Oct. 10, 1961 C. H. LEATHERS ET AL 3,003,559

SECTION MILL

Filed Dec. 21, 1959

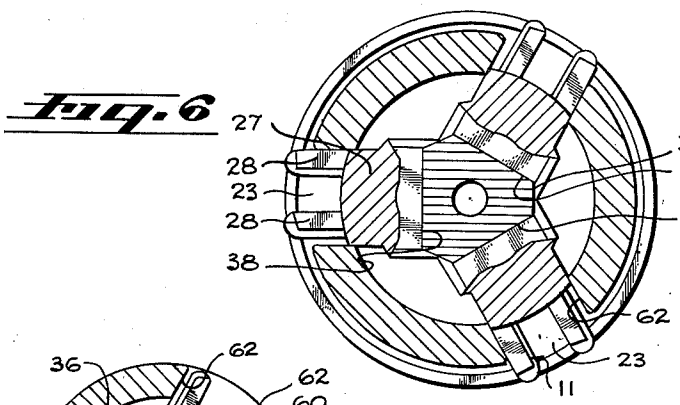


Fig. 6

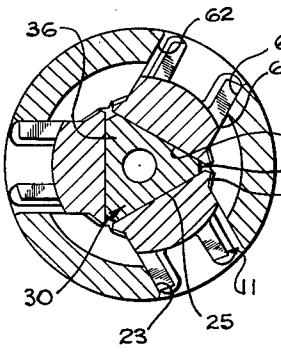


Fig. 5

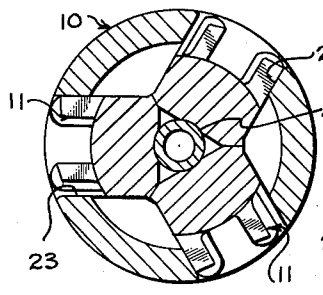


Fig. 4

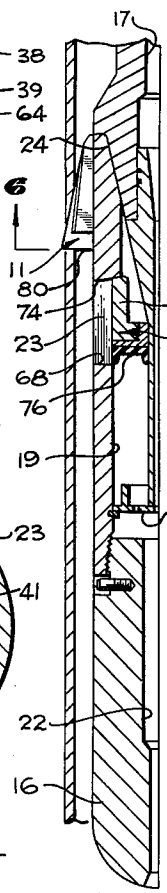


Fig. 3

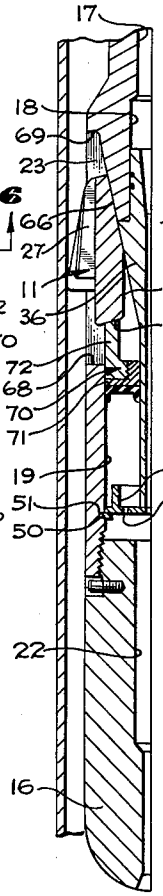


Fig. 2

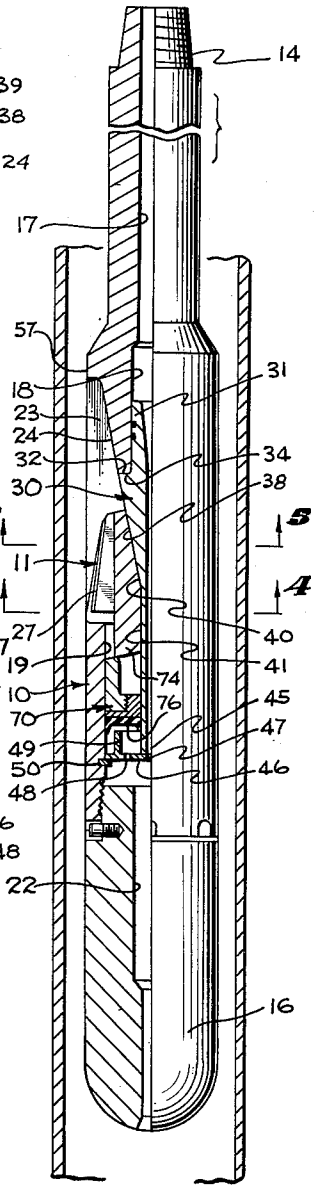


Fig. 1

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SECTION MILL

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This invention relates to oil well tools and more particularly to an expansible cutter tool such as an oil well casing mill.

The casing mill tool of the present invention is of the type which includes generally a tool body to be lowered into a well and a number of cutter members which are expansibly mounted within the body for radial movement therefrom. The cutters are actuated in their radial movement by and in response to axial movement of a member within the body.

Under various circumstances it is necessary to remove a section of the casing in a well at a predetermined location and for a considerable length. Since the casing is steel pipe or tubing the removal is usually accomplished by milling or cutting away the section by rotation of a casing or section mill. In order to mill out a section of casing at a predetermined depth, it is necessary to lower the tool, with the cutter elements retracted, into the casing to the desired location, at which point the tool is rotated and the cutter elements are expanded into cutting engagement with the inner surface of the casing. By rotating the tool at a substantially constant depth the cutter elements, under outward pressure, pierce the casing and the section to be removed is then milled away by rotating the cutter under downward force upon the exposed end of the casing. It will be appreciated that the force with which the cutters are expanded against the casing wall must be sufficient to cause the cutters to pierce the wall in a reasonable length of time. In addition, the cutters, after piercing the casing, must remain in a fully expanded position and must be of sufficient strength and durability to mill through an extensive length of steel casing.

Accordingly, it is an object of the present invention to provide an expansible casing mill in which the cutter elements are moved radially outward with a maximum amount of force.

It is another object of the present invention to provide an expansible cutter casing mill which provides positive expansion and retraction of the cutters.

It is a further object of the present invention to provide an expansible casing mill in which the cutters are mounted in radial-axial planes and moved outward in the radial direction by means of a mandrel having a tapered surface coacting with an inner surface of the cutters.

It is further object of the present invention to provide an expansible casing mill in which radially extensible cutters are moved radially outward from the tool body by means of hydraulic pressure within the body with sufficient force to pierce the wall of the casing.

The expansible casing mill, in accordance with the present invention comprises a tubular body having three casing cutter members mounted circumferentially spaced about the body in radial slots therein for longitudinal radial movement with respect to the body along radial-axial planes thereof. The cutters each have an upwardly and outwardly extending inner guide surface in co-operatively guiding relationship with a similarly upwardly and outwardly tapered surface of the tool body. A piston is axially movable within the body in response to fluid pressure at the lower surface thereof. The piston is positioned beneath the lower end of each of the cutter members in bearing contact therewith, such that upward movement of the piston causes the cutters to be moved

upward and outward along the tapered surface of the body.

The novel features which are believed to be characteristic of the invention both as to its organization and method of operation together with further objects and advantages thereof will be better understood from the following description considered in connection with the accompanying drawing in which a presently preferred embodiment of the invention is illustrated by way of example. It is to be expressly understood, however, that the drawing is for the purpose of illustration and description only and is not intended as a definition of the limits of the invention.

FIGURE 1 is a view in elevation partly in section showing the present invention in position within the section of casing with the cutter members retracted into the tool body;

FIGURE 2 is a partial view corresponding to FIGURE 1 showing the cutter members expanded into cutting engagement with the inner wall of the casing;

FIGURE 3 is a view corresponding to FIGURE 1 showing the cutter members in fully expanded position after the wall of the casing has been pierced preliminary to milling away a longitudinal portion thereof;

FIGURE 4 is a view in section taken along line 4—4 of FIGURE 1;

FIGURE 5 is a view in section taken along line 5—5 of FIGURE 1; and

FIGURE 6 is a view in section taken along line 6—6 of FIGURE 3.

Referring now to the drawing a presently preferred embodiment of the present invention is shown and includes in general terms a body 10, a plurality of cutter members 11, and a mandrel and piston contained within the body. The mandrel is stationary with respect to the body while the piston is longitudinally movable therein with respect to the mandrel and the inner wall of the body. The body is tubular and has a customary upper threaded box end or pin end 14 which may be screwed into a service or tool joint for connection with the drill string. The lower end of the body may be formed to carry a guide or piloting means such as a bullnose 16 of the type well known to the art. The body 10 is formed with a succession of counterbores 17, 18, and 19, the latter of which communicates with a fluid passage 22 for the circulation of fluid through the tool. A plurality of radial slots 23 extend through the wall of body 10 to receive the cutters as described hereinafter. The radial slots are of sufficient length to accommodate the longitudinal movement of the cutters as they are radially moved with respect to the body as will become more apparent hereinafter.

The plurality of casing cutters 11 are circumferentially spaced about the body and are slidably mounted with respect to the body upon tapered surfaces 24 and 38 in the body and mandrel respectively. The cutters are mounted in radial-axial planes and are mounted to move radially and longitudinally in those planes. The cutter members 11 in this embodiment are formed as shown with a cutting section 27 divided into a plurality of fingers or blades 28 to utilize the maximum cutting surface and number of cutting edges. The cutting surfaces are formed of hardened material such as tungsten carbide in a metal matrix.

Contained within the body 10 is a mandrel designated generally as 30 which includes a cylindrical section 31 having an outside diameter substantially equal to the inside diameter of the body at the counterbore 18. An outwardly extending shoulder 32 is formed at the lower end of the cylindrical section 31 and is mateable and in bearing contact with a shoulder 34 beneath the counterbore of the body. Extending downwardly from the shoul-

der 32 the mandrel has a non-cylindrical inwardly and downwardly tapered section 36 which is generally hexagonal in configuration with three sides 38 of the hexagon being of substantially equal width throughout the inward and downward length of the tapered section 36. Thus, as shown in FIGURES 5 and 6, the hexagonal shape of the mandrel throughout the tapered section is generally six sided but with alternate ones of the six sides forming the bearing surface for each of the cutters and therefore remaining substantially constant in width. Accordingly, the sides 38 between the bearing sides decrease in width as the cross-sectional area of the tapered section 36 becomes smaller. That is, near the shoulder 32 the sides 39 of the hexagon will be substantial in width but near the lower end 40 of the guide surfaces 38 the alternate sides 39 will become smaller until the cross-sectional configuration of the tapered section 36 approaches a triangle. Beneath the lower end of the hexagonal tapered section 36 of the mandrel 30 the mandrel assumes the cylindrical configuration of a wash-pipe 41. A bore is provided throughout the length of the mandrel to allow the passage of fluid therethrough. At the lower end 47 of the mandrel 30 a base plate 46 is positioned substantially transverse to the wash-pipe 41 and affixed thereto with an outside diameter substantially equal to the inside diameter of the body 10 and the counterbore 19. Base plate 46 has an opening 47 coextensive with the longitudinal opening through the mandrel and in addition has a plurality of openings 48 spaced circumferentially at a radius approximately midway between the center line of the mandrel and the outside diameter of the plate. An upstanding cylindrical wall 49 is formed on the base plate and a lock ring 50 is provided in a groove 51 formed in the inside wall of the body and the counterbore. Thus, the mandrel 30 can be inserted in position in the body 10 by inserting it through the lower end of the body with the bullnose removed such that the cylindrical portion 31 moves into contact with the counterbore 18 and the shoulder 32 of the mandrel abuts the shoulder 34 of the body after which the lock ring 50 is positioned to retain the mandrel at the proper location. It should be noted that the tapered surfaces 38 are coextensive with similarly tapered surfaces 24 on the body which forms the bearing wall of the radial slots of the body. That is, the slots are formed between that section of the body at the counterbore 18 and the section of the body at the counterbore 19 such that the slots extend to the shoulder 34 from the outside diameter 57 at a taper similar to the taper of the surfaces 38. Thus, with the mandrel in position as shown in the figures the tapered surfaces 24 and 38 are coextensive and form a bearing surface for the cutters as described hereinafter.

The cutters are formed such that their body sections are substantially rectangular in configuration with the distances between the surfaces 60 of each of the cutters being substantially equal to but less than the width of the slots 23 between the walls 62. The outer surface of the body of the cutter is, however, arcuate where mated with the toothed part of the cutter, while the lower or inner surface of the cutter, as shown in FIGURES 5 and 6, is flared outwardly to provide a shoulder 64 which is tapered and mateable with a similar taper at the base of the slots. That is, as shown in FIGURES 4, 5 and 6, the slots 23 are formed in the body extending outwardly from the counterbores 18 and 17 and are tapered inwardly and downwardly. An undercut is provided in the bearing wall 24 which undercut is mateable with the shoulder 64 on the blades. A portion 66 of the inner surface of the blades extending from the upper end thereof partially along the length of the blades is tapered to mate with the taper of the bearing surfaces 24 and 38. The lower portion 67 of the blade is substantially vertical. Accordingly, as shown in FIGURES 1, 2 and 3 when the blade is in its lowermost position at which the fingers rest on the shoulder 68 of the body the vertical portion of the blades is proximate the lower cylindrical surface 41 forming the wash-pipe section of the mandrel while the upper portion is in contact with the tapered surface 38 of the mandrel. As the blades moves upwards it rides in the slot and is maintained in position by the shoulder 64 and mating undercut. As shown particularly in FIGURE 2, as the blade progresses upward the vertical portion thereof is moved away from the lower cylinder 41 and extends away from the tapered surface 38. At its uppermost position as shown in FIGURE 3, the upper end of the blade is in bearing contact with the shoulder of the body at the upper end of the tapered surface 24.

Positioned beneath the blade in bearing contact therewith is a piston 70 which surrounds the lower cylindrical portion 41 of the mandrel and is movable longitudinally in the tool in sliding contact with the lower cylindrical portion 41 of the mandrel and the inner surface of the body at the counterbore 19. The piston 70 has a base portion 71 which is substantially transverse to the body with an upstanding flange 72 having an upper bearing surface 73 in contact with the lower bearing surface of the blades. The lower bearing surface 74 of the blade body and the upper bearing surface 73 of the piston are preferably tapered downwardly and outwardly with respect to the orientation of the tool body since the body of the cutter must slide across the bearing surface of the piston as it moves radially outward. Thus, as shown in FIGURE 1 at the lowermost position of the cutter the outer edge of the bearing surface 74 of the cutter overlaps the inner portion of the piston bearing surface 73, while at the upper position of the cutter the inner portion of the cutter bearing surface 74 is in contact with the outer portion of the piston bearing surface 73. A sealing means such as a gasket 76 is affixed to the lower surface of the piston to provide a fluid tight seal between the piston and the inner surface of the tool at the counterbore 19 and the outer surface of the cylindrical portion 41 of the mandrel.

Thus, it may be seen that fluid passing downward through the tool body along the fluid flow path defined by the counterbores passes outward through the lower end of the mandrel. A restriction is provided in the guide means or bullnose 16 which causes a pressure to build up in the body beneath the lower end 45 of the mandrel. Pressure then causes the fluid to pass through the openings 48 and into the chamber beneath the piston. Fluid pressure built up beneath the piston will force the piston upward, which in turn will force the cutters upward and outward.

In operation, the casing mill of the present invention is attached to a drill string in the customary manner and lowered into a cased well hole. At the predetermined depth in the casing at which the casing is to be cut away, circulation of fluid is begun and fluid under pressure is admitted into the bore of the tool from the drill string. A portion of the fluid escapes from the bore by passing through the openings 48 and into the fluid volume beneath the piston to exert an upward force on the piston and cutters as described hereinbefore. Rotation of the drill string and casing cutter without downward movement causes the outer radial surface of the cutters to cut through the wall of the casing. As the cut is made the cutters move radially outward until the wall of the casing has been completely pierced. At this point the piston and cutters reach the uppermost limit of their travel with the upper bearing surface in contact with the shoulder 69. The cutters are thus forced to a position which is fully expanded and the lower surface 80 of the cutter blades is approximately horizontal. With the lower surface of the cutter blades resting upon the exposed end of the casing as shown in FIGURES 3 and 6 of the drill string and tool are rotated and lowered to mill the casing under pressure. The downward force of the tool causes the cutter to be maintained in bearing contact with the shoulder.

After the desired length of casing has been milled away,

fluid circulation is stopped and the tool is raised out of the hole. As the tool is raised the cutters strike the end of the casing at which milling was begun and are forced downward to the retracted position.

Thus, the present invention provides an improved casing or section mill which is positive and efficient in operation and which pierces a casing and removes a section thereof in a minimum length of time.

What is claimed is:

1. An oil well casing mill comprising, in combination: a vertically extending elongate cylindrical body of a predetermined diameter, said body having an axial passageway therethrough formed by upper, intermediate and lower successive cylindrical counterbores of successively larger predetermined diameters, the junctions between adjacent counterbores forming horizontally extending shoulder surfaces, said body defining a plurality of longitudinal identical slots extending radially therethrough, said slots being evenly spaced around the periphery of said body and proceeding downwardly from the horizontal shoulder surface formed at the junction between said intermediate and lower counterbores, the uppermost portion of said body being adapted for connection to a drill string, the lowermost portion of said body being adapted for connection to guide means; an elongate mandrel rigidly mounted to said body within said intermediate and lower counterbores, said mandrel having an axial cylindrical bore therethrough, said mandrel defining an upper section and an intermediate section and a lower section, said upper section of said mandrel being of cylindrical configuration with a diameter substantially equal to said intermediate counterbore of said body, said intermediate section of said mandrel being of downwardly linearly tapered configuration with a polygonal cross-section having a number of sides equal to twice the number of slots in said body, alternate sides of the polygon being of equal and constant width throughout the taper of said intermediate mandrel section to thereby define a plurality of rectangular inclined bearing contact surfaces, each of said bearing contact surfaces being aligned opposite a slot in said body, the uppermost part of said intermediate section of said mandrel being of greater cross-sectional area than the cross-sectional area of said cylindrical upper section of said mandrel, the junction between said upper and intermediate sections of said mandrel forming a horizontally outwardly extending shoulder surface abutted in bearing contact with the horizontal shoulder surface formed by the junction between said intermediate and lower counterbores of said body, the lower section of said mandrel being of cylindrical configuration with a diameter substantially less than the diameter of the lower counterbore of said body; a plurality of identical casing cutter members having a longitudinal bearing surface adapted for sliding contact with said contact bearing surfaces of said mandrel and a longitudinally extending cutting edge and a substantially transverse cutting surface at the lower end thereof, said cutting members being disposed within said body with one each of said cutting members in alignment with a slot in said body and with its bearing surface in contact with said bearing contact surface of said mandrel; an annular base plate mounted to the bottom of said mandrel, the outer diameter of said base plate being substantially equal to the diameter of said lower counterbore in said body, the inner diameter of said base plate being substantially equal to the diameter of the axial bore through said mandrel, said base plate being mounted transversely to said mandrel with the central opening in said base plate in substantial alignment with the axial bore through said mandrel, said base plate defining a plurality of small circumferentially spaced openings extending therethrough; annular piston means slideably mounted within said body surrounding said cylindrical lower section of said mandrel above said base plate and below said cutting members, said piston means having an inside diameter substantially equal to the diameter of said cylindrical

lower section of said mandrel and an outside diameter substantially equal to that of said lower counterbore in said body, said piston means being adapted for fluid tight vertically sliding contact with said lower section of said mandrel and with said lower counterbore of said body; and, guide means coaxially detachably mounted to the bottom of said body, said guide means having an axial passageway therethrough communicating with the lower counterbore of said body and the axial bore through said mandrel to thereby provide a fluid passage through said casing mill, said guide means being adapted upon the flow of fluid through said casing mill to create a high fluid pressure area in said lower counterbore of said body below said piston means.

2. An oil well casing mill comprising, in combination: a vertically extending elongate cylindrical body of a predetermined diameter, said body having an axial passageway therethrough formed by upper, intermediate and lower successive cylindrical counterbores of successively larger predetermined diameters, the junctions between adjacent counterbores forming horizontally extending shoulder surfaces, said body defining a plurality of longitudinal identical slots extending radially therethrough, said slots being evenly spaced around the periphery of said body and proceeding downwardly from the horizontal shoulder surface formed at the junction between said intermediate and lower counterbores, the uppermost portion of said body being adapted for connection to a drill string, the lowermost portion of said body being adapted for connection to guide means; an elongate mandrel rigidly mounted to said body within said intermediate and lower counterbores, said mandrel having an axial cylindrical bore therethrough, said mandrel defining an upper section and an intermediate section and a lower section, said upper section of said mandrel being of cylindrical configuration with a diameter substantially equal to said intermediate counterbore of said body, said intermediate section of said mandrel being of downwardly linearly tapered configuration with a polygonal cross-section having a number of sides equal to twice the number of slots in said body, alternate sides of the polygon being of equal and constant width throughout the taper of said intermediate mandrel section to thereby define a plurality of rectangular inclined bearing contact surfaces, each of said bearing contact surfaces being aligned opposite a slot in said body, the uppermost part of said intermediate section of said mandrel being of greater cross-sectional area than the cross-sectional area of said cylindrical upper section of said mandrel, the junction between said upper and intermediate sections of said mandrel forming a horizontally outwardly extending shoulder surface abutted in bearing contact with the horizontal shoulder surface, formed by the junction between said intermediate and lower counterbores of said body, the lower section of said mandrel being of cylindrical configuration with a diameter substantially less than the diameter of the lower counterbore of said body; a plurality of identical casing cutter members having a longitudinal bearing surface adapted for sliding contact with said contact bearing surfaces of said mandrel and a longitudinally extending cutting edge and a substantially transverse cutting surface at the lower end thereof, said cutting members being disposed within said body with one each of said cutting members in alignment with a slot in said body and with its bearing surface in contact with said bearing contact surface of said mandrel; an annular base plate mounted to the bottom of said mandrel, the outer diameter of said base plate being substantially equal to the diameter of said lower counterbore in said body, the inner diameter of said base plate being substantially equal to the diameter of the axial bore through said mandrel, said base plate being mounted transversely to said mandrel with the central opening in said base plate in substantial alignment with the axial bore through said mandrel, said base plate defining a plurality of small circumferentially spaced

openings extending therethrough; annular piston means slideably mounted within said body surrounding said cylindrical lower section of said mandrel above said base plate and below said cutting members, said piston means having an inside diameter substantially equal to the diameter of said cylindrical lower section of said mandrel and an outside diameter substantially equal to that of said lower counterbore in said body, said piston means being adapted for fluid tight vertically sliding contact with said lower section of said mandrel and with said lower counterbore of said body; and, cylindrical guide means having a diameter substantially equal to the diameter of the lower section of said body and being coaxially detachably mounted thereto, said guide means having an axial passageway therethrough formed by upper and lower counterbores of successively smaller predetermined diameters, said axial passageway through said guide means being in communication with the lower counterbore of said body and with the axial bore through said mandrel to thereby provide a fluid passage through said casing mill and upon the flow of fluid therethrough to create a high fluid pressure area in said lower counterbore of said body below said piston means.

3. An oil well casing mill comprising, in combination: a vertically extending elongate cylindrical body of a predetermined diameter, said body having an axial passageway therethrough formed by upper, intermediate and lower successive cylindrical counterbores of successively larger predetermined diameters, the junctions between adjacent counterbores forming horizontally extending shoulder surfaces, said body defining three longitudinal identical slots extending radially therethrough, said slots being evenly spaced around the periphery of said body and proceeding downwardly from the horizontal shoulder surface formed at the junction between said intermediate and lower counterbores, the uppermost portion of said body being adapted for connection to a drill string, the lowermost portion of said body being adapted for connection to guide means; an elongate mandrel rigidly mounted to said body within said intermediate and lower counterbores, said mandrel having an axial cylindrical bore therethrough, said mandrel defining an upper section and an intermediate section and a lower section, said upper section of said mandrel being of cylindrical configuration with a diameter substantially equal to said intermediate counterbore of said body, said intermediate section of said mandrel being of downwardly linearly tapered configuration with a hexagonal cross-section, alternate sides of the hexagon being of equal and constant width, throughout the taper of said intermediate mandrel section to thereby define three rectangular inclined bearing contact surfaces, each of said bearing contact surfaces being aligned opposite a slot in said body, the uppermost part of said intermediate section of said mandrel being of greater cross-sectional area than the cross-sectional area of said cylindrical upper section of said mandrel, the junction between said upper and intermediate sections of said mandrel, forming a horizontally outwardly extending shoulder surface abutted in bearing contact with the horizontal shoulder surface formed by the junction between said intermediate and lower counterbores of said body, the lower section of said mandrel being of cylindrical configuration with a diameter substantially less than the diameter of the lower counterbore of said body; three identical casing cutter members having a longitudinally bearing surface adapted for sliding contact with said contact bearing surfaces of said mandrel and a longitudinally extending cutting edge and a substantially transverse cutting surface at the lower end thereof, said cutting members being disposed within said body with one each of said cutting members in alignment with a slot in said body and with its bearing surface in contact with said bearing contact surface of said mandrel; an annular base plate mounted to the bottom of said mandrel, the outer diameter of said base plate being substantially equal to the diameter of said lower counterbore in said body, the inner diameter of said base plate being substantially equal to the diameter of the axial bore through said mandrel, said base plate being mounted transversely to said mandrel with the central opening in said base plate in substantial alignment with the axial bore through said mandrel, said base plate defining a plurality of small circumferentially spaced openings extending therethrough; annular piston means slideably mounted within said body surrounding said cylindrical lower section of said mandrel above said base plate and below said cutting members, said piston means having an inside diameter substantially equal to the diameter of said cylindrical lower section of said mandrel and an outside diameter substantially equal to that of said lower counterbore in said body, said piston means being adapted for fluid tight vertically sliding contact with said lower section of said mandrel and with said lower counterbore of said body; and, cylindrical guide means having a diameter substantially equal to the diameter of the lower section of said body and being coaxially detachably mounted thereto, said guide means having an axial passageway therethrough formed by upper and lower counterbores of successively smaller predetermined diameters, said axial passageway through said guide means being in communication with the lower counterbore of said body and with the axial bore through said mandrel to thereby provide a fluid passage through said casing mill and upon the flow of fluid therethrough to create a high fluid pressure area in said lower counterbore of said body below said piston means.

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