said mandrel being adapted further to move longitudinally relative to the assembled bit elements and to wedge the elements laterally against the tubular element, the improvement which comprises an abrasive-type cutting surface on each bit element

and on the end portion of said mandrel, said mandrel end portion being coextensive with said bit elements when wedged together so as to integrate the various cutting surfaces, positive-type pivotal interengaging means associated with said bit elements and said tubular member, the end of said tubular member and said bit element being shaped so as to define mating curved bearing surfaces to permit pivotal expansion and retraction of said bit elements and of a character to resist lateral movement between the wedged bit elements and the tubular member.

11. An apparatus as defined in claim 10 in which said positive-type pivotal interengaging means comprises mating splines on said bit elements and said tubular member.

12. In a retractable and expansible drill including a tubular member attachable to the lower end of a string of drill pipe, a mandrel longitudinally insertable into said tubular member from said drill string, a plurality of bit elements suspended from the mandrel by means of separate support members which are movable along the mandrel, said tubular member being cooperable with said mandrel and said bit elements and said support members to retractably assemble the elements adjacent the lower end of the tubular member, said mandrel being adapted to wedge the bit elements against said lower end of said tubular member, the improvement which comprises an abrasive cutting surface on each bit element and on the lower end of said mandrel, said mandrel in its wedging action being adapted to render its cutting surface coextensive with the cutting surfaces of the bit elements, interengaging pivotal means associated with each bit element and said tubular member, said interengaging pivotal means including mating arcuate splines on each bit element and on said tubular member to permit pivotal expansion and retraction of said bit elements and of a character to resist lateral peripheral movement between the wedge bit elements and the tubular member.

References Cited in the file of this patent

UNITED STATES PATENTS

1,996,132	Walker	Apr. 2, 1935
2,099,859	Macready	Nov. 23, 1937
2,208,457	Hurley	July 16, 1940
2,360,088	Walker	Oct. 10, 1944
2,545,037	Kammerer	Mar. 13, 1951
2,755,071	Kammerer	July 17, 1956
2,764,388	Camp	Sept. 25, 1956