

April 2, 1963

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3,083,765

METHOD AND APPARATUS FOR CONDITIONING BORE HOLES

Filed Oct. 28, 1960

5 Sheets-Sheet 1

FIG. 1.

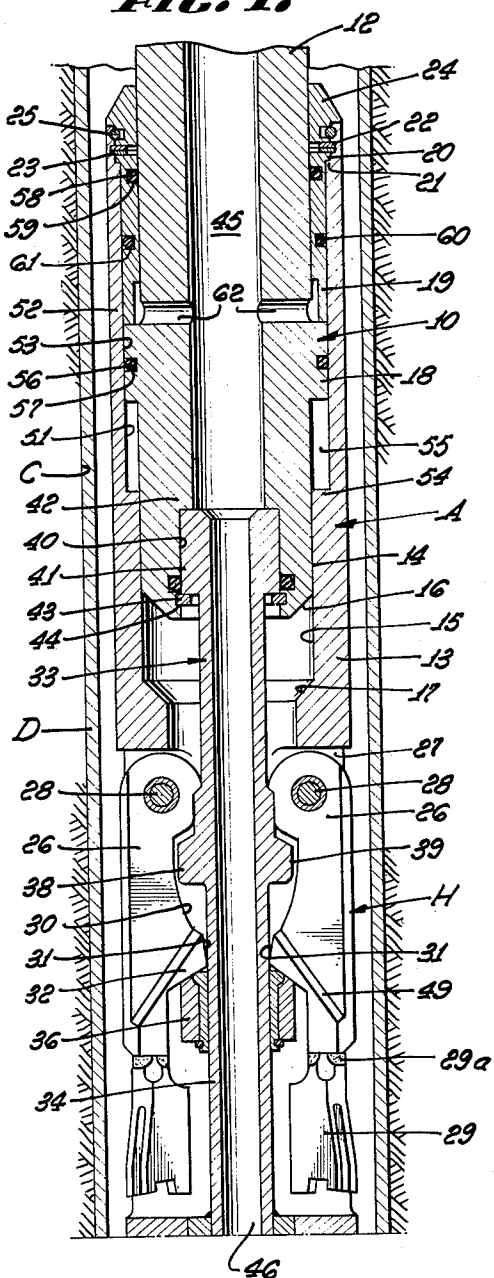


FIG. 1a.

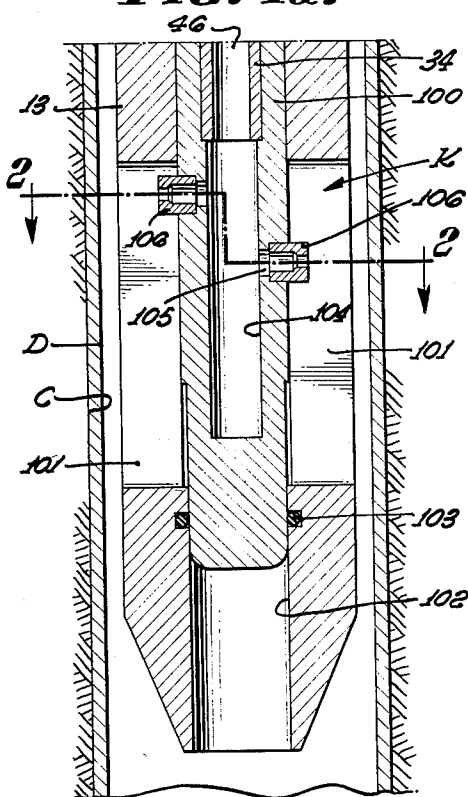
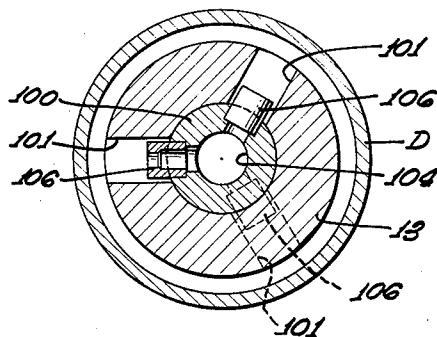


FIG. 2.



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FIG. 3.

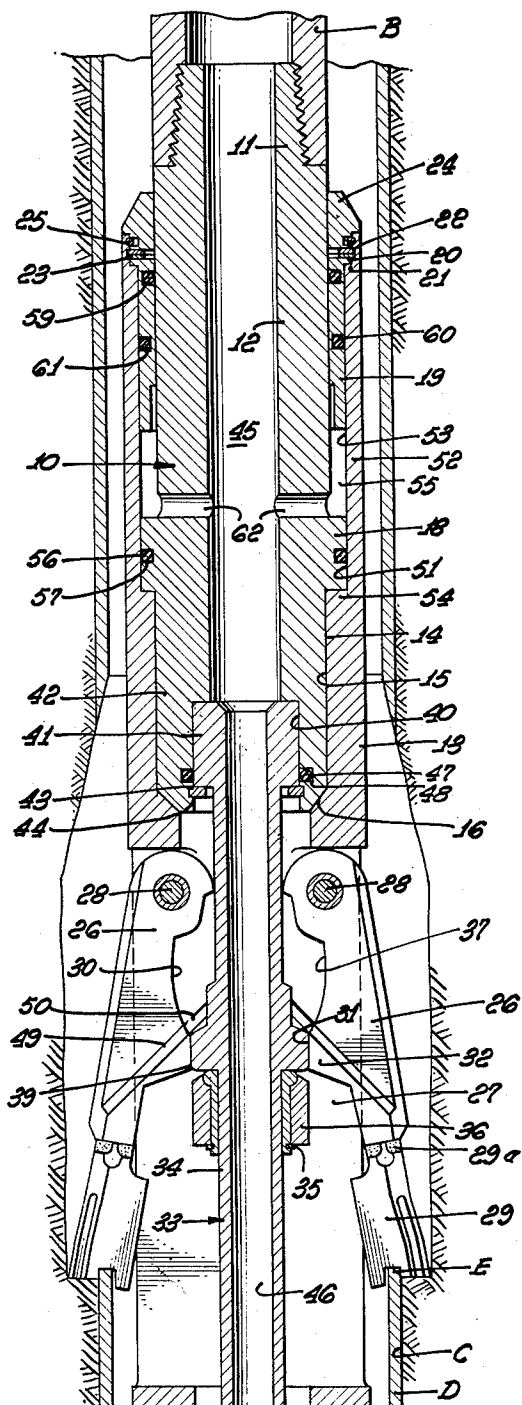
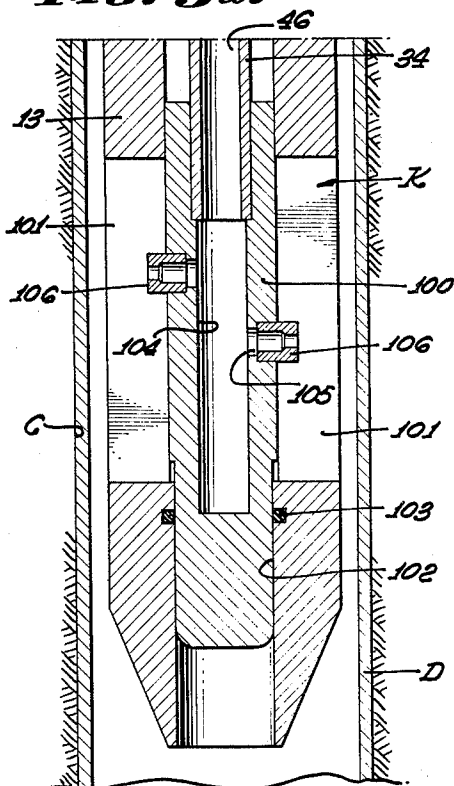


FIG. 3a.



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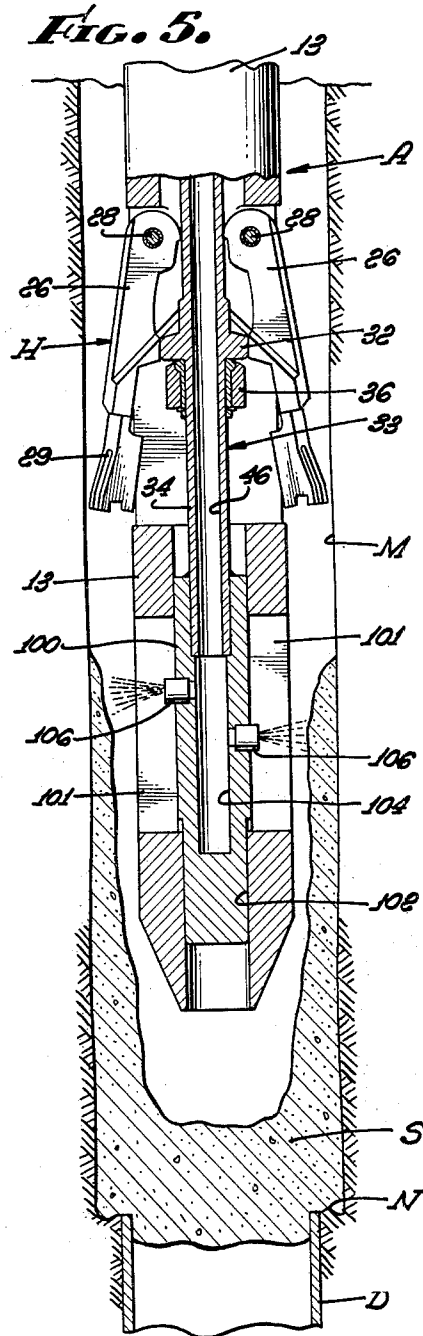
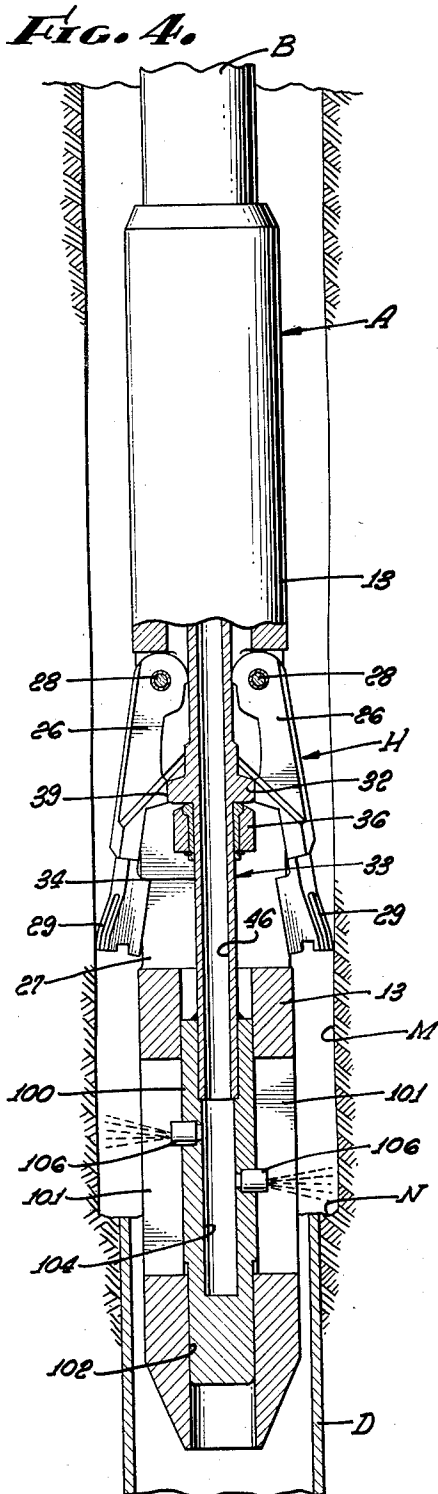
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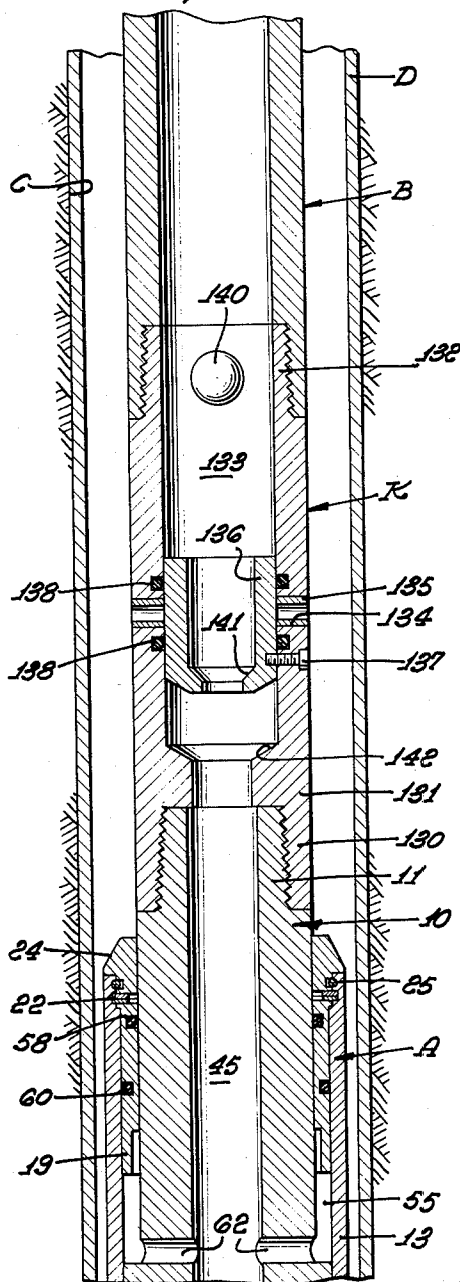


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FIG. 7.



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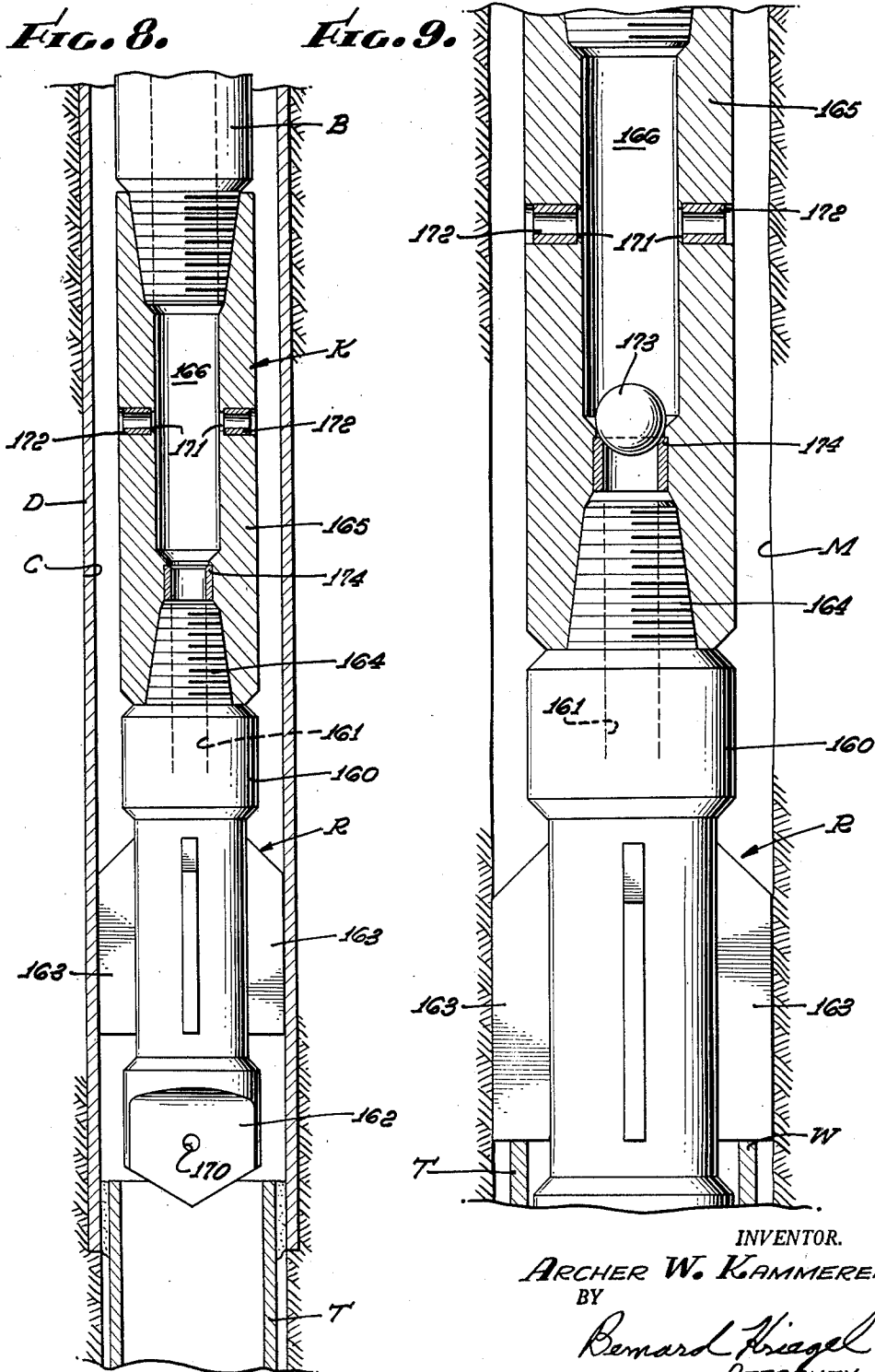
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FIG. 8.

FIG. 9.



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METHOD AND APPARATUS FOR CONDITIONING BORE HOLES

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Filed Oct. 28, 1960, Ser. No. 65,620
19 Claims. (Cl. 166—21)

The present invention relates to methods and subsurface apparatus for performing various operations in bore holes.

An object of the invention is to enlarge a bore hole, such as a well bore, and provide a cementitious plug in the enlarged hole, all with a single trip of equipment in the bore hole, resulting in the attainment of a better plug at a substantial savings in time and cost.

Another object of the invention is to mill or cut away casing or liner in a well bore to open the latter along a predetermined length and introduce cementitious material into the opened portion of the well bore, all with a single trip of equipment in the well bore.

A further object of the invention is to mill or cut away casing or liner in a well bore to open the latter along a desired length and hydraulically enlarge the open portion of the well bore, all with a single trip of equipment in the well bore.

Yet another object of the invention is to expose a portion of a cased or lined well bore and then condition the wall of the exposed well bore, all with a single trip of equipment in the well bore.

An additional object of the invention is to provide apparatus capable of being lowered in a well bore and of performing cutting, well conditioning, and cementing operations therein without removing the apparatus from the well bore.

Still a further object of the invention is to provide apparatus capable of being lowered in a well bore to remove a desired length of casing or liner therewithin and to perform one or more of the following additional operations without removing the apparatus from the well bore: washing or otherwise conditioning the exposed portion of the well bore, enlarging the exposed portion of the well bore, or depositing cementitious material along such exposed portion.

Another object of the invention is to provide apparatus capable of being lowered in a well bore to remove a desired length of casing or liner therewithin and of simultaneously performing a hydraulic jetting action against the wall of the exposed well bore.

This invention possesses many other advantages and has other objects which may be made more clearly apparent from a consideration of several forms and methods embodying the invention. These forms and methods are shown and described in the present specification and in the drawings accompanying and constituting a part thereof. They 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, since the scope of the invention is best defined by the appended claims.

Referring to the drawings:

FIGURES 1 and 1a together constitute a longitudinal section through an apparatus disposed in a well casing, with parts in their initial position for lowering the apparatus in the well bore, FIG. 1a constituting a lower continuation of FIG. 1;

FIG. 2 is a cross-section taken along the line 2—2 on FIG. 1a;

FIGS. 3 and 3a are views corresponding to FIGS. 1 and 1a, with parts of the apparatus in expanded condition, FIG. 3a constituting a lower continuation of FIG. 3;

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FIG. 4 is a longitudinal section, parts being shown in side elevation, of the apparatus disclosed in FIGS. 1 to 3a in condition for performing a jetting action in the well bore;

FIG. 5 is a view similar to FIG. 4 illustrating the apparatus depositing cementitious material in the well bore;

FIG. 6 is a longitudinal sectional view, parts being shown in side elevation, of a modified form of apparatus;

FIG. 7 is a longitudinal section through still another embodiment of the apparatus;

FIG. 8 is a combined longitudinal section and side elevational view of yet another form of the apparatus in condition for milling away a liner section;

FIG. 9 is an enlarged view, partly in longitudinal section and partly in side elevation, of the apparatus disclosed in FIG. 8 conditioned for performing a jetting action on the wall of a well bore.

The apparatus A illustrated in FIGS. 1 to 5, inclusive, is specifically designed for cutting or milling away a portion of casing D disposed in a well bore along a desired length, and of then performing a jetting action upon the exposed well bore for the purpose of conditioning the well bore, or enlarging the diameter of the same, or of depositing cementitious material in the well bore, or a combination of such last-mentioned operations. The apparatus A is secured to the lower end of a string of drill pipe B that extends to the top of the well bore C and by means of which the apparatus is lowered through the string of well casing D to a location therein where a casing milling operation is to commence, and where other operations are also to be performed without removing the apparatus from the well casing.

The apparatus A disclosed includes a rotary drill bit H, the upper portion of which consists of a mandrel 10 having an upper pin 11 threadedly connected to the lower end of the string of drill pipe B. This mandrel includes an upwardly kelly or a drill stem member 12 slidably splined to the main body 13 of the drill bit. The exterior of the lower portion 14 of the kelly is non-circular in shape being telescopically received in a companion non-circular socket 15 formed in the main bit body 13. Specifically, the kelly exterior and the socket 15 may be of hexagonal shape to enable the kelly 12 to be moved longitudinally with respect to the body 13, while still being capable of transmitting rotary motion to the body.

The mandrel 10 has a limited range of longitudinal movement within the body, downward movement being determined by engagement of the lower end 16 of the kelly with an inwardly directed body shoulder 17, and its upward movement being limited to engagement of an external shoulder or piston portion 18 of the kelly with a cylinder head 19 secured to the body. The upper end of the head has a flange 20 engaging a body shoulder 21, the flange being prevented from moving upwardly of the body by split snap retainer rings 22 fitting in a body groove 23 and overlying the flange 20. An annular guide 24 is releasably secured to the body 13 by a split snap ring 25 above the retainer rings 22.

The body has a plurality of expansible parts mounted on it. These include cutter supporting member 26 pivotally mounted in body slots 27 on hinge pins 28 suitably secured to the body to prevent their loss therefrom. Each cutter supporting member 26 depends from the hinge pin 28 and carries a drag or milling cutter structure 29 at its lower ends, which may be suitably attached to each supporting member 26, as by welding material 29a.

The cutter supporting members 26 and the cutter structures 29 themselves tend to occupy a retracted position substantially entirely within the confines of the main body 13 of the bit. These cutter supporting members and the cutter structures are expandible outwardly to sever the

casing D and mill it away by operating upon the upper end E of the casing therebelow. To accomplish the expansion, each cutter supporting member has an inclined expander surface 30 on its inner portion below the hinge pin 28, which tapers in a downward and inward direction. Each expander surface terminates in a lock surface 31 formed on a lock portion 32 of the cutter supporting member. The outward expansion is accomplished by producing relative longitudinal movement between the mandrel 10 and the bit body 13, which will produce relative longitudinal movement between the cutter supporting members 26 and the tubular member 33 of the mandrel 10.

The tubular member includes a portion 34 slidably within a guide bushing 35 mounted in a bridge 36 secured to the body and extending across the body slots 27. This guide bushing 35 is disposed below the lock portions 32 of the cutter supporting members 26. The tubular member 33 extends downwardly of the guide bushing 35 to a substantial extent and is piloted within a head 100 to which it is suitably secured, as by welding material or soldering, this head being slidable longitudinally in the body 13 and along a plurality of elongate lower body slots 101. The head extends below the slots and is slidable in a bore 102 in the lower portion of the body, leakage of fluid between the head and the lower portion of the body being prevented by a suitable pliant elastic seal ring 103 mounted in the body and slidably and sealingly engaging the periphery of the head 100.

The head has a central passage 104 communicating with the passage 46 through the tubular member 33 and a plurality of circumferentially spaced side ports 105 opening into the passage 104. Mounted in each side port 105 and secured to the head 100, as by welding, are jets or nozzles 106 arranged generally radially of the head, and which are in alignment with the lower slots 101 or extend thereinto, so that fluid pumped down through the passage 104 of the head will discharge from the jets or nozzles 106 through the slots 101 and against the wall of the well casing D or wall of the open well bore C.

Located initially and substantially above the guide bushing 35, and below the hinge pins 28, and in cutter member recesses 37 is a mandrel lock and expander 38, which has outer surfaces 39 adapted to engage the expander surfaces 30 and lock surfaces 31. The lock and expander 38 may be formed integrally with the tubular member 33, the upper end of the latter being piloted within a socket 40 formed on the lower portion 14 of the kelly 12. An enlarged boss 41 on the tubular member 33 engages a downwardly facing shoulder 42 of the kelly, the tubular member being held against this shoulder by a suitable split retainer or lock ring 43, snapped into an internal groove 44 encompassing the kelly socket and engaging the lower end of the tubular member boss 41.

Drilling mud or other fluid can pass down through the central passage 45 and the kelly or drill stem 12 and into the central passage 46 that extends completely through the tubular member 33, this fluid or fluent material passing into the head passage 104 and then outwardly through the nozzles 106 and the lower body slots 101 into the surrounding well bore. Leakage of fluid around the exterior of the tubular member 33 is prevented by a suitable side seal ring 47, such as a rubber O ring, in a peripheral groove 48 in the kelly which engages the exterior of the boss 41.

Assuming the body 13 of the tool to be elevated relatively along the tubular mandrel 10, the inclined expander surfaces 30 of the cutter supporting members 26 will be shifted upwardly along the lock and expander portion 33 of the tubular member 33. During such upward shifting, the cutter supporting members 26 and the cutter structures carried thereby will be pivoted about the hinge pins 28 and urged in an outward direction. The upward movement of the body 13 with respect to the tubular mandrel 10 can continue until the cutter structures 27, 29

have been shifted outwardly to their fullest extent, as determined by engagement of stop shoulders 49 on the cutter supporting members 26 with companion shoulders 50 formed in the body on opposite sides of the body slots 27. When such engagement occurs, the lower end 16 of the kelly portion 12 of the tubular mandrel will engage the body shoulder 17, and the lock and expander 38 on the tubular member 33 will be disposed behind and in engagement with the lock portions 32 on the cutter supporting members 26 (FIG. 3).

It is to be noted that the surfaces 31 on the lock portions 32 of the cutter supporting members 26 and the companion surfaces 39 on the lock and expander portions 38 of the tubular member are substantially parallel to the axis of the drill bit to prevent reactive forces on the cutter structures 29 from moving the latter inwardly. As a practical matter, it is preferred that the coengaging lock surfaces 39, 31 be inclined slightly in a downward direction toward the axis of the tool to insure release of the lock and expander portion 38 from the cutter supporting members 26 when the latter and the cutter structures 29 are to be shifted to retracted position.

Relative longitudinal movement between the tubular mandrel 10 and the body 13 of the tool is accomplished hydraulically in the specific form of apparatus disclosed in the drawings. Thus, the piston or enlarged portion 18 on the drill stem 12 is received within a counterbore 51 in the upper portion of the body of the tool. This upper portion actually constitutes a cylinder 52 having a cylindrical wall 53 extending from a lower shoulder 54, defining the bottom of the counterbore 51, to the cylinder head 19.

A confined cylinder space 55 is formed between the piston portion 18 of the kelly, the periphery of the kelly above the piston, and the cylinder 52. A suitable packing or side seal ring 56 may be disposed in a suitable piston ring groove 57 formed in the piston portion 18, which is adapted to slidably seal against the cylindrical wall 53 of the cylinder 52. Fluid is thereby prevented from passing in a downward direction between the piston and cylinder. Similarly, fluid is prevented from passing in an upward direction out of the annular cylinder space 55 by an inner side seal ring 58 carried in an internal groove 59 in the cylinder head 19 and slidably and sealingly engaging the periphery of the kelly 12 above the piston 18, and also by an outer side seal ring 60 disposed in an external groove 61 on the head 19 and sealingly engaging the cylinder wall 53.

Fluid under pressure in the string of drill pipe B and in the tubular mandrel passage 45 can be fed into the cylinder space 55 through one or more side ports 62 establishing communication between the central passage 45 through the kelly and the cylinder space. Such fluid under pressure is developed, in the form of invention disclosed in the drawings, by virtue of the fact that the total area through the jets or nozzles 106 is substantially less than the area of the passage 45 through the kelly portion of the mandrel, or because of the fact that the passage 46 through the tubular member 33 of the mandrel is of a restricted diameter as compared to the passage 45. As a result, the pumping of drilling mud or other fluid at an adequate rate through the apparatus will build up a back pressure of fluid in the passage 45, which pressure will be imposed on the fluid in the cylinder space 55, acting upon the cylinder head 19 to urge the body 13 of the tool in an upward direction with respect to the tubular mandrel 10, to secure outward expansion of the cutter supporting members 26 and cutter structures 29 to their fullest extent as above described. During such upward movement of the body along the mandrel, the lower body slots 101 are shifted upwardly along the nozzles 106 mounted in the head 100 secured to the mandrel 10. However, the slots 101 have a sufficient length such that fluid discharged through the nozzles can pass freely through the slots to the exterior of the body 13 of the tool.

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As apparently disclosed in the drawings, a set of diametrically opposed supporting members 26 and cutter structures 29 are supplied, disposed substantially 180 degrees apart from each other. Actually, it is preferred to supply three sets of supporting member and cutter structures displaced substantially 120 degrees from each other to secure a smoothly running rotary expansible bit. Two sets of supporting member structures are shown in FIGS. 1, 1a, 3, 3a, 4 and 5 in the interest of simplicity of the drawings. However, regardless of the number of cutters 29 used, the jet nozzles 106 employed can be any suitable number displaced circumferentially from one another to the desired extent. As shown in FIG. 2, three nozzles 106 displaced about 120 degrees are illustrated, each nozzle being adapted to direct its fluid through its companion body slot 101.

In the use of the apparatus A, it is run in the well casing with the cutter supporting members 26 and their cutter structures 29 in their initial retracted position, such as disclosed in FIGS. 1 and 1a. When the apparatus has been lowered to the desired point in the well casing, at which the latter is to be severed, the pumps (not shown) at the top of the well bore are started to pump fluid at a sufficient rate through the drill pipe B and into the mandrel passages 45, 46, 104 and through the nozzles 106, building up a back pressure in the kelly passage 45, in the ports 62 and cylinder space 55, which pressure acts upon the cylinder head 19 to urge the body 13, the cutter supporting members 26 and the cutter members 29 in an upward direction with respect to the mandrel 10. During such upward movement, the expander surfaces 30 are brought to bear against the lock and expander portions 38 of the mandrel, the cutter structures being urged in an outward direction against the wall of the well casing D. The drill pipe B and the apparatus A are rotated at the proper speed while fluid is being pumped through the apparatus, the outer edges of the cutters 29 acting upon the wall of the casing and gradually milling it away, as described in United States Patent No. 2,922,627, for example. During this operation, the apparatus is retained in substantially the same longitudinal position in the well casing. As the casing is cut away, the hydraulic force acting upon the body 13 raises it and the cutter supporting members 26 and cutter structures 29 to a further extent until the outer edges of the cutters have completely severed the casing. Thereafter, rotation of the drill pipe B and the apparatus A continues so that the remaining portions of the cutters 29 continue to cut away the casing and dig into the formation, until the cutters have been fully expanded outwardly to the maximum extent, as determined by engagement of the stop shoulders 49, 50 and the lower end 16 of the kelly portion 12 of the mandrel with the body shoulder 17. With the parts in this position, the lock portion 32 of each cutter supporting member 26 will bear against the lock and expander portion 38 of the tubular member 33 to preclude inadvertent partial retraction of the cutter structures 29 from their fully expanded position.

Downweight in the proper amount is now imposed on the string of drill pipe B, this downweight being transmitted through the kelly 12 to the body shoulder 17 and from the body 13 to the stop shoulders 50, 49 directly to the cutter supporting members 26 and the cutter structures 29, urging the latter against the upwardly facing severed end E of the well casing. The imposition of the proper downweight or drilling weight on the apparatus and its rotation at the proper speed will cause the cutters to effect a cutting action upon the severed end E of the casing and mill it away. During such milling action, drilling fluid is being pumped down through the drill pipe B and through the kelly, discharging from the nozzles 106 into the well bore around the apparatus, and carrying the cutters upwardly around the apparatus and the drill pipe B to the top of the hole.

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After the desired length of casing has been milled away, which, for example, may be of a length of 20 feet to 40 feet, the downweight imposed on the apparatus is discontinued. A subsequent operation can now be performed in the well bore without removing the apparatus A from the well bore. If it is desired to enlarge the well bore C, circulating fluid is pumped down through the drill pipe B and through the apparatus A, discharging from the nozzles 106 and directing a jet of fluid against the wall of the exposed well bore M (FIG. 4). The drill string and apparatus connected thereto are rotated at the desired speed during such pumping operation so that the entire circumference of the well bore is covered by the jets of fluid issuing from the nozzles 106. During the rotation and pumping operation, the drill pipe B and the apparatus A can be gradually elevated, so that the jet streams are caused to impinge upon the desired length of the wall of the well bore above the lower shoulder N produced by the cutters. If, for example, the well casing has been severed along a length of about 20 feet, the tool will be elevated a distance of about 20 feet so that the fluid jets operate along the entire length of the exposed well bore M. Of course, the apparatus can be raised and lowered as many times as desired, depending upon the hole enlarging operation that is to be performed by the streams issuing at high velocity from the jets. To insure such high velocity streams, pumps at the top of the well bore will be used capable of forcing a relatively large volume of fluid through the drill pipe and apparatus.

If it is only desired to enlarge the wall of the well bore by the jetting action, after such enlargement has been completed, the pumping action can be stopped and the apparatus A removed through the well casing D. It is merely necessary to elevate the tubular mandrel 10 with respect to the body 13 and the cutter supporting members 26, raising the lock and expander portion 38 above the expander surfaces 30, whereupon the cutter structures 26, 29 will drop back to their retracted position, such as disclosed in FIG. 1. The drill pipe and apparatus can then be elevated through the well casing above the enlarged well bore portion M to remove the apparatus at the top of the hole.

After the section of casing has been milled away, the wall of the well bore M can be conditioned by pumping fluid downwardly through the drill pipe B, the apparatus A, and out through the nozzles 106, in the manner described above, the apparatus being rotated by the drill pipe during the pumping operation, and moved longitudinally along that face of the exposed well bore M to insure the conditioning operation along the desired length of the latter. Suitable washing fluid can be used in the performance of the washing operation. The washing operation is desirable for the purpose of exposing the wall of the well bore, and particularly to remove a drilling mud cake from the wall in the event a cement plug is to be placed in the lower portion of the exposed hole M, so that a subsequent operation can be performed in the hole, such as the setting of a whipstock (not shown) on the cement plug, and the drilling of a hole deflected from the existing well bore C.

In depositing the cement plug in the well bore, the proper amount of cement slurry S is pumped down through the drill pipe B, passing through the mandrel passages 45, 46 and into the jetting head 100, then discharging through the nozzles 106 and against the wall of the hole M. If desired, a certain proportion of abrasive sand or similar material can be mixed with the cement, so that the abrasive sand impinges upon the wall of the hole and dislodges any mud cake that might be adherent thereto, insuring the intimate contact of the cement slurry against the wall of the well bore. As the cement is discharged from the nozzles 106, the drill pipe B and the apparatus A are gradually elevated in the well bore, while the drill pipe and the apparatus

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are rotated at the proper speed, to insure uniform deposition of cement slurry in the well bore, the latter stuffing downwardly to completely fill the entire cross-sectional area of the well bore M and along the desired length of the exposed well bore (FIG. 5). The cement slurry will be followed by displacement fluid pumped down the drill pipe B. After all of the cement slurry has been discharged from the nozzles 106, the displacement fluid is then forced through the apparatus A and its nozzles to clear all passages of the apparatus and all regions of the tool of cement slurry, as the tool is elevated above the mass of cement slurry S deposited in the open well bore as a plug. The pumping action can then be stopped to relieve the pressure in the apparatus, whereupon the body 13 of the tool will drop downwardly along the mandrel 10, the cutters 29 retracting and allowing the drill string B to be elevated to remove the apparatus A through the well casing D to the top of the well bore.

The deposited cement or cementitious material S will set and harden in the well bore, forming a cement plug therein. This plug will remain in place and cannot be displaced, particularly in a downward direction, since its outer margins are resting upon the lower formation shoulder N produced by the cutters in the well bore (FIG. 5). In fact, such formation shoulder can have a much greater lateral extent than is illustrated in FIGS. 4 and 5, for example, in view of the fact that the jetting action of the fluid pumped through the nozzles 106 can further enlarge the diameter of the exposed portion M of the well bore. Accordingly, the cement will extend laterally to a greater degree beyond the internal diameter of the well casing D, insuring against downward dislodgement of the cement plug in the well bore, as under the drilling action of a drill bit (not shown) being deflected laterally by a whipstock (not shown) set in the well bore above the cement plug.

It is, accordingly, apparent that the apparatus A is capable of performing several operations in the well bore with a single round trip of the apparatus in the well bore. Not only will the milling action occur to remove the desired length of well casing, but the well bore can be further enlarged by the fluid jets issuing from the nozzles 106. The wall of the well bore M can be conditioned, as by removing the mud cake therefrom, and cement slurry S, or the like, can be discharged from the nozzles to form a strong cement plug in the well bore. The jetting action of the cement slurry insures an intimate plastering of the cement on the well bore wall, particularly since the substantial force of the fluid jets will have the tendency of dehydrating the cement slurry by forcing the water mixed therewith into the surrounding formation.

The apparatus illustrated in FIG. 6 is capable of operation in the same manner as the apparatus shown in FIGS. 1 to 5, inclusive. As disclosed in FIG. 6, the apparatus is the same as in the prior mentioned figures, insofar as the casing milling portion H of the equipment is concerned. However, it differs from the prior described apparatus in the construction of its jetting portion K. In lieu of the nozzles 106 being mounted in a jetting head secured to the mandrel 10, they are mounted within a head portion 120 of the bit body 13. Thus, the lower end of the tubular mandrel or member 33 extends downwardly into a body chamber or central passage 121 below the slots 27 in which the supporting members 26 and cutting structures 29 are movable. Leakage of fluid between the mandrel 33 and the body of the tool below the slots is prevented by a suitable side seal ring 122 mounted in the body and slidably and sealingly engaging the periphery of the mandrel. Accordingly, the fluid under pressure discharging from the mandrel 46 into the body chamber 121 cannot pass upwardly out of the chamber. Instead, such fluid in the chamber passes out through the radial nozzles 123, dis-

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charging against the wall of the surrounding well bore or casing. The chamber or passage 121 extends downwardly in the body substantially below the nozzles 123 so that a mass of substantially dormant fluid or liquid is disposed in the lower portion of the body chamber below the nozzles against which fluid from the mandrel 33 will discharge, thereby preventing such issuing fluid from eroding the body wall of the chamber or passage 121.

The apparatus disclosed in FIG. 6 operates in essentially the same manner as the apparatus shown in FIGS. 1 to 5, inclusive. The cutters 29 are expanded outwardly in the same manner and the tool will mill away a desired length of the well casing D in the same manner. Following the milling operation, fluid is pumped down the drill pipe B and through the mandrel 10, 46 into the chamber 121, then discharging through the generally radial nozzles 123 directly against the wall of the surrounding well bore or casing. Hole enlarging jetting fluid can be pumped through the apparatus A, the latter being rotated at the proper speed during the jetting action so that the jets cover the entire circumference of the exposed well bore M, during which time the tool A is elevated in the well bore along the desired length of the exposed hole, to cover the required length of hole with the jetting fluid. Washing fluid can be jetted from the apparatus in the same manner as in the other form of the invention, and also cementitious material, such as cement slurry, for the purpose of forming a cement plug in the well bore.

In the form of apparatus disclosed in FIG. 7, the casing severing and milling tool H is essentially the same as in the other forms of the apparatus, with the exception that the jet nozzles 106 or 120 need not be included in the lower portion of the apparatus. That is to say the milling portion H of the tool A can be the same as illustrated in United States Patent No. 2,922,627. The jetting portion K of the apparatus is attached to the upper end of the milling tool. Thus, the threaded pin 11 of the mandrel 10 is threadedly attached to the lower box 130 of a tubular head or sub 131, the upper end of which has a threaded pin 132 secured to the string of drill pipe B. This head or sub 131 has a central passage 133 extending therethrough provided with a plurality of circumferentially spaced generally radial ports 134 which may have nozzles 135 mounted therein communicating with the central passage 133 of the head. These nozzles or ports 135 are closed initially by a sleeve valve 136 extending thereacross, which is initially held in position by one or more shear screws 137 extending laterally through the head and into the sleeve. Suitable side seal rings 138 are mounted in the head or sub 131 on opposite sides of the ports 134, 135, sealingly engaging the periphery of the sleeve valve 136.

Initially, the passage 133 through the sleeve valve 136 is open, so that fluid can be pumped downwardly through the string of drill pipe B and through the apparatus K and into the mandrel passage 45 for the purpose of expanding the cutters 29 and providing the necessary fluid for carrying the cuttings upwardly around the apparatus and drill pipe to the top of the well bore. When the side ports or nozzles 135 are to be opened, a suitable trip ball 140 can be dropped or pumped down through the drill string B, this trip ball engaging a seat 141 in the sleeve valve to allow the building up of fluid pressure in the drill string B and the sub 131 above the sleeve valve 136 sufficient to shear the screws 137 and shift the sleeve valve downwardly to the extent limited by its engagement with a lower shoulder 142 in the head 131, at which time the sleeve valve 136 is disposed below the ports or nozzles 135, which are now in an open condition. Fluid under pressure can now be pumped down through the string of drill pipe B and into the central passage 133 of the head or sub, such fluid pressure

then discharging through the nozzles 135 for action upon the wall of the well bore.

In the use of the apparatus disclosed in FIG. 7, the sleeve valve 136 is at first disposed in closed position across the ports 134, 135. The apparatus is lowered in the well casing to the desired location at which the milling operation is to take place, after which the fluid under pressure is pumped down through the drill string and through the apparatus. A back pressure is built up through the kelly passage 45 because of the restricted passage 46 through the tubular mandrel 33, such pressure elevating the body 13 along the mandrel 10, to expand the cutters 29 outwardly, rotation of the drill pipe and the apparatus causing the cutters to sever the well casing, whereupon downward feeding of the apparatus with the cutters expanded will cause the cutters to act upon the upwardly facing casing shoulder E and mill away the casing to the desired extent, as well as to enlarge the well bore to a diameter exceeding the outside diameter of the well casing.

After the desired length of casing has been milled away, the trip ball 140 is dropped or pumped down through the drill string B, engaging its companion seat 141 in the sleeve 136. Pressure is then built up to shear the screw 137 and move the sleeve valve 136 downwardly to the port opening position, which will then preclude downward pumping of fluid through the milling apparatus H. All fluid will then pass outwardly through the nozzles 135, jetting against the wall of the exposed hole M. The drill string B and apparatus A is then rotated while the jetting fluid is discharged from the nozzles 135 for the purpose of performing whatever operations are desired, and which have been described above in connection with the other forms of the apparatus. These include the washing of the wall of the exposed well hole M along the desired length, the hydraulic enlargement of the wall of the well bore by the eroding action of the impinging fluid upon the formation, or the depositing of cementitious material through the nozzles 135 into the enlarged well bore, the tool A being gradually elevated while being rotated so that cement slurry will sluff downwardly and below the lower end of the apparatus to completely bridge across the well bore and form the cement plug. Following completion of the desired operation of the well bore, the drill string B can be elevated to remove the apparatus A through the casing D to the top of the hole.

In the form of invention illustrated in FIGS. 8 and 9, a milling tool R is disclosed, capable of being moved downwardly on a string of drill pipe B, or other tubular drill string, through a well casing D for the purpose of cutting and milling away a portion of a liner T disposed in the well casing and extending therebelow. The milling tool can be of any desired type as, for example, the one illustrated in United States Patent No. 2,855,994, and includes a body 160 having a central passage 161 therethrough and terminating in a pilot bit 162 adapted to pass into the liner, and a plurality of circumferentially spaced cutter blades 163 adapted to engage the upper end of the liner T.

The body 160 has an upper threaded pin 164 for threaded connection to the head or sub 165 of jetting apparatus K, which has a central passage 166 therewithin and which is, in turn, threadedly secured to the lower end of the string of drill pipe B extending to the top of the well bore. The drill pipe is rotated at a proper speed with the proper weight imposed on the liner mill R for the purpose of reducing the liner to cuttings and to mill it away in a downward direction because of the cutting action of the blades 163 on the liner. Drilling fluid is pumped downwardly through the drill string B and through the sub or head 165 into the central passage 161 of the milling tool, discharging through the tool ports 170 and commingling with the cuttings to carry them upwardly around the apparatus to the top of the well bore.

The head 165 of the apparatus K includes generally radial ports or openings 171 through its side wall in which nozzles 172 can be secured, as by welding. Fluid will discharge through these nozzles 172, as well as through the ports 170 of the milling tool, so that the fluid discharging through the relatively small area of nozzles 172 can act on the open well bore M, resulting from the milling away of the liner T, and perform a cleaning action on the wall of the hole, or a hole enlarging operation thereon, during the time that the apparatus is being rotated in milling away the liner (FIG. 9). The liner T can be cut away to the desired length, which may, for example, be 20 feet to 40 feet; whereupon a valve element 173, such as a ball, can be lowered or pumped down the drill string B into engagement with a companion valve seat 174 secured in the head or sub 165 below the nozzles 172 for the purpose of closing the central passage 166. Thereafter, all of the fluid pumped down through the drill string passes outwardly through the nozzles 172 at a high velocity, jetting against the wall of the well bore M.

The drill string B and apparatus are rotated at the proper speed to insure that the jet streams cover the entire circumference of the well bore. By moving the apparatus upwardly and downwardly in the open hole, the jets can be caused to progressively impinge upon the wall of the well bore along its length for the purpose of enlarging its diameter, if desired. To assist in accomplishing this action, abrasive laden fluid can be used. Such action will also remove any mud cake on the wall of the well bore and insure its flushing upwardly through the annulus between the string of drill pipe B and the casing D to the top of the hole.

If a cement plug is to be formed in the open well bore M, the apparatus is lowered to the maximum extent, determined by engagement of the cutter blades 163 with the upwardly facing end W of the severed liner T, whereupon cementitious material is pumped down the drill string B, such cementitious material discharging through the jets 172 while the apparatus is being rotated by the drill pipe. The drill pipe and the apparatus are then elevated gradually in the well bore until the required amount of cement slurry has been deposited in the well bore, such cement slurry sluffing downwardly in the well bore and coming to rest substantially at the shoulder formed by the upwardly facing end W of the liner and the transverse formation shoulder that might surround such liner. The gradual elevation of the apparatus, while cement is discharged, allows the cement to slump downwardly and form a bridge across the entire cross-sectional area of the well bore. After all of the cement has been discharged through the ports, the apparatus is elevated in the well bore and flushing fluid pumped down through the drill string B and tool to insure that the tool is clean of cement slurry, such flushing fluid passing upwardly around the apparatus to the top of the hole. The apparatus can now be elevated by the drill string through the casing and removed therefrom at the top of the hole. Following the setting and hardening of the cement, a firm cement plug is provided in the hole above the liner, which will remain in place.

Here again, it is to be noted that with a single trip in the well bore, a desired section of the liner T has been milled away, the well bore conditioned, or enlarged, by the jetting action of the fluid issuing from the jets, and cement slurry, or similar cementitious material, deposited in the well bore to form a plug therewithin.

I claim:

1. In apparatus adapted to be lowered in a bore hole on a tubular drill string: a rotary drill bit having cutting means thereon for performing a cutting action in the bore hole by operating upon an upwardly facing transverse surface in the bore hole; and a fluid jetting device secured to said bit and having a fluid passage adapted to receive fluid from the tubular drill string; said jetting device in-

cluding a generally radial nozzle disposed below said cutting means for directing fluid from the passage predominantly against the wall of the bore hole; said fluid passage above said generally radial nozzle being closed against flow of fluid outwardly therefrom, whereby all of the fluid received by said passage from the tubular string flows through said passage to the location of said radial nozzle.

2. In apparatus adapted to be lowered in a bore hole on a tubular drill string: a rotary drill bit having expandible cutting means thereon for performing a cutting action in the bore hole and means for expanding said cutting means after said bit has been lowered in the bore hole, said bit having a fluid passage adapted to receive fluid from the tubular drill string; and a generally radial nozzle secured to said bit and in communication with said passage to direct fluid therefrom predominantly against the wall of the bore hole without impinging on said cutting means; said fluid passage above said generally radial nozzle being closed against flow of fluid outwardly therefrom, whereby all of the fluid received by said passage from the tubular string flows through said passage to the location of said radial nozzle.

3. In a rotary bit adapted to be lowered in a bore hole on a tubular drill string: a body; expandible cutter means on said body; a mandrel movable longitudinally in said body and having a passage adapted to receive fluid from the drill string; coengageable expander means on said mandrel and cutter means for expanding said cutter means in response to relative longitudinal movement between said body and mandrel; a generally radial nozzle secured to said bit below said cutter means and adapted to jet fluid received from said mandrel passage predominantly against the wall of the bore hole.

4. In a rotary bit adapted to be lowered in a bore hole on a tubular drill string: a body; expandible cutter means on said body; a mandrel movable longitudinally in said body and having a passage adapted to receive fluid from the drill string; coengageable expander means on said mandrel and cutter means for expanding said cutter means in response to relative longitudinal movement between said body and mandrel; a generally radial nozzle secured to said mandrel below said cutter means and adapted to jet fluid received from said mandrel passage predominantly against the wall of the bore hole.

5. In a rotary bit adapted to be lowered in a bore hole on a tubular drill string: a body; expandible cutter means on said body; a mandrel movable longitudinally in said body and having a passage adapted to receive fluid from the drill string; coengageable means on said mandrel and cutter means for expanding said cutter means in response to relative longitudinal movement between said body and mandrel; said body having an elongate slot below said cutter means; and a generally radial nozzle secured to said mandrel and extending into said slot and adapted to jet fluid received from said mandrel passage through said slot against the wall of the bore hole.

6. In a rotary bit adapted to be lowered in a bore hole on a tubular drill string: a body; expandible cutter means on said body; a mandrel movable longitudinally in said body and having a passage adapted to receive fluid from the drill string; coengageable expander means on said mandrel and cutter means for expanding said cutter means in response to relative longitudinal movement between said body and mandrel; said body having a chamber into which said mandrel discharges fluid; and a generally radial nozzle secured to said body and communicating with said chamber to receive fluid therefrom and discharge said fluid against the wall of the bore hole.

7. The method of conditioning a bore hole, comprising lowering cutting and fluid jetting apparatus in the bore hole on a tubular drill string, said apparatus being adapted to jet fluid substantially radially of the bore hole and predominantly against the wall thereof, rotating the drill string and apparatus to perform a cutting opera-

tion in the bore hole and to expose the wall of the bore hole to a desired longitudinal extent, then pumping a fluent material down the drill string and jetting the fluent material substantially radially and predominantly against the exposed wall of the bore hole while rotating the drill string and apparatus, and elevating the drill string to elevate the apparatus along the exposed wall of the bore hole while the fluent material is being jetted against the wall of the bore hole.

8. The method of conditioning a bore hole, comprising lowering cutting and fluid jetting apparatus in the bore hole on a tubular drill string, said apparatus being adapted to jet fluid substantially radially of the bore hole and predominantly against the wall thereof, rotating the drill string and apparatus to perform a cutting operation in the bore hole and to expose the wall of the bore hole to a desired longitudinal extent, and then pumping cementitious material down the drill string and jetting the cementitious material substantially radially and predominantly against the exposed wall of the bore hole while rotating the drill string and apparatus.

9. The method of conditioning a bore hole, comprising lowering cutting and fluid jetting apparatus in the bore hole on a tubular drill string, said apparatus being adapted to jet fluid substantially radially of the bore hole and predominantly against the wall thereof, rotating the drill string and apparatus to perform a cutting operation in the bore hole and to expose the wall of the bore hole to a desired longitudinal extent, then pumping cementitious material down the drill string and jetting the cementitious material substantially radially and predominantly against the exposed wall of the bore hole while rotating the drill string and apparatus, and elevating the drill string to elevate the apparatus along the exposed wall of the bore hole while the cementitious material is being jetted against the wall of the bore hole.

10. The method of conditioning a bore hole, comprising lowering cutting and fluid jetting apparatus in the bore hole on a tubular drill string, said apparatus being adapted to jet fluid substantially radially of the bore hole and predominantly against the wall thereof, rotating the drill string and apparatus to perform a cutting operation in the bore hole and to expose the wall of the bore hole to a desired longitudinal extent, then pumping a fluent material down the drill string and jetting the fluent material substantially radially and predominantly against the exposed wall of the bore hole while rotating the drill string and apparatus to enlarge the diameter of the bore hole, and then pumping cementitious material down the drill string and jetting the cementitious material substantially radially and predominantly against the exposed wall of the enlarged bore hole while rotating the drill string and apparatus to form a cementitious plug therein.

11. The method of conditioning a bore hole, comprising lowering cutting and fluid jetting apparatus in the bore hole on a tubular drill string, said apparatus being adapted to jet fluid substantially radially of the bore hole and predominantly against the wall thereof, rotating the drill string and apparatus to perform a cutting operation in the bore hole and to expose the wall of the bore hole to a desired longitudinal extent, then pumping a fluent material down the drill string and jetting the fluent material substantially radially and predominantly against the exposed wall of the bore hole while rotating the drill string and apparatus to enlarge the diameter of the bore hole, then pumping cementitious material down the drill string and jetting the cementitious material substantially radially and predominantly against the exposed wall of the enlarged bore hole while rotating the drill string and apparatus to form a cementitious plug therein, and elevating the drill string to elevate the apparatus along the exposed wall of the enlarged bore hole while the cementitious material is being jetted against the wall of the enlarged bore hole.

12. The method of conditioning a bore hole having a conduit therein, comprising lowering cutting and fluid jetting apparatus in the bore hole on a tubular drill string, said apparatus being adapted to jet fluid substantially radially and predominantly against the wall of the bore hole, rotating the drill string and apparatus to cut the conduit away along a desired length in the bore hole to expose the surrounding wall of the bore hole, and then pumping a fluent material down the drill string and jetting the fluent material substantially radially and predominantly against the exposed wall of the bore hole while rotating the drill string and apparatus.

13. The method of conditioning a bore hole having a conduit therein, comprising lowering cutting and fluid jetting apparatus in the bore hole on a tubular drill string, said apparatus being adapted to jet fluid substantially radially and predominantly against the wall of the bore hole, rotating the drill string and apparatus to cut the conduit away along a desired length in the bore hole to expose the surrounding wall of the bore hole, then pumping a fluent material down the drill string and jetting the fluent material substantially radially and predominantly against the exposed wall of the bore hole while rotating the drill string and apparatus, and elevating the drill string to elevate the apparatus along the exposed wall of the bore hole while the fluent material is being jetted against the wall of the bore hole.

14. The method of conditioning a bore hole having a conduit therein, comprising lowering cutting and fluid jetting apparatus in the bore hole on a tubular drill string, said apparatus being adapted to jet fluid substantially radially and predominantly against the wall of the bore hole, rotating the drill string and apparatus to cut the conduit away along a desired length in the bore hole to expose the surrounding wall of the bore hole, and then pumping cementitious material down the drill string and jetting the cementitious material substantially radially and predominantly against the exposed wall of the bore hole while rotating the drill string and apparatus.

15. The method of conditioning a bore hole having a conduit therein, comprising lowering cutting and fluid jetting apparatus in the bore hole on a tubular drill string, said apparatus being adapted to jet fluid substantially radially and predominantly against the wall of the bore hole, rotating the drill string and apparatus to cut the conduit away along a desired length in the bore hole to expose the surrounding wall of the bore hole, then pumping cementitious material down the drill string and jetting the cementitious material substantially radially and predominantly against the exposed wall of the bore hole while rotating the drill string and apparatus, and elevating the drill string to elevate the apparatus along the exposed wall of the bore hole while the cementitious material is being jetted against the wall of the bore hole.

16. The method of conditioning a bore hole having a conduit therein, comprising lowering cutting and fluid jetting apparatus in the bore hole on a tubular drill string, said apparatus being adapted to jet fluid substantially radially and predominantly against the wall of the bore hole, rotating the drill string and apparatus to cut the conduit away along a desired length in the bore hole to expose the surrounding wall of the bore hole, then rotating the apparatus and moving the apparatus longitudinally in the bore hole to enlarge the diameter of the exposed bore hole, and pumping a fluent material down the drill string and jetting the fluent material substantially radially and predominantly against the exposed wall of the enlarged bore hole while rotating the drill string and apparatus.

17. The method of conditioning a bore hole having a conduit therein, comprising lowering cutting and fluid jetting apparatus in the bore hole on a tubular drill string, said apparatus being adapted to jet fluid substantially radially and predominantly against the wall of the bore hole, rotating the drill string and apparatus to cut the conduit away along a desired length in the bore hole to expose the surrounding wall of the bore hole, then rotating the apparatus and moving the apparatus longitudinally in the bore hole while jetting fluent material substantially radially and predominantly against the exposed wall of the well bore to enlarge the diameter of the exposed bore hole, and pumping another fluent material down the drill string and jetting another fluent material substantially radially and predominantly against the exposed wall of the enlarged bore hole while rotating the drill string and apparatus.

18. The method of conditioning a bore hole having a conduit therein, comprising lowering cutting and fluid jetting apparatus in the bore hole on a tubular drill string, said apparatus being adapted to jet fluid substantially radially and predominantly against the wall of the bore hole, rotating the drill string and apparatus to cut the conduit away along a desired length in the bore hole to expose the surrounding wall of the bore hole, rotating the apparatus and moving the apparatus longitudinally in the bore hole to enlarge the diameter of the exposed bore hole, and pumping cementitious material down the drill string and jetting the cementitious material radially and predominantly against the exposed wall of the enlarged bore hole while rotating the drill string and apparatus.

19. The method of conditioning a bore hole having a conduit therein, comprising lowering cutting and fluid jetting apparatus in the bore hole on a tubular drill string, said apparatus being adapted to jet fluid substantially radially and predominantly against the wall of the bore hole, rotating the drill string and apparatus to cut the conduit away along a desired length in the bore hole to expose the surrounding wall of the bore hole, rotating the apparatus and moving the apparatus longitudinally in the bore hole to enlarge the diameter of the exposed bore hole, pumping cementitious material down the drill string and jetting the cementitious material radially and predominantly against the exposed wall of the enlarged bore hole while rotating the drill string and apparatus, and elevating the drill string to elevate the apparatus along the exposed wall of the enlarged bore hole while the cementitious material is being jetted against the wall of the enlarged bore hole.

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