

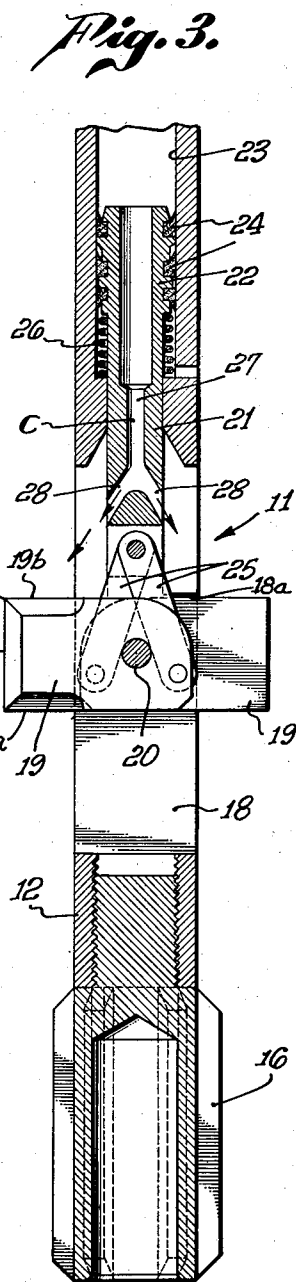
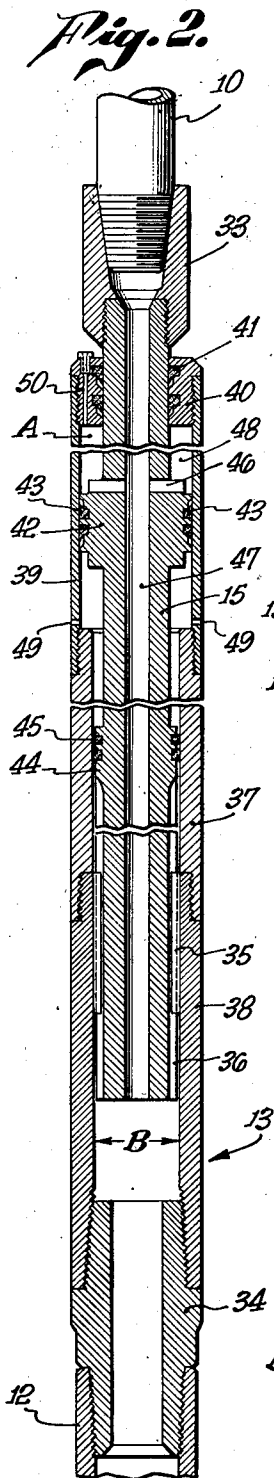
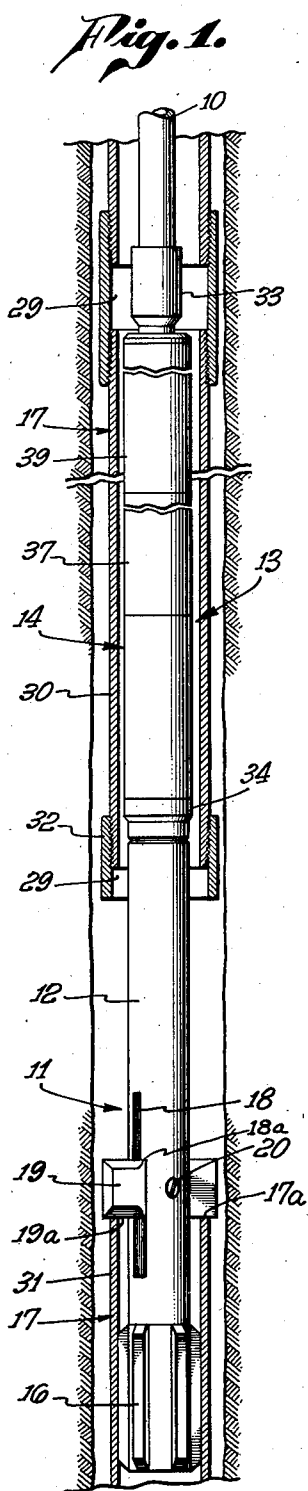
Sept. 20, 1949.

B. KRIEGL
CASING CUTTER APPARATUS

2,482,674

Filed June 5, 1945

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

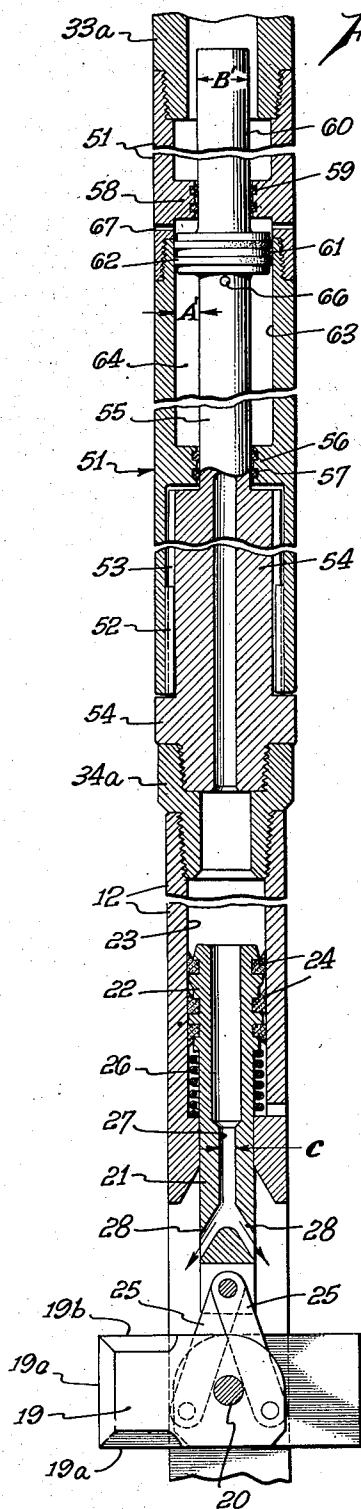


Fig. 4.

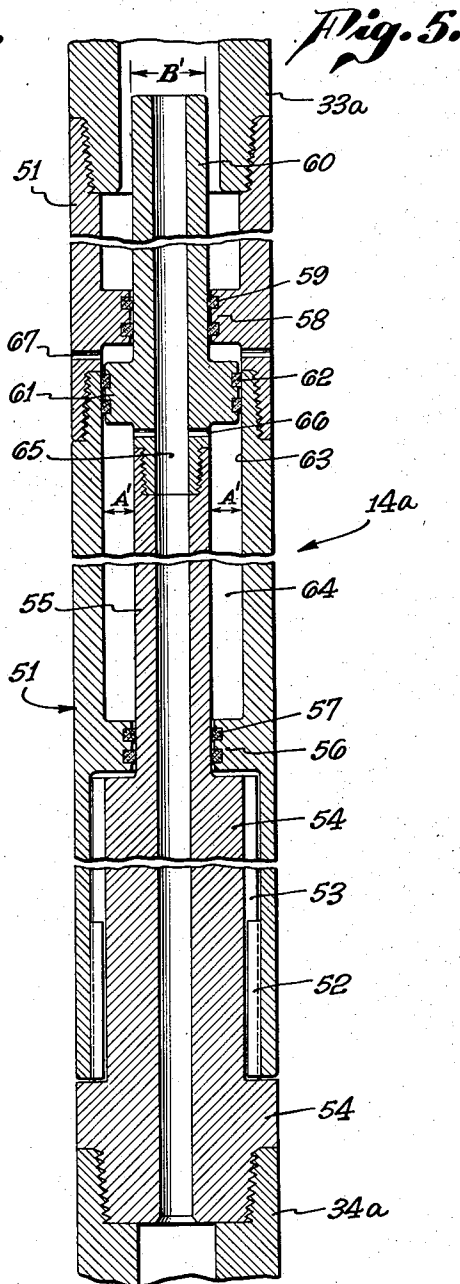


Fig. 5.

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CASING CUTTER APPARATUS

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Application June 5, 1945, Serial No. 597,627

18 Claims. (Cl. 164—0.8)

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This invention relates to apparatus for cutting materials in a well bore, and is more specifically directed to apparatus for cutting and milling casings, liners, and similar conduits while positioned in the well bore.

In the cutting and milling of casing and similar conduits positioned in a well hole, the peripheral cutting speed and downward feed or force of the rotating cutters against the casing for most effective operation can be predetermined, being dependent upon the casing size, its material and the type of cutters employed. The cutters can be rotated at the proper speed, but difficulties are encountered in maintaining constant the optimum downward feed or force of the cutter on the conduit. This is due to the inability of the driller to lower and impose the proper weight of the drill string on the cutter, and to the force imposed on the cutting tool by the hydraulic fluid pumped down the drilling string for the purpose of flushing the chips and other severed material from the cutting area for removal to the top of the well hole.

Accordingly, it is an object of the present invention to provide a cutter apparatus for use in a well bore in which a predetermined force is imposed on one or more cutters of the apparatus without regard to the downward feed of the drill string or the hydraulic force of the fluid circulated down through the drill string.

A further object of the invention is to offset the effect of hydraulic forces tending to impose weight on one or more cutters operating in a well bore.

Another object of the invention is to utilize the pressure of the fluid pumped down a drill string to counterbalance or offset the hydraulic effect of such fluid tending to force one or more cutters against the material operated upon.

Yet a further object of the invention is to provide a cutting apparatus for operation in a well bore in which the gravitational force imposed on the apparatus cutter can be completely or partially offset.

Still another object of the invention is to impose a predetermined gravitational force on cutters operating in a well bore independently of the weight of the drill string extending to the top of the well bore.

Another object of the invention is to provide a telescopic expansion joint for use in a well bore tubular string, in which the effect of the hydraulic force of the fluid within the joint is partly or entirely neutralized or counterbalanced to facilitate telescopic movement of the joint.

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The invention has other objects that will become apparent from a consideration of several of its embodiments shown in the drawings accompanying and forming part of the present specification. These embodiments will now be described in detail, but it is to be understood that such detailed description is not to be taken in a limited sense, since the scope of the invention is best defined by the appended claims.

Referring to the drawings:

Figure 1 is a side elevation of one form of apparatus in operative position within a well casing;

Figure 2 is a longitudinal section through the upper part of the apparatus shown in Figure 1;

Figure 3 is a longitudinal section through the lower part of the apparatus shown in Figure 1, forming a lower continuation of Figure 2;

Figure 4 is a view similar to Figures 2 and 3 of another embodiment of the invention; and

Figure 5 is a longitudinal section, on an enlarged scale, of the upper part of the apparatus illustrated in Figure 4.

The cutting apparatus disclosed in the drawings is designed for operation in a well bore on the lower end of a string of drill pipe or other tubing 10. Its lower portion consists of a casing cutting and milling tool or underreamer 11, whose body 12 is suitably secured to the driven member 13 of the upper expansion joint portion 14 of the apparatus, which has a driving member 15 attached to the drill pipe. The driving and driven members 15, 13 of the expansion joint are slidably splined to one another to form a telescopic driving connection for transmitting the rotary motion of the drill pipe 10 to the cutting tool 11.

The general type of cutting tool shown in the drawings for purposes of illustration is disclosed and described in detail in United States Patent No. 1,857,616, granted May 10, 1932 for a "Hydraulic underreamer." Its main body 12 preferably has a centering guide or pilot portion 16 at its lower end for centering the device in a casing or liner 17. The body is provided with an intermediate longitudinal slot 18 in which cutting blades 19 are pivotally mounted on a hinge pin 20 extending across the slot. These blades are normally retained inwardly of the slot within the confines of the tool body, and are movable outwardly hydraulically by a mechanism including a plunger 21 having a piston 22 at its upper end reciprocable within a cylinder bore 23 in the body. Leakage along the exterior of the piston is prevented by the piston rings 24 slidably engag-

ing the cylinder wall. A link 25 connects the plunger 21 with each of the cutter blades 19, the point of attachment between the lower ends of the links and the cutter blades being on the other side of the cutter pivot pin from which the cutting edges of the cutters are located, so that downward movement of the piston 22 and plunger 21 swings the cutter blades about their hinge pin 20 in opposite and upward and outward directions.

A helical spring 26 is disposed around the plunger 21 between the lower end of the piston and the bottom of the cylinder bore. The action of fluid under pressure against the piston 22 moves it downwardly against the force exerted by the spring 26 whenever the cutter blades 19 are to be swung outwardly. Release of this hydraulic pressure allows the spring to move the piston upwardly to its original position, and in so doing elevates the plunger 21 to retract the cutter blades 19 once more into the transverse slot 18 and within the confines of the tool body 10. Further details of the operating mechanism of the particular tool in question are unnecessary to a proper understanding of the present invention and may be found in the patent above referred to.

The cuttings removed by the blades 19 are washed away from the cutting region by the fluid circulating down the drill pipe string 10 and expansion joint 14, which passes through the central passageway 27 in the piston and plunger and discharges from the oppositely directed flow beans 28 onto the cutting blades 19, to cleanse them of cuttings and flush the latter upwardly to the top of the well bore. The restricted area through the plunger passageway 27 and flow beans 28 causes a back pressure to be built up on the upper side of the piston 22 to shift the plunger downwardly against the force of the spring 26 and urge the blades 19 outwardly against the casing 17 or wall of the well bore.

Each cutter when in its open and outwardly expanded position has a lower cutting edge 19a designed to operate upon the upper end 17a of the severed casing or liner section 17, for milling the casing or liner away upon rotation of the cutting tool. Each blade also has upper and outer cutting surfaces 19b, 19c which together form an upper outer corner 19d used for making the severing cut in the casing and for locating casing couplings. The forward portions of the bottom, outer and upper cutting edges are all suitably hardfaced to increase the useful life of the cutter and allow a substantial amount of casing or other material to be removed from the well bore before the cutters become worn sufficiently to require replacement.

When used for casing milling purposes, the apparatus is lowered in the well casing on the end of the drill pipe string 10 until an approximate location is reached above the point at which the casing milling operation is to begin. During this lowering operation, the cutter blades 19 are held in retracted position by the spring 26. Fluid is then circulated through the drill pipe for action under pressure upon the piston 22, to move it downwardly and swing the cutters 19 on their hinge pin 20 outwardly until their upper, outer corners 19d bear against the wall of the casing. The drill string is then lowered gradually until these corners 19d expand out into the first coupling space 29 reached, formed by adjacent casing sections 30, 31 and the coupling 32 securing

them together, which prevents further downward movement of the drilling string 10 and advises the operator that the desired location has been reached at which the severing cut is to be made and milling of the casing is to begin. It is to be understood that the severing cut could be made at points other than at a coupling.

While circulating fluid down through the drill string 10 to impose hydraulic pressure on the piston 22 and exert an expanding force on the blades 19, the drill pipe string is rotated at the proper speed to rotate the cutting tool through the expansion joint 14, and, in so doing, rotate the cutters 19 and force their upper and outer edges 19b, 19c against the wall of the casing or coupling. Such upper and outer edges begin cutting away the casing, the fluid pressure acting downwardly on the piston 22 gradually feeding and expanding the cutters outwardly until the casing or coupling is completely severed. Rotation of the tool and hydraulic forcing of its piston downwardly are continued until the upper edges 19b of the cutters have cut upwardly and removed a sufficient length of collar 32 and casing 31 as to be disposed in fully expanded, horizontal position, with the cutters 19 engaging the upper end 18a of the longitudinal slot 18 in the body 12. The cutting apparatus and drill string can then be lowered to rest the lower cutting edges 19a of the cutters upon the upper end 17a of the lower severed casing section 31. The drill pipe and casing apparatus are rotated to move the cutters at the proper peripheral speed around the end 17a of the casing, and a downward force is imposed on the cutters 19 to mill away the casing for the required length.

For most effective operation of the cutting tool, its cutters should be rotated at the proper speed and a definite downward force imposed upon them continuously during their engagement with the severed end 17a of the casing, to insure rapid removal of the casing material and maximum life of the cutters themselves. It is difficult for the driller to control this weight from the surface of the well bore for many reasons, including the elasticity and spring-like action of the relatively long string of drill pipe, and the pulsations imposed on the drill pipe by the reciprocating pumps used in pumping the circulating and washing fluid therethrough. A further factor is also encountered in the nature of the hydraulic forces acting downwardly on the piston 22 and the cutter body 12 (or parts secured to it) after the cutters 19 are expanded outwardly to their maximum extent, which tend to exert a downward force on the cutter blades.

The present invention avoids the above difficulties by incorporating an expansion joint 14 between the cutting tool 11 and the drill string 10. This expansion joint, as shown in Figures 1 to 3, inclusive, includes an inner mandrel 15 threaded into a sub 33 secured to the end of the drill pipe string 10, and an outer driven housing or barrel 13, telescopically receiving the mandrel 15, whose lower end is threaded onto a sub or adapter 34 screwed into the body 12 of the milling tool. The lower portion of the barrel 13 is provided with internal driven splines 35 slidably engaged by external driving splines 36 on the lower part of the inner mandrel 15. The outer barrel also comprises a relatively small diameter cylindrical member 37 threaded onto the upper end of the splined portion 38 of the barrel, which is threaded into a relatively large diameter cylinder

39 having a head 40 screwed in its upper end provided with suitable side seals 41 for making leak-proof slidable engagement with the upper end of the mandrel 15.

The mandrel 15 has a relatively large diameter piston 42 carrying suitable opposed seals 43 for slidable engagement with the wall of the large cylinder 39, and a lower relatively small diameter piston 44 carrying suitable piston rings or seals 45 slidably engageable with the wall of the small cylinder 37.

One or more ports 46 are formed through the mandrel 15 above the large piston 42 and below the cylinder head 40 to allow fluid under pressure to pass from the central passage 47 in the mandrel into the annular cylinder space 48 between the upper large piston 42 and cylinder head 40. Bleeder holes 49 are provided at the lower end of the large cylinder 39 between the upper and lower pistons 42, 44 to allow fluid to pass into and out of the cylinders between the pistons during telescopic movement of the mandrel 15 within the outer barrel 13.

The combined weight of the outer barrel 13, lower sub 34, and cutting tool 11 is of a known amount, and is preferably such as to provide the required and most efficient downward cutting force on the lower edges 19a of the cutter blades 19 to effect most rapid removal of cutting material from the casing, preferably through reducing the casing to relatively small chips that are easily washed away by the circulating fluid passing down through the drill pipe string 10, expansion joint 14 and cutting tool 11. In the event that this barrel, sub and cutting tool are insufficient in weight, a suitable additional tubular section of proper length and weight can be inserted between the expansion joint 14 and cutting tool 11 to provide the required total gravitational load on the cutters 19 urging them against the severed upper end 17a of the casing.

The splined or slidably keyed driving connection 35, 36 in the telescopic joint is sufficient in length to allow an adequate range of movement of the outer driven barrel 13 with respect to the inner mandrel 15. For example, a range of 18 inches to 36 inches could be provided. In operation, with the cutters 19 fully expanded and resting on the severed casing end 17a, the drill pipe string 10 is lowered to collapse the expansion joint 14 to its fullest extent, and is then elevated a short distance, such as an inch or two, to insure that the weight of drill pipe 10 is not imposed on the cutting apparatus 11. The tubular string is then rotated at the proper speed to rotate the cutting tool through the splined driving connection; and as the cutters 19 mill away the casing, the force of gravity gradually pulls the outer barrel 13 and cutting tool 11 down with respect to the mandrel 15 and maintains the cutters 19 snugly in engagement with the severed end 17a of the casing, with the predetermined cutting or drilling weight imposed on the cutters at all times. After a certain length of casing has been removed (but before the expansion joint 14 is extended fully), the drill pipe string 10 is again lowered a short distance to again collapse the expansion joint 14, without imposing the weight of the former on the cutter apparatus 11, and rotation continued to allow continued downward movement of the outer driven barrel 13 and other parts of the apparatus depending from it.

The telescopic joint 14 prevents the fluid circulated down through the drill pipe string 10

from imposing a downward hydraulic force on the cutters 19, which would add to the desired predetermined gravitational force on the cutters provided by the weights of the outer barrel 13, sub 34 and cutting tool 11 themselves, and thereby subject the cutters to too great a cutting force or feed. The effect of this downward hydraulic force is counteracted by creating an upwardly directed substantially equal hydraulic force. In the present instance, the annular area "A" of the cylinder space 48 between the upper portion of the mandrel 15 and the wall of the upper cylinder 39 is equal to the area "B" across the lower portion of the barrel minus the area "C" through the piston 22 and plunger 21 or the combined area through the flow beans 28, whichever is the lesser. By this arrangement the hydraulic pressure in the expansion joint 14 and cutter body 12 is caused to be exerted through the mandrel ports 46 and in an upward direction on the outer barrel head or cylinder head 40 across the annular area "A." This same hydraulic force is also being exerted in a downward direction on the cutter apparatus across the area "B" less the passage area "C" through the piston 22. The downward hydraulic force on the cutting apparatus is thus counterbalanced by an upward hydraulic force exerted on the outer barrel 13. Regardless of the pressure of the hydraulic fluid circulated through the drill pipe string 10 and cutting apparatus, it can have no effect in varying or altering the predetermined downward weight or gravitational pull imposed on the cutters 19, urging them against the upper severed end 17a of the casing.

If desired, the area of the annular cylinder "A" can be made equal to the area "B" by incorporating flow beans or nozzles 50 in the head equal in area to the area of the flow beans 28 or passage 27 in the cutting tool (whichever is the lesser). The fluid entering the annular cylinder 48 through the mandrel ports 46 passes upwardly and out through the flow beans or nozzles 50 in the head to assist in washing the cuttings upwardly to the top of the well bore. By making the annular area "A" equal to the area "B," a hydraulic balance can be maintained at all times regardless of changes in the area through the cutting tool flow beans 28, simply by using nozzles in the head whose passage area is equal to the area of such beans.

If desired, some of the downward weight of the outer barrel, sub and cutting tool can be removed from the cutters by making the area "A" greater than the area "B." In this manner, a lifting force is imposed hydraulically on the outer barrel 13 and cutting tool 11. Conversely, the area "A" can be decreased with respect to the area "B," to still allow downward imposition of hydraulic force on the cutters to a definite extent, as requirements might dictate.

In the modification shown in Figures 4 and 5, the telescopic joint 14a between the drill pipe string 10 and the cutting tool 11 has been altered with respect to the joint shown in the other embodiment. Instead of driving into the inner portion of the telescopic expansion joint, the drill pipe string is secured by sub 33a to an outer driving barrel 51 having a plurality of internal driving splines or keys 52 at its lower end for slidable driving relation with external driven splines 53 on an inner driven mandrel 54 secured to the sub or adapter 34a attached to the body 12 of the cutting tool 11.

The areas and the action of hydraulic fluid in

the expansion joint are also proportioned in such manner as to neutralize or counteract the downward effect of hydraulic force tending to impose additional weight on the cutters 19. In the present instance the inner driven mandrel 54 projects upwardly within the outer driving barrel 51 and has a lower relatively small diameter piston 55 in slidable sealing engagement with an internal flange 56 formed on the outer driving barrel. Suitable side seals 57 are mounted on the internal flange for slidable sealing engagement with the small extended piston 55 on the inner driven mandrel 54. The outer driving barrel 51 also has an upper internal flange 58 carrying one or more seals 59 in slidable engagement with the exterior of the upper portion 60 of the inner driven mandrel.

Between the internal flanges 56, 58 on the driving barrel 51, the mandrel 55 is provided with a relatively large diameter piston 61 carrying one or more seals 62 slidably engaging the wall of a cooperable barrel cylinder 63 extending between the two internal flanges 56, 58. An annular cylinder space 64 is formed between the exterior of the small piston 55 and the inner wall 63 of the barrel, having an annular area A^1 which is equal to the pressure active area B^1 across the inner driven mandrel 54 minus the area "C" of the flow beans 28 or passage 27. Fluid from the central mandrel passageway 65 enters the annular cylinder 64 through the mandrel ports 66 and exerts an upward hydraulic force on the large piston 61, counteracting the downward hydraulic force exerted on the mandrel 54, sub 34a and cutting tool 11.

Bleeder ports 67 are provided in the outer driving barrel 51 between the upper end of the large piston 61 and the upper internal barrel flange 58 to facilitate telescopic movement of the inner driven mandrel 54 with respect to the outer driving barrel 51, by allowing free passage of fluid between the exterior of the barrel and the space between the large piston 61 and the upper internal flange 58, which varies in accordance with the telescopic movement of the mandrel and barrel.

It is, therefore, apparent that apparatus has been provided in which the down weight imposed on the cutters can be predetermined by suitably selecting the weight of the cutting tool itself and the parts rigidly secured thereto. Such cutters can be rotated to remove material from the well bore independently of the weight of the drill pipe string and independently of the action of hydraulic forces passing through or imposed upon the apparatus. The invention has other uses in addition to the milling away of casing sections. It can be used in connection with cutters in a well bore performing underreaming operations, or with bits for drilling the bore hole itself. Moreover, the expansion joint has general application in connection with well packers, for example. It permits ease of movement of the expansion joint, since the hydraulic forces are neither tending to extend nor contract the expansion joint. The proportioning and relationship of the area "A" or " A^1 " to the area "B" or " B^1 " can be such as to counterbalance the effect of hydraulic forces completely, as pointed out specifically in describing the use of the device for milling out casing sections.

Having thus described my invention, what I claim and desire to secure by Letters Patent is:

1. Cutting apparatus adapted to be secured to a tubular string for operation in a well bore, including cutter means, telescopic means at-

tached to said cutter means for rotating the same upon rotation of said tubular string, and means acting upon said telescopic means to exert an upwardly directed force upon said cutter means while said telescopic means is in collapsed position.

2. Cutting apparatus adapted for operation in a well bore on the end of a tubular string, including a cutting tool, a telescopic joint secured to said cutting tool, and means within said telescopic joint for partially relieving said cutting tool of downwardly directed force imposed thereupon while said telescopic joint is in collapsed position.

3. Casing milling apparatus adapted for operation in a well bore on the end of a tubular string, including cutter means, a telescopic joint having a driven member attached to said cutter means and a driving member adapted for attachment to said tubular string, and means responsive to the pressure of the fluid passing through said tubular string and joint for exerting an upward force on said driven member and its attached cutter means.

4. Casing cutting apparatus adapted for operation in a well bore through rotation of a tubular string, including cutter means, a telescopic joint having a driven member attached to said cutter means and a driving member adapted for attachment to said tubular string, and means responsive to the pressure of the fluid passing through said tubular string and joint for exerting an upward hydraulic force on said driven member and its attached cutter means to substantially offset the downward hydraulic force exerted by such fluid on said driven member and its attached cutter means.

5. Casing milling apparatus adapted for operation in a well bore, including cutter means, and a substantially hydraulically balanced telescopic joint attached to said cutter means.

6. Casing milling apparatus adapted for operation in a well bore on the end of a tubular string, including cutter means, a telescopic joint comprising a driving member adapted to be driveably connected to said tubular string and a driven member in driving relation to said driving member and adapted to be driveably connected to said cutter means, and means responsive to the pressure of the fluid passing through said tubular string and joint for exerting an upward hydraulic force on said driven member and its associated cutter means to substantially offset the downward hydraulic force exerted by such fluid on said driven member and its associated cutter means.

7. Cutting apparatus adapted for operation in a well bore on the end of a tubular string, including cutter means, a tubular driving member adapted to be driveably connected to said tubular string, a tubular driven member keyed to said driving member in slideable telescopic relation therewith and driveably connected to said cutter means, and hydraulically operable means on said driven member responsive to the action of fluid passing through said members for exerting an upward force on said driven member and its associated cutter means.

8. Cutting apparatus adapted for operation in a well bore on the end of a tubular string, including cutter means, a driving member adapted to be driveably connected to said tubular string, a driven member keyed to said driving member in slideable telescopic relation therewith and driveably connected to said cutter means, said driving and driven members being spaced from one an-

other to form an annular cylinder, means for feeding fluid from the interior of one of said members to said annular cylinder, and means secured to said driven member and responsive to the pressure of the fluid within said cylinder for exerting an upward force on said driven member.

9. Cutting apparatus adapted for operation in a well bore on the end of a tubular string, including cutter means, a driving member adapted to be driveably connected to said tubular string, a driven member splined to said driving member in slideable telescopic relation therewith and driveably connected to said cutter means, said driving and driven members being spaced from one another to form an annular cylinder, means for feeding fluid from the interior of one of said members to said annular cylinder, and means secured to said driven member and adapted to be acted upon by the fluid within said cylinder.

10. Casing milling apparatus adapted for operation in a well bore on the end of a tubular string, including a cutting tool, a driving member adapted to be driveably connected to said tubular string, a driven member splined to said driving member in slideable telescopic relation therewith and driveably connected to said cutting tool, said driving and driven members being spaced from one another to form an annular cylinder, means for feeding fluid from the interior of one of said members to said annular cylinder, means secured to said driven member and responsive to the pressure of the fluid within said cylinder for exerting an upward force on said driven member, the cross-sectional area of said annular cylinder being such that the upward hydraulic force on said driven member is substantially equal to the downward force exerted by said fluid on the driven member and cutting tool.

11. Casing milling apparatus adapted for operation in a well bore on the end of a tubular string, including a cutting tool, a telescopic joint comprising an inner member adapted to be driveably connected to said tubular string and an outer member slideably splined to said inner member and driveably connected to said cutting tool, said inner and outer members being spaced from one another to form an annular cylinder, means for feeding fluid from the interior of said inner member to said annular cylinder, and means secured to said outer member and responsive to the pressure of the fluid within said cylinder for exerting an upward force on said outer member.

12. Casing milling apparatus adapted for operation in a well bore on the end of a tubular string, including a cutting tool, a telescopic joint comprising an outer member adapted to be driveably connected to said tubular string and an inner member slideably splined to said outer member and driveably connected to said cutting tool, said inner and outer members being spaced from one another to form an annular cylinder, means for feeding fluid from the interior of said inner member to said annular cylinder and means secured to said inner member and responsive to the pressure of the fluid within said cylinder for exerting an upward force on said inner member.

13. A tubular expansion joint adapted to be secured to a tubular string for operation in a well bore, comprising upper and lower members telescopically arranged in leakproof relation with respect to one another, said members being spaced from one another to form an annular cylinder, means for feeding fluid from the in-

terior of one of said members to said annular cylinder, and means secured to said lower member and responsive to the pressure of the fluid within said cylinder for exerting an upward force on said lower member.

14. A tubular expansion joint adapted to be secured to a tubular string for operation in a well bore, comprising upper and lower members telescopically arranged in leakproof relation with respect to one another, means providing a cylinder space within one of said members, means for feeding fluid from the interior of one of said members to said cylinder space, and means secured to said lower member and responsive to the pressure of the fluid within said cylinder space for exerting an upward force on said lower member.

15. A tubular expansion joint adapted to be secured to a tubular string for operation in a well bore, comprising upper and lower members telescopically arranged in leakproof relation with respect to one another, means providing a cylinder space within one of said members, means for feeding fluid from the interior of one of said members to said cylinder space, means secured to said lower member and responsive to the pressure of the fluid within said cylinder space for exerting an upward force on said lower member, the pressure active surface on said last-mentioned means being such that the upward fluid force thereon substantially equals the downward force of the fluid on said lower member.

16. A tubular expansion joint adapted to be secured to a tubular string for operation in a well bore, comprising inner and outer members telescopically arranged in leakproof relation with respect to one another, means providing an annular cylinder space between said members, means for feeding fluid from the interior of one of said members to said cylinder space, means secured to one of said members and responsive to the pressure of the fluid within said cylinder space for exerting an upward force on said one member, the pressure active surface on said last-mentioned means being such that the upward fluid force thereon substantially equals the downward force of the fluid on said one member.

17. A tubular expansion joint adapted to be secured to a tubular string for operation in a well bore, comprising inner and outer members telescopically arranged in leakproof relation with respect to one another, means providing an annular cylinder space between said members, means for feeding fluid from the interior of said inner member to said cylinder space, means secured to said outer member and responsive to the pressure of the fluid within said cylinder space for exerting an upward force on said outer member, the pressure active surface on said last-mentioned means being such that the upward fluid force thereon substantially equals the downward force of the fluid on said outer member.

18. A tubular expansion joint adapted to be secured to a tubular string for operation in a well bore, comprising inner and outer members telescopically arranged in leakproof relation to one another, means providing an annular cylinder space between said members, means for feeding fluid from the interior of said inner member to said cylinder space, means secured to said inner member and responsive to the pressure of the fluid within said cylinder space for exerting an upward force on said inner member, the pressure active surface on said last-mentioned means being such that the upward fluid force thereon

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substantially equals the downward force of the fluid on said inner member.

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12

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Name	Date
Denny	May 19, 1931

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Country	Date
Germany	Mar. 17, 1914