May 31, 1955 H. C. TRIMBLE ET AL 2,709,490

TOOL FOR SEVERING AND MILLING AWAY A SECTION OF CASING IN THE BORE OF A WELL

Filed Sept. 28, 1951

3 Sheets-Sheet 1

Fig 1.

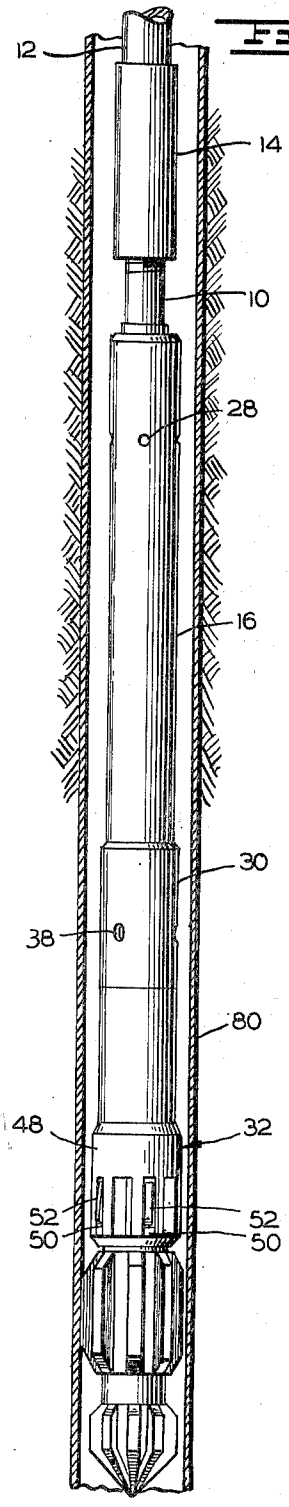


Fig 2A.

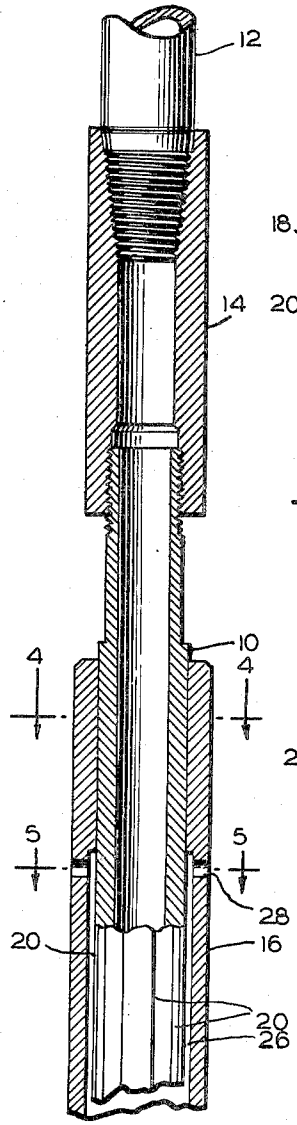


Fig 4.

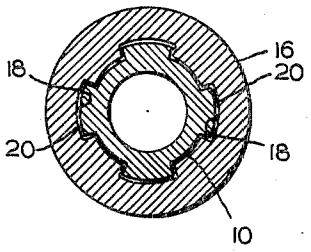
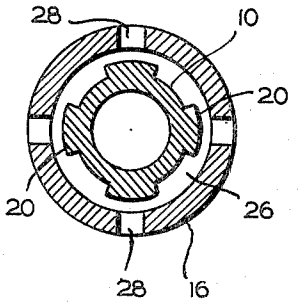


Fig 5.



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3 Sheets-Sheet 2

Fig 2a.

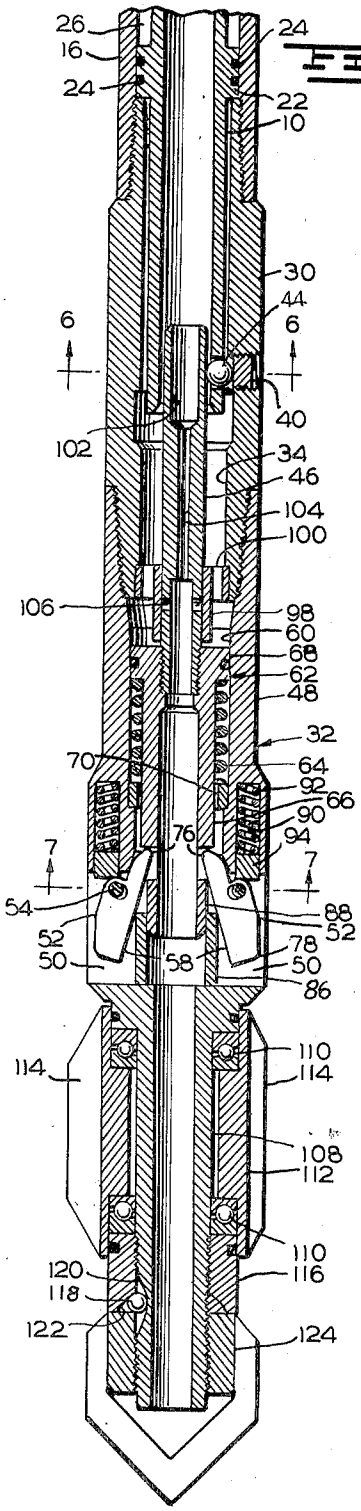

Fig 6.

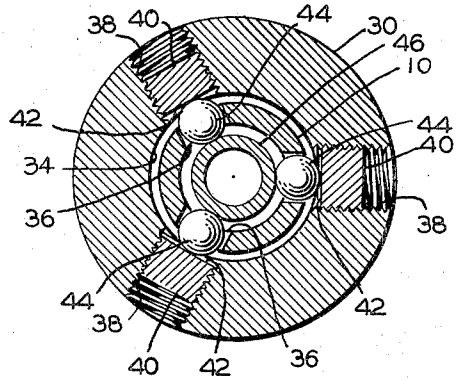

Fig 7.

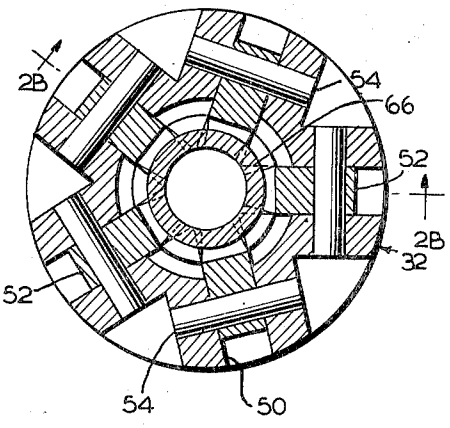

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Fig 8.

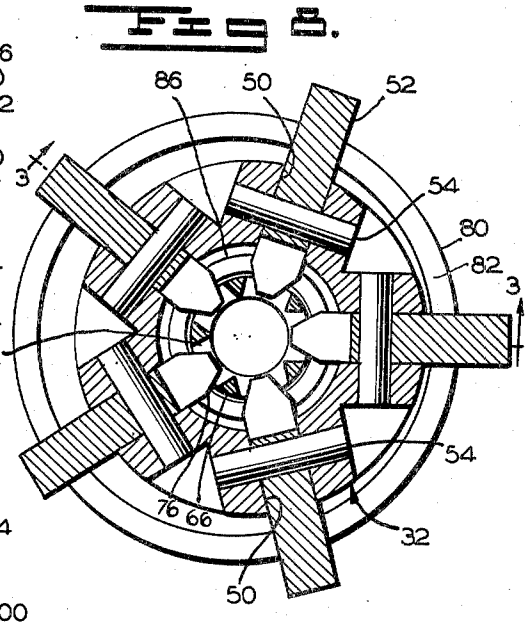
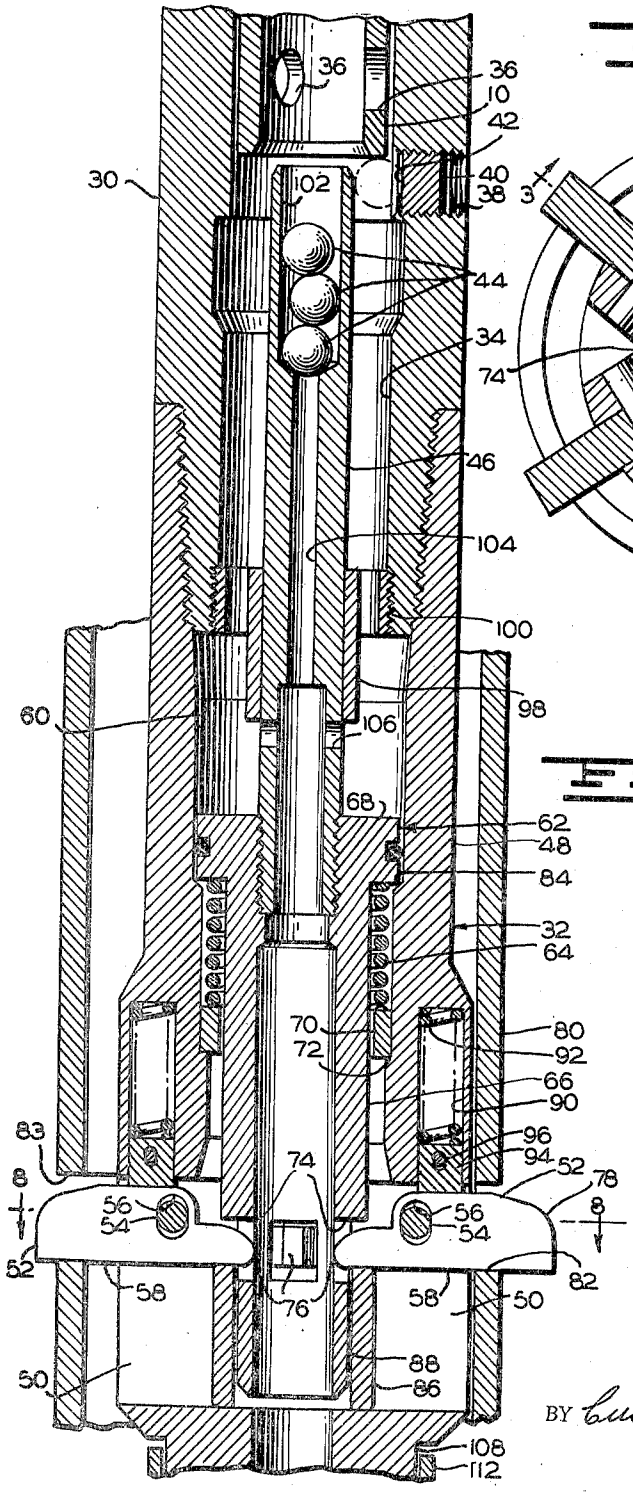


Fig 3.



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TOOL FOR SEVERING AND MILLING AWAY A SECTION OF CASING IN THE BORE OF A WELL

Harry C. Trimble, New Orleans, La., and Albert E. Woelfel, Houston, Tex., assignors to A-1 Bit & Tool Company, Incorporated, Houston, Tex., a corporation of Texas

Application September 28, 1951, Serial No. 248,702

14 Claims. (Cl. 164—0.8)

This invention relates to a casing mill, and more particularly to an improved milling tool for severing and milling away a section of the casing in the bore of a well.

In the production and operation of wells, and particularly oil wells, it is frequently necessary to remove a portion of the casing in the well at some predetermined location for various purposes, such as side tracking operations or to expose a producing stratum. Thus, it may be desirable to remove a section of the casing to allow a whipstock to be set in an open window, or to expose a sand stratum or other potentially productive formation which has been previously cased off.

Such operations frequently must be conducted at great depths in the well, which depth presents serious problems in both the character of the tools employed and the manner in which the operation is carried out. These problems arise principally because of the great weight of the operating string by which milling tools usually are operated and also because of frequent deviation of the bore of the well from the vertical.

Milling tools generally in use consist of a cutter head which is connectable to the lower end of a drill string for rotation thereby and has a plurality of cutters pivotally mounted for radial outward movement into cutting engagement with the casing. Means within the cutter head and operable by pressure of drilling fluid in the string are normally employed to move the cutters outwardly against the casing. After the cutters have been projected, the drill string is rotated to operate the cutters against the inner wall of the casing to sever the same, after which severance the cutters move further outwardly through the cut into milling engagement with an end of the severed casing. Continued rotation of the drill string combined with axial movement thereof then is employed to mill away a section of the casing.

The above described operation presents a serious problem in controlling the load on the cutters, both because of the tremendous weight of the drill string and the stretch therein when the milling operation is conducted at a great depth in the well. It can easily be seen that if the entire weight of the drill string is supported on the cutters, the latter are apt to be severely damaged by breakage or to wear too rapidly for practical purposes. In other words, accurate control of the pressure of the engagement of the cutters with the casing is extremely difficult from the mouth of the well.

In addition to the aforementioned problem arising with conventional casing mills, there is still another problem in maintaining all of the cutter blades in equally effective cutting engagement with the end of the casing. Although conventional casing mills are constructed with utmost precision, because of uneven wear of the several cutters and various dimensional and material imperfections in the construction of milling tools, the cutting edges of the cutters of casing mills heretofore in use cannot be maintained in a single transverse plane. The consequent result is that usually only one, or less than all, of the numerous cutters are effective at any one time so that the full benefit from the use of a plurality of cutters is not obtained.

Hence, it is an object of this invention to provide a casing mill of the type under consideration in which axial movement of the cutter head during a milling operation may be controlled without axial movement of the drill string.

It is another object of this invention to provide an improved casing mill in which the cutter head is mounted for axial movement on the end of a drill string, and such axial movement controlled at the mouth of the well by fluid pressure.

It is still another object of this invention to provide an improved casing mill in which the cutter head is mounted for axial movement on the end of the drill string, and such axial movement controlled by fluid pressure at the mouth of the well, but in which the cutter head is locked against such axial movement until the cutters have severed the casing and moved into milling engagement with a severed end thereof.

It is still another object of this invention to provide an improved casing mill in which the cutters are individually maintained in milling engagement with the severed end of a casing so that all of the cutters are equally effective at all times, with a consequent increase in milling rate.

It is a further object of this invention to provide an improved casing mill of simple and, consequently, relatively inexpensive construction for accomplishing the above objects.

Other objects and advantages of this invention will be apparent from the following description and accompanying drawings, in which:

Figure 1 is an elevational view of a casing mill embodying this invention showing the mill in position in a section of a cased bore hole.

Figures 2A and 2B are enlarged fragmentary elevational sectional views of upper and lower portions, respectively, of the milling tool shown in Figure 1. The section through the cutter head is taken, for purposes of illustration, on line 2B—2B of Figure 7.

Figure 3 is an enlarged fragmentary view of a portion of the milling tool shown in Figure 2B, with the cutters shown in the position of milling engagement with the severed end of a casing. The section through the cutter head is taken, for purposes of illustration, on line 3—3 of Figure 8.

Figures 4 and 5 are sectional views taken on the correspondingly numbered section lines of Figure 2A.

Figures 6 and 7 are enlarged sectional views taken on the corresponding section lines of Figure 2B.

Figure 8 is a sectional view taken on line 8—8 of Figure 3.

Referring now to the drawings, the improved casing mill embodying this invention comprises an elongated tubular mandrel 10 adapted to be connected to, supported from, and to receive pressure fluid from the lower end of a drill string 12 by a threaded coupling member 14. Telescoped over the mandrel 10 is a sleeve 16 having, for the major portion of its length, an inner diameter greater than the outer diameter of the mandrel. The upper portion of the sleeve 16, however, is extended inwardly into sliding engagement with the mandrel 10 and provided with longitudinal grooves 18 which receive corresponding longitudinal ribs 20 on, and extending substantially the full length of, the mandrel to form a splined joint. By means of this construction it will be seen that the sleeve 16 is rotatable with the mandrel 10, but axially movable with respect thereto. Adjacent its lower end, the mandrel 10 is provided with a piston-like annular enlargement 22 (see Figure 2B) having outer circumferential grooves in which O-ring packing 24 is disposed for sealing engagement with the inner wall of the sleeve 16. Thus, the

splined joint is sealed, and relative axial movement between the sleeve **16** and the mandrel **10** permitted, without hindrance from fluid in the chamber **26** therebetween, by lateral vent ports **28** in the sleeve immediately below the mandrel-engaging upper portion of the latter.

A threaded coupling **30** is secured to the lower end of the sleeve **16** and supports a cutter head **32** in spaced relation below the lower end of the mandrel **10**. The lower end of the mandrel **10** projects into the bore **34** of the coupling **30** and, adjacent its lower end, is provided with a circumferential series, three as shown in the drawings, of circular radial apertures **36**. A corresponding number of radial apertures **38** are provided in the coupling **30** and closed by threaded plugs **40** to provide a number of relatively shallow recesses **42** in the inner wall of the coupling **30**, such recesses being radially alignable with their corresponding apertures **36** in the mandrel.

Positioned in and substantially filling each corresponding pair of apertures **36** and recesses **42** is a ball detent **44** which serves to lock the mandrel **10** and the sleeve **16** against relative axial movement. A tubular member **46** projects upwardly from the cutter head **32** into the lower end of the mandrel **10** and engages the inner sides of all of the ball detents **44** to retain the latter within the apertures **36** and recesses **42** and thereby maintain the sleeve **16** and mandrel **10** locked against relative axial movement. It will be seen, however, that when the tubular element **46** is removed, the ball detents **44** may escape from their respective apertures and recesses and thereby permit relative axial movement between the mandrel and the sleeve. The means for effecting removal of the tubular detent-retaining member **46** will be described later.

The cutter head **32** comprises a tubular member **48** having a plurality (five as shown in the drawings) of longitudinally extending radial slots **50** through the side walls thereof. A cutter blade **52** is mounted in each slot **50** for radial outward movement by means of a pivot pin **54** anchored in the opposed side walls of the slot **50** and carrying the blade by means of an elongated bearing aperture **56** in the latter. Such bearing aperture **56** is elongated in a direction substantially normal to the milling edge **58** of the blades **52**, for reasons later described. The interior of the upper portion of the cutter head **32** forms a cylinder **60** in which a tubular piston **62** is mounted for reciprocation axially of the cutter head. The piston **62** is spring-biased into an upward position by means of a coil spring **64** disposed between a reduced portion **66** of the piston and the cylinder wall **60** and bearing against the underside of the piston head **68** and an abutment ring **70** seated on a shoulder **72** formed in the bore of the cutter head below the cylinder **60**. The reduced portion **66** of the piston extends downwardly and has a plurality of radial apertures **74** which somewhat loosely receive the inwardly-extending tapered operating tongues **76** of the cutter blades **52**.

From this construction it will be seen that when the piston **62** is in the position shown in Figure 2B, the cutter blades are retracted within the slots, but that when the piston moves downwardly, under the influence of fluid pressure from the drill string **12** as later described, the cutters are pivoted about the pins **54** so that their outer severing edges **78** move outwardly into engagement with the inner wall of the casing **80**. Rotation of the drill string **12** then serves to cut a groove in the inner wall of and subsequently to sever the casing **80**. After the casing has been severed, the cutters **52** are moved further outwardly, by the piston **62**, until their milling edges **58** are in milling engagement with the end **82** of the severed casing **80**, as shown in Figure 3. The piston **62** is stopped at the end of its cutter projecting movement by engagement of its head **68** with a shoulder **84** formed in the cutter head bore at the lower end of the cylinder **60**. In this position of the piston the cutter tongues **76** are free of engagement with the upper and lower sides of the apertures **74**, but instead engage with the upper edge of an annular guide ring **86** for the reduced lower end **88** of the operating extension **66** of the piston **62**. In this position of the cutters, the elongated bearing slot **56** renders the pivot pins **54** inoperative so that the cutters **52** are fulcrumed about the upper edge of the annular guide ring **86**.

At the upper end of each slot **50**, the cutter head **32** is provided with a longitudinal bore **90** in which is mounted a spring **92** bearing against the base of the bore **90** and a follower **94** that is engaged with the back of each cutter blade **52**. The followers **94** are retained within the bores **90** by means of transverse retaining pins **96** passing through elongated openings in the followers and having their ends anchored in the bore side walls, as shown best in Figure 3. The action of the springs **92** is to hold each cutter blade **52** against the end edge **82** of the casing **80** so that all of the cutters are simultaneously, and uniformly, effective in their milling action. It will be seen that by fulcruming the cutter blades **52** on the guide ring **86**, instead of on their pivot pins **54**, an increased mechanical advantage is obtained. As a result of this construction an increased milling rate, from three to five times greater than conventional casing mills, is obtained.

The tubular detent retaining member **46** extends through a central sleeve **98** of a spider-like guide element **100**, threaded into the lower end of the coupling **30**, and is threaded into the upper end of the piston **62**. The length of the detent retaining member **46** is so proportioned that when the piston **62** has moved downwardly into position to project the cutter blades **52** into their milling position, the upper end of the member **46** clears the ball detents **44** sufficiently to permit the latter to drop, or be forced out of, their corresponding apertures **36** and recesses **42** and fall into a cup-like upper enlarged portion **102** of the bore through the retaining member. Thus the sleeve **16** and mandrel **10** are released for relative axial movement.

The cutter blade projecting movement of the piston **62** is effected by means of fluid pressure from the drill string **12** which passes between the mandrel **10** and detent-retaining member **46**, through the guide element **100**, and into the cylinder **60** to act on the upper surface of the piston **62**. In this connection it will be noted that although the fluid pressure may also pass through the bore of the tubular detent-retaining member **46** and through the bore of the tubular piston **62** for escape outwardly through the apertures **74** and slots **50** to both lubricate the cutters **52** and carry away cuttings, the bore of the detent retaining member has a somewhat restricted throat portion **104** so that sufficient fluid pressure may be built up within the cylinder **60** to force the piston **62** downwardly. It also will be noted that even though the bore of the member **46** may be closed by the seating of a detent ball **44** against the upper end of the throat portion **104**, as shown in Figure 3, lateral ports **106** are provided in the detent-retaining member, that are normally closed by the sleeve **98** of the spider-like guiding element **100**. In the position of the parts shown in Figure 3, however, these ports **106** are uncovered to permit drill fluid to pass inwardly therethrough and continue to flow downwardly through the tubular piston **62** in order to provide the aforementioned lubricating and cuttings disposal action.

In operation, the apparatus is connected to a drill string **12** and run into a cased bore hole to the desired depth. Fluid pressure is then applied through the string **12** to force the piston **62** down and move the cutter blades **52** into severing engagement with the casing **80**. Rotation of the string **12** then serves to sever the casing **80** at the selected depth, whereupon the cutter blades **52** move through the resulting annular aperture and into milling engagement with a severed end **82**. Simultaneously the mandrel **10** and sleeve **16** are unlocked by the release of the ball detents **44**. Continued rotation of

the string 12 then serves to rotate the cutters 52 against the casing edge 82 to mill away the same, while fluid pressure from the drill string acts against the piston 62 and the annular enlargement 22 on the mandrel 10 to effect axial movement between the sleeve 16 and the mandrel and to thereby move the cutter head 32 downwardly to maintain the cutter blades 52 in engagement with the edge 82 of the casing section being milled away. Of course, the fluid pressure necessary to accomplish such downward movement of the cutter head has an equal and opposite reaction tending to cause upward movement of the drill string. Since the latter is of great weight, however, such fluid pressure is insufficient to raise the same and instead, the cutter head is moved downwardly. The pressure with which the blades 52 bear against the casing 80 is accurately controlled from the surface by controlling the fluid pressure in the string 12. Obviously, the mandrel 10 and sleeve 16 may be made as long as practical for milling away casing sections of any desired length.

After the casing section has been removed, the drill string pressure is reduced to permit retraction of the cutter blades 52 by upward movement of the piston 62 by the spring 64. The string and tool are then withdrawn from the well. In the event the blades 52 stick in their projected position or the spring is not strong enough to retract them, the backs of the blades will engage the edge 83 of the severed casing, upon withdrawal of the string, and be deflected thereby back into their slots 50.

The cutter head 32 preferably is provided with a depending reduced tubular extension 108 on which is rotatably mounted, by means of anti-friction bearing assemblies 110, an eccentric guiding assembly 112. This assembly 112 is provided with a circumferential series of longitudinally extending ribs 114, the outer surfaces of which lie in a cylindrical surface that is eccentric with respect to the axis of the cutter head 32. The guiding assembly 112 is held in place by means of a nut 116 that is locked in position by a ball detent 118 received in radially aligned grooves 120 and 122 in the outer surface of the extension and the inner surface of the nut, respectively. The ball detent 118 may be held in place by a conical ribbed guiding cap 124 threaded onto the lower end of the cutter head extension 108. In operation, the ribs 114 of the guiding assembly 112 engage the inner wall of the casing 80, as shown in Figure 1, and serve to maintain the cutter head 32 in position to rotate about an axis that is off-center with respect to the axis of the casing 80, to thereby achieve, in effect, a simultaneously reciprocating and rotating movement of the blades 52 in order to effectively utilize their entire milling edge 53 and prevent grooving of the same. The eccentric guiding assembly 112 and its function are described more fully in detail in the copending application of Earl J. Robishaw, Serial No. 157,533, filed April 22, 1950, now Patent No. 2,690,217. Also, a considerable portion of the drilling fluid escapes, via the extension 108, into the casing below the tool. This fluid returns to the surface upwardly between the tool and the casing to aid in the cuttings' disposal.

It will thus be seen that the purposes of this invention have been effectively accomplished. It will be realized, however, that the specific embodiment of a casing mill, used to illustrate the principles of this invention, may be changed without departing from the principles of the invention. Therefore, this invention includes all modifications which are encompassed by the spirit and scope of the following claims.

We claim:

1. A tool for severing the casing of a cased bore hole and milling away a section thereof comprising: a cutter head; means for connecting said head to a drill string for rotation therewith and for axial movement relative thereto; means for locking said connecting means against said axial movement; at least one cutter mounted on said head for outward radial movement into severing and subsequent milling engagement with the casing; means for moving said cutter outwardly; and means operable by said cutter moving means for unlocking said locking means upon severance of the casing and movement of said cutter into milling engagement with a severed end thereof.

2. A tool for severing the casing of a cased bore hole and milling away a section thereof comprising: a cutter head; means for connecting said head to a drill string for rotation therewith and for axial movement relative thereto, said connecting means including means operable by drill string fluid pressure for forcefully effecting said axial movement; means for locking said connecting means against said axial movement; at least one cutter mounted on said head for outward radial movement into severing and subsequent milling engagement with the casing; means operable by drill string fluid pressure for effecting said radial cutter movement; and means operable by said last-mentioned fluid pressure means for unlocking said locking means upon severance of the casing and movement of said cutter into milling engagement with a severed end thereof.

3. The structure defined in claim 2 including resilient means urging the cutter for inward radial movement.

4. A tool for severing the casing of a cased bore hole and milling away a section thereof comprising: a cutter head; splined means for connecting said head to a drill string for rotation therewith and axial movement relative thereto, said connecting means including a fluid passageway therethrough to communicate with the drill string for forcefully effecting said axial movement by application of fluid pressure through the drill string; means for locking said connecting means against said axial movement including at least one detent positionable in radially aligned apertures in relatively movable elements of said splined means; at least one cutter mounted on said head for outward radial movement into severing and subsequent milling engagement with the casing; movable means in said head engageable with said cutter and operable by drill string fluid pressure for effecting said outward cutter movement; and retaining means carried by said cutter moving means and engageable with said detent for retaining the latter in said apertures until said cutter has severed the casing and moved into milling engagement with a severed end thereof.

5. A tool for severing the casing of a cased bore hole and milling away a section thereof comprising: a cutter head having a cylinder therewithin and at least one cutter mounted thereon for outward radial movement into severing and subsequent milling engagement with the casing; spring-biased piston means within said cylinder and engageable with said cutter for effecting said outward movement; a tubular mandrel connectable to a drill string; a sleeve sealingly splined to said mandrel and carrying said cutter head for rotary movement with the drill string and axial movement relative thereto, said sleeve and mandrel serving to conduct fluid from the string to said cylinder; means for locking said mandrel and said sleeve in their fully telescoped position against relative axial movement, said locking means including at least one radial aperture in said mandrel alignable with a shallow recess in the inner wall of said sleeve and a ball detent substantially filling said aperture and recess; and rod-like means secured to said piston means and extending into said mandrel in position to engage and retain said ball detent in locking position, said rod-like means being disengaged from said detent to release the latter for movement from locking position upon movement of said piston means into position for effecting milling engagement of said cutter with the casing, whereupon relative axial movement between said cutter head and the drill string may be effected by drill string fluid pressure to move the cutter against the casing during the milling operation.

6. In a tool rotatable by a drill string for severing the

casing of a cased bore hole and milling away a section thereof, and having a cutter head, a plurality of cutters pivotally carried by said head for outward projection into cutting relation with the casing to first sever the same and then mill away a section thereof by axial movmeent of the head, the combination of spring means carried by the head and engaging the back of each said cutter at a longitudinal location between its pivotal mounting and its effective milling edge to individually maintain each said cutter in milling engagement with the end of the severed casing.

7. A tool rotatable by a drill string for severing the casing of a cased bore hole and milling away a section thereof, said tool comprising: a cutter head connectable to a drill string for rotation therewith; a plurality of cutters pivotally mounted in said head for radial outward movement into cutting engagement with the casing, each said mounting comprising a pivot pin passing through an elongated bearing opening in the corresponding cutter, the direction of elongation of said opening being normal to the milling edge of the cutter; fluid-pressure-operable means within said head engageable with the inner ends of said cutters to effect said outward movement; abutment means on said head engageable by said inner ends at the end of their pivotal movement and constituting a fulcrum point therefor; and a spring interposed between said head and the back of each said cutter at a location between the ends thereof for individually maintaining each cutter in milling engagement with the end of the casing after severance thereof.

8. Apparatus for severing the casing of a cased bore hole and milling away a section thereof comprising: an operating string having upper and lower sections; means for connecting said lower section to said upper section for rotation therewith and for axial movement relative thereto; a cutter head carried by said lower section; at least one cutter mounted on said head for outward projection into severing and subsequent milling engagement with the casing; means for projecting said cutter; means for locking said connecting means against said axial movement while severing the casing; and means for automatically unlocking said locking means as said cutter moves into milling position after the casing has been severed to release said operating string lower section for movement of said cutter head carried thereby longitudinally of the casing while milling the latter.

9. Apparatus for severing the casing of a cased bore hole and milling away a section thereof comprising: a tubular operating string having upper and lower sections; means for connecting said lower section to said upper section for rotation therewith and for axial movement relative thereto, said connecting means including means operable by fluid pressure for forcefully effecting said axial movement; a cutter head carried by said lower section; at least one cutter mounted on said head for outward projection into severing and subsequent milling engagement with the casing; means for projecting said cutter; means for locking said connecting means against said axial movement while severing the casing; and means for automatically unlocking said locking means when said cutter moves into milling position after the casing has been severed to release said operating string lower section for axial movement by said fluid pressure means to move said cutter head longitudinally of the casing while milling the latter.

10. Apparatus for severing the casing of a cased bore hole and milling away a section thereof comprising: a tubular operating string having upper and lower sections; means for connecting said lower section to said upper section for rotation therewith and for axial movement relative thereto; a cutter head carried by said lower section; at least one cutter mounted on said head for outward projection into severing and subsequent milling engagement with the casing; means operable by fluid pressure for effecting said cutter projection; means for locking said connecting means against said axial movement while severing the casing; and means operable by said fluid-pressure means for unlocking said locking means after the casing has been severed to release said lower section for movement of said cutter head carried thereby longitudinally of the casing while severing the latter.

11. In a milling tool for operation against the end of a tubular casing and having a cutter head provided with a circumferential series of cutters extending generally radially thereof and having cutting edges facing generally longitudinally of the tool for substantially simultaneous engagement with the casing end, the combination of means mounting each cutter on the head for independent movement relative thereto in directions extending generally longitudinally thereof, and resilient means interposed between each of the cutters and a separate part of the head for individually yieldingly limiting said relative movement of each cutter in a direction opposite that faced by its cutting edge in order to individually maintain the cutters in engagement with the work.

12. The structure defined in claim 11 in which the resilient means comprises a spring.

13. In a tool rotatable by a drill string for severing the casing of a cased bore hole and milling away a section thereof, and having a cutter head carrying a plurality of cutters mounted for generally radial outward projection into cutting relation with the casing, the cutters having end cutting edges to first sever the casing and intermediate cutting edges substantially simultaneously engageable, by additional outward projection, with the severed end edge of the casing to mill away a section thereof by axial movement of the head, the combination of means mounting each cutter on the head for generally longitudinal independent movement relative thereto when in milling position, and resilient means mounted on the head and engaged with each cutter for individually urging the latter in the direction faced by its intermediate cutting edge to maintain each cutter in milling engagement with the severed casing end.

14. In a milling tool for operation against the end of a tubular casing to mill away a section thereof and carrying a circumferential series of cutters, having cutting edges facing generally longitudinally of the tool and adapted to bear substantially simultaneously against the casing end edge, the combination of means mounting each cutter on the tool for individual movement generally longitudinally of the tool, and means mounted on the tool and bearing against each cutter for yieldably resisting movement thereof in a direction opposite that faced by its cutting edge, as urged by the longitudinal reaction force on each cutter caused by longitudinal movement of the tool against the casing end, in order to maintain the cutters in cutting engagement with the casing end edge.

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