Jan. 7, 1941. J. J. SANTIAGO 2,227,763

EXPANSIVE REAMER

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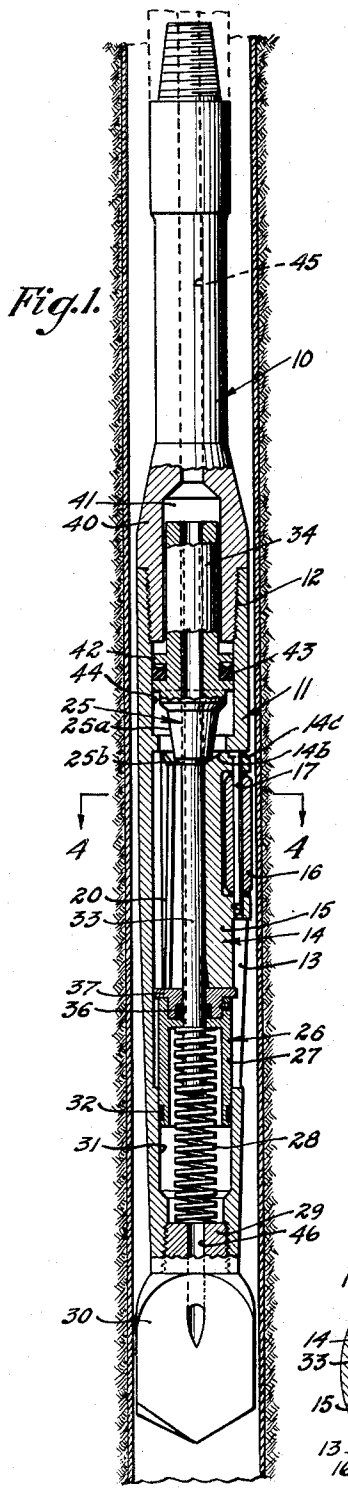


Fig. 1.

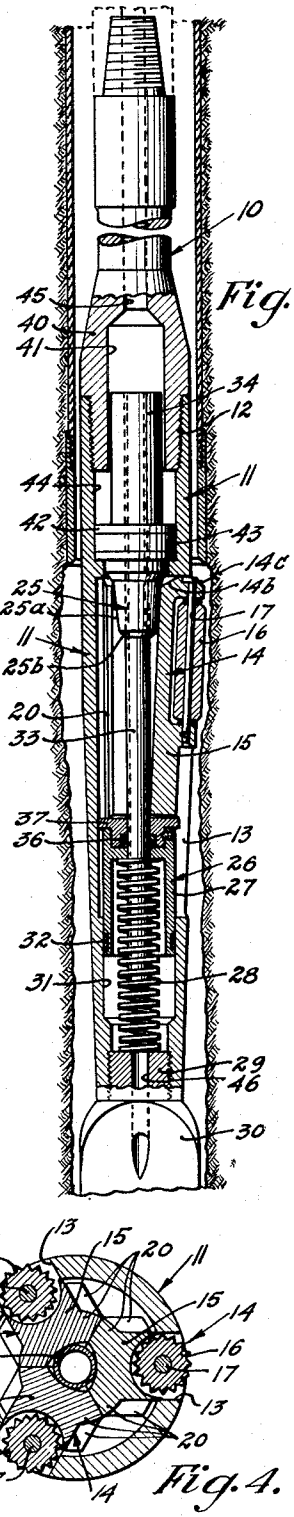


Fig. 2.

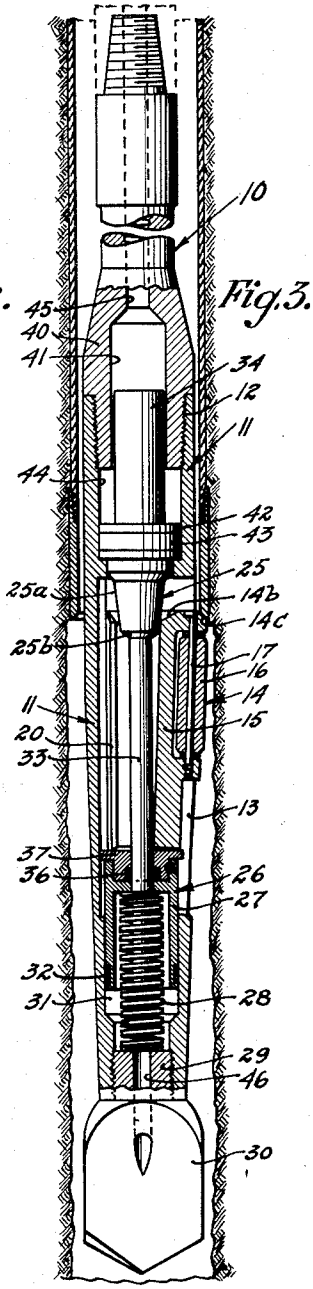


Fig. 3.

Fig. 4.

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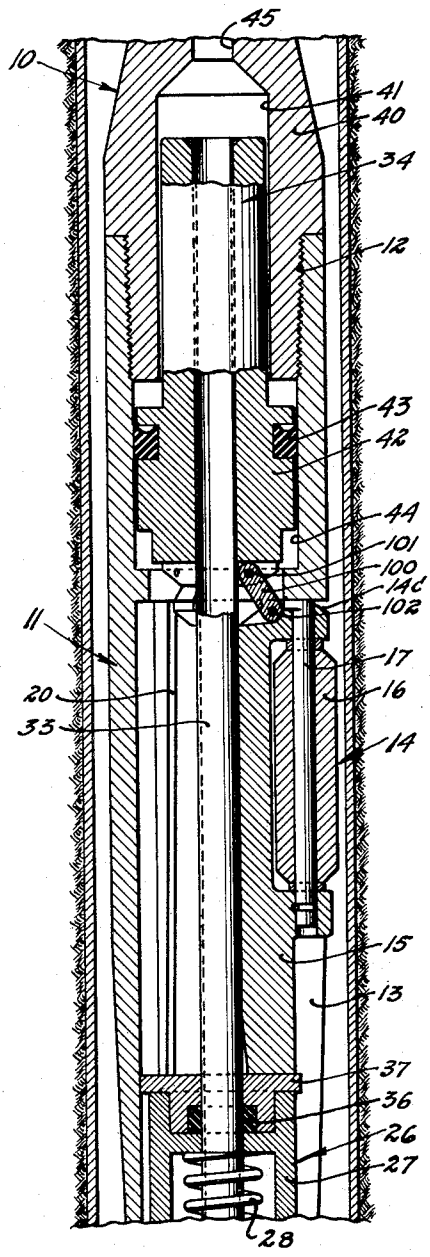


Fig. 5.

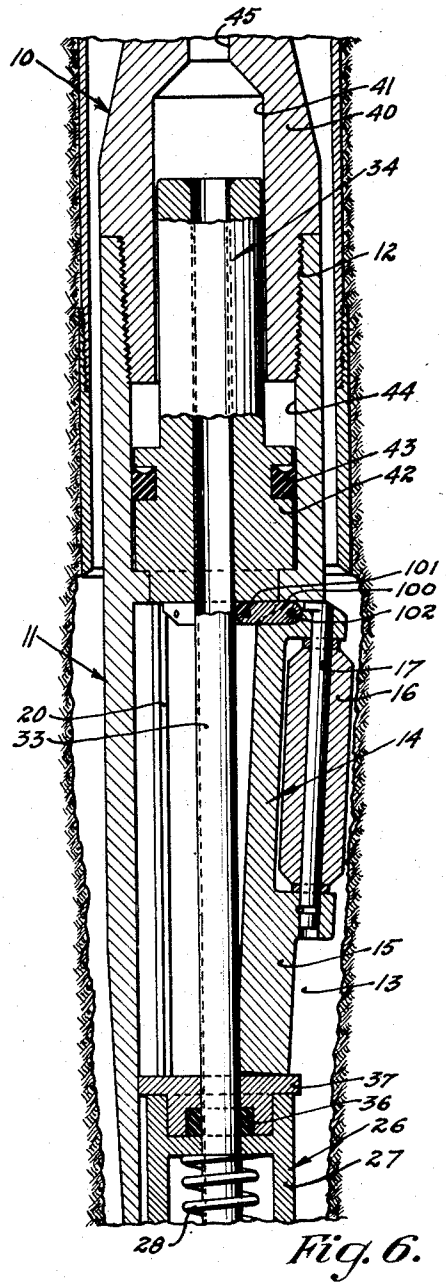


Fig. 6.

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2,227,763

EXPANSIVE REAMER

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Application February 5, 1940, Serial No. 317,326

7 Claims. (Cl. 255—76)

My invention refers to expansive reamers of the type used in deep wells, commonly known as underreamers. In the past such reamers commonly have been expanded by either spring or hydraulic pressure action, and contracted by being pulled into the casing, or contracted by spring action after having been expanded by some other action such as hydraulic.

Various difficulties have been encountered. In the most common type of underreamer, expanded by spring action and contracted by being pulled into the casing, the spring expanding action constantly presses the cutters outwardly, and when riding up and down through the casing there may be considerable friction and wear. To reduce that friction and wear the spring pressure must be kept at or near the minimum necessary to expand the cutters when they pass out of the casing, and then there is present the liability that the cutters will not be expanded.

Hydraulic expansion has the advantage that it is under control of the operator and therefore need not act to urge the cutters out until they have passed out of the casing and reached the working zone. But the hydraulically actuated element, such as a plunger, must have some means to return it to its cutter retracting position; and such means may involve complications of structure, or a connection between the cutters and plunger such that considerable hydraulic pressure is required to hold the cutters expanded. Or if a spring is used to retract the hydraulic plunger, it must be strong enough to force retraction with certainty, and the hydraulic pressure on the plunger must be correspondingly high to expand the cutters and also overcome the spring. High hydraulic pressures on the actuating plungers are objectionable because they can only be attained by back pressures caused by high velocities through restricted passages, accompanied by rapid abrasion.

My invention in large measure overcomes the disadvantages of previous underreamers of both types, and attains the advantages of both. By utilizing controllable expansion it avoids the disadvantage inherent in spring expansion of forcing the cutters to ride the casing. On the other hand, by utilizing a spring or other yielding element against which the cutters are contracted by pulling into the casing, the expansive power of that spring is then used to return the hydraulic or other controllable expanding means to its cutter contractive position. In its expanding action the hydraulic means does not have to work against the spring; and so the hydraulic pressure need not be great, and the spring pressure may be great enough to insure the return of the hydraulic expander.

The nature of the invention, and how it performs these operations, will be understood from the following detailed description of an illustrative and preferred design, reference being had to the accompanying drawings, in which

Fig. 1 is a vertical central section showing the preferred form of my improved expansive reamer, with its parts in the position which they assume in passing up and down through the casing;

Fig. 2 is a similar section showing the cutters expanded for reaming operations below the casing;

Fig. 3 is a similar section showing the parts in positions assumed during contraction of the cutters;

Fig. 4 is a cross section on line 4—4 of Fig. 1;

Fig. 5 is a fragmentary vertical section showing a modified construction with the parts in the same position as shown in Fig. 1; and

Fig. 6 shows the modified structure in the position of Fig. 2.

In the drawings the body of the tool is illustrated as being made up of two parts, an upper part 10 and a lower tubular part 11 joined together at the threaded joint 12. The tubular body part 11 is provided with cutter-receiving slots 13 through its walls, here shown as three in number. The cutters, which are referred to generally by the numeral 14, may be of any type and have any kind of cutting edge, but are here shown as composed of a cutter bar or carrier 15 and a cutter proper in the form of a roller cutter 16 mounted on spindle 17 which is mounted in the bar or carrier 15. These cutters, specifically the cutter carriers 15, fit the body slots 13 rather snugly in width as is shown in Fig. 4; but the slots 13 are considerably longer vertically than the cutters so that the cutters may move vertically between the position shown in Fig. 1 and the position shown in Fig. 3.

The inner parts of the cutter carriers as here shown are provided with vertically extending flanges or lugs 20 which bear outwardly against the inner surface of tubular body member 11 when the cutters are expanded. In their contracted position, as shown in Fig. 4, the cutters may bear inwardly against each other throughout their vertical lengths, to thus provide a limit of contraction. When the cutters expand, as in Fig. 2, they do so by tipping outwardly at their upper ends, their lower ends remaining in contact with each other and with the inner surface

of the body, and their lower ends are thus internally radially supported. When expanded, their upper ends are internally radially supported by abutment against the expanding plunger head **25**. The foregoing described typical construction of the cutters, their mounting in the body, and their manner of support, is shown in prior Grant patents, for instance in Patent No. 1,819,367, dated August 18, 1931; as are also the general features of the spring actuation of the cutters, in and of itself, to be described. These constructions are here described merely as illustrative and typical of known forms of underreamers to which my invention is applicable or which may form one of the sub-mechanism elements of the combination that constitutes my invention.

Below the cutters, and forming a support for them is a spring actuated cutter propeller **26**. The form of this propeller which I prefer is shown in the drawings and comprises a hollow plunger **27** resting upon the cutter-actuating spring **28** which at its lower end rests upon any suitable support in the body, as for instance upon the pin end **29** of the bit **30** which is screw-threadedly attached to the lower end of the body. Tubular plunger **27** rides vertically in a cylindric bore **31** in the lower part of body part **11**, and is provided with packing **32** to make a fluid-tight joint. The central circulation pipe **33**, which is here shown as being rigidly attached at its upper end to the plunger or piston **34**, has its lower end extending downwardly through the upper end of the cutter propeller **26** and into the interior of the hollow plunger **27** of the cutter propeller. A packing gland is provided at **36** for a fluid-tight joint, and the follower member **37** of this packing gland constitutes, in the present specifically preferred design, the part of cutter propeller **26** which immediately engages and supports the lower ends of the cutters **14**.

In prior underreamer designs of the type most nearly like the parts of my underreamer that have thus far been described (see for instance the Grant patent above referred to) the plunger head **25** has usually been relatively stationary with reference to the body, and in a position such as shown in Fig. 2. The cutters then expand by moving up and out to the relative position shown in Fig. 2, and contract by moving down and in as indicated in Fig. 3, the part **25** remaining stationary with relation to the body. In my improved underreamer I make this part **25** in the form of a relative member—specifically a vertically movable plunger head—so that this cutter expanding plunger on the one hand and the cutter and spring actuating assembly on the other hand, are vertically movable relative to each other and to the body. I accomplish that relative vertical movement in my prefered design by making th part **25** as a plunger head, or a part of a plunger, which is movable vertically with reference to the body and the other parts, and is actuated vertically in one direction, here downwardly, by hydraulic pressure. It will however be understood that in the broader aspects of my invention this plunger head represents any suitable movable expanding means actuated by any controllable actuating means.

As illustrated in preferred form in the drawings the vertically movable plunger **34** has an upper cylindric guide part **40** which fits somewhat loosely in a bore **41** in the lower end of body part **10**. Below the lower extremity of body part **10**, plunger **34** has an enlarged head **42**, provided with suitable packing **43**, and fitting and reciprocating in cylindric bore **44** in the upper portion of body part **11**. Below the head **42** the vertically reciprocable plunger **34** carries the downwardly tapering cutter expanding plunger head **25**. The vertical movement of plunger **34** is such that plunger head **25** may be moved between the positions shown in Figs. 1 and 2, preferably being stopped on the body in its lower position. In its lower position, of Fig. 2, plunger head **25** lies between the upper ends of cutters **14** when those cutters are in their uppermost positions. In this position the upper ends of the inner surfaces of the cutters **14** bear back against the slightly tapered surface **25a** of plunger head **25**. The lower end of plunger head **25** has a more abruptly tapered surface **25b** with which the correspondingly beveled surfaces **14b** of the cutters cooperate as hereinafter described.

The upper body portion **10** has a longitudinal circulation passage **45** taking fluid under pressure from the drill pipe and communicating with the upper end of plunger bore **41**. Thence the circulating fluid passes downwardly through the circulation pipe **33** and into the bore **31** in the lower part of the body, and thence through the circulation passage or passages **46**. When circulation under pressure is set up, a certain downward pressure, depending upon the pressure maintained on the fluid and also upon the relative sizes of passage **45** and pipe **33**, will be maintained downwardly upon the upwardly facing surfaces of plunger **34** and head **42**, thus tending to force the whole plunger **34** and plunger head **25** downwardly.

The tool is put into the casing with its parts in the positions shown in Fig. 1, with plunger **34** in its upper position either above or supported on the upper ends of cutters **14**. Cutters **14** are in their inward retracted positions, spring **28** holding them in their upper positions where their upper ends are pressed upwardly against the upper ends of slots **13**. In this contracted condition the extreme diameter of the tool is slightly less than the internal diameter of the casing, and when the tool is lowered through the casing there is no forcible frictional contact of the cutters with the casing, as there are no appreciable forces exerted on the cutters tending to expand them.

When the cutters emerge from the lower end of the casing and the tool reaches the position at which it is desired to start the reaming operation, sufficient pressure is put upon the circulating fluid to force the plunger **34** downwardly. The pressure taking surfaces of plunger **34**, and the relative sizes of the circulation passages, are preferably such that when the circulating fluid is put under a normal or usual minimum circulating pressure, the plunger will be pressed downwardly with sufficient force to force the cutters outwardly against and into the formation. In the meantime the tool is being rotated, so that the cutters cut their way out into the formation until the cutters are fully expanded. This condition of the parts is shown in Fig. 2. Underreaming may then procede by lowering the tool as it is rotated; and normally the circulation pressures will be continuously maintained and thus hold plunger **34** in its lower position. However, if the circulation pressure should momentarily lower or cease, it will be noted that the tapering angle of surface **25a** of plunger head **25** is small enough that the inward pressure of the cutters upon that surface will not directly force the plunger up.

When the plunger head **25** is forced down, the

more abruptly tapered surface **25b** first comes into contact with the corresponding surfaces **14b** on the upper ends of the cutters, forcing the cutters outwardly until the inner surfaces of the cutters are far enough out to ride on the slightly tapered surface **25a** of the plunger head. The last small part of the expansion takes place by coaction of the two last mentioned surfaces.

When it is desired to remove the tool from the well it is pulled upwardly until the upper ends of the expanded cutters come into contact with the lower end of the casing or with the casing shoe. Beveled surfaces **14c** at the upper outer corners of the cutters then engage the lower end of the casing, or the lower end of the shoe which usually has a corresponding beveled surface; and the action of those surfaces tends to press the cutters inwardly as the tool is pulled up. Relative to the body the cutters are pressed downwardly and inwardly. Plunger **34** still remains in its lower position whether the circulation pressure is being kept up or not; as there is as yet no force exerted upon it to move it upwardly. Consequently the cutters cannot be contracted until they are relatively pushed down, as indicated in Fig. 3 where the cutters are shown in a partially lowered and contracted position. At the end of the operation of pushing the cutters downwardly and inwardly, the plunger **34** is still substantially in the relative position shown in Fig. 3, but the cutters are down far enough that they are below plunger head **25** and are also fully collapsed. The cutters and the plunger head **25** then occupy the positions relative to each other shown in Fig. 1, but with both plunger and cutters in their lower positions.

Immediately the parts reach the last described positions the cutters can pass up into the casing, and are urged upwardly by spring **28**. Being then prevented from expanding by the surrounding casing, the cutters then move upwardly and move plunger **34** upwardly with them, reaching the relative positions shown in Fig. 1, and being then in the same positions that they occupied when the tool was lowered through the casing. The tool can then be removed from the casing in the same condition in which it was lowered, and without any forcible frictional contact of the cutters with the casing.

The foregoing describes the normal mode of operation of my reamer. In that normal mode of operation it will be seen that the cutters are not expanded by any active action of spring **28** but by the active relative downward movement of plunger **34**. During this expanding action the spring **28** performs only the non-moving function of holding the cutters in their elevated positions. Expansion of the cutters, or tendency to expand, consequently does not automatically take place when the cutters emerge from the casing, for the same reasons that the cutters are not urged outwardly against the casing during the lowering of the tool. Expansion is caused only by the operation of plunger **34** which is under the control of the operator.

Contraction initially takes place by forcing the cutters downwardly and inwardly against the upward pressure of spring **28**. This initial contractive action is, in itself, the same as the contractive action of the usual spring actuated underreamer. When the cutters have reached their lower and contracted positions, they then can be pulled up through the casing even if something has occurred to bind plunger **34** in its lower position. If plunger **34** is accidentally held down, the contracting action of the tool, and its condition during removal through the casing, is the same as in the usual spring-actuated underreamer. Thus, the tool can still be contracted and removed even if the plunger should for any reason become stuck in its lower position.

However, the final action and function of spring **28**, after the cutters have been contracted and lowered, is to move both the cutters and the plunger up to their initial positions as shown in Fig. 1, with the cutters in their final contracted positions.

The coacting surfaces **25b** of the plunger head and **14b** of the cutters constitute a simple and preferred form of interconnective means between the expanding plunger and the cutters which have an angular action that will move the cutters outwardly when the plunger moves in one direction (down) and which will move the plunger oppositely (up) when the cutters move in that latter direction. Other forms of interconnection, per se, are known and can be used, for instance angular toggle link interconnection. The wedging surface form of interconnection has however the advantage of simplicity. For the functions specified its angle should be preferably around 30° to 45° to the horizontal; that is, the taper of surface **25b** should be sufficiently abrupt that the cutters will not bind between the plunger and the casing, and at the same time sharp enough to force the cutters out when the plunger is moved down. The angle of 30° to 45° is a good median value; the smaller angle is perhaps preferable.

In Figs. 5 and 6 a modified structure is shown wherein all the parts are the same as in Figs. 1, etc., except the operative angular connection between the plunger and cutters. Here a pivoted link or links **100**, disposed angularly as shown, is pivoted at **101** to the plunger and at **102** to the cutter. In the normal contracted position of Fig. 1 the link stands at an angle to the vertical that corresponds to the angle of surface **25b** (Fig. 1) to the horizontal. When the plunger moves down the cutter is forced out by the angular action of the link, until the link is in or near a horizontal position (with the cutter expanded) as in Fig. 6. In the latter position the cutter is laterally supported by the link and plunger in the same manner as it is supported by the nearly vertical surface **25a** of the plunger in Fig. 2. And from the latter position the cutter, when drawn up against the casing, is moved down and in, substantially as it is in Fig. 3. If it is considered that the pressure taking surfaces at link pivots **101** and **102** are always at right angles to the length of the link, it will be recognized that those surfaces in their changing positions correspond in position and function to the angular engaging surfaces **25a** and **25b** of Figs. 1, etc.

The downward force necessarily exerted by the plunger to expand the cutters need not be large. The only force within the tool itself that holds the cutters in, is the frictional engagement of their upper ends with the upper ends of the body slots. This frictional force may be reduced to a minimum by placing those upper surfaces at an angle to the length of the cutter. They are so shown in the drawings when the cutter is tilted outwardly. The plunger also must exert sufficient force to expand the cutters against the wall of the hole as they cut their way outwardly, and thus to dependably cause expansion. By making the taper of wedge surface **25b** somewhat more sharp, the necessary plunger pressure may be kept at a minimum.

The plunger pressure does not have to overcome the force of the cutter supporting spring which returns the plunger to normal elevated position. Because of that, and because the spring does not expand the cutters, the spring may be made quite strong to insure dependable return of the parts to normal position. The plunger pressure may in fact be less than the spring pressure; and the spring will then push the plunger up even if the downward force applied to the plunger is still maintained or is constant. Thus dependability of action may be had without utilizing a large hydraulic pressure or other force on the plunger; and consequently the constriction of flow and attendant velocities and wear in the circulation pipe 33 may be small.

I claim:

1. An expansive reamer comprising in combination with a body, a cutter movable vertically and transversely relative to the body, yielding means urging the cutter upwardly, a cutter expander movable vertically relative to the body, connective means between the expander and the cutter acting to move the cutter outwardly on downward movement of the expander and to move the expander upwardly on upward movement of the cutter, and means for moving the expander down.

2. An expansive reamer comprising in combination with a body, a cutter movable vertically and transversely relative to the body, yielding means urging the cutter upwardly, a cutter expanding plunger vertically movable in the body and having wedging means adapted on downward movement to engage the cutter and move it outwardly relative to the body, said wedging means lying at such an angle that upward movement of the cutter caused upward movement of the plunger, and means for applying pressure to the plunger to move it down.

3. An expansive reamer comprising in combination with a body, a cutter movable vertically and transversely relative to the body, yielding means urging the cutter upwardly, a cutter expanding plunger vertically movable in the body and having a wedge surface adapted on downward movement to engage the cutter and move it outwardly relative to the body, said wedge surface making an angle of approximately 30° to 45° to the horizontal, and means for applying pressure to the plunger to move it down.

4. In an expensive reamer having a body, a cutter movable vertically and transversely relative to the body and having an external formation adapted to cause downward and inward movement of the cutter when it is moved upwardly against the lower end of a well casing, and yielding means urging the cutter upwardly; the combination of cutter expanding means movable vertically relative to the body, coacting on downward movement with the cutter to expand it, and controllable means for applying pressure to said means to move it down.

5. In an expansive reamer having a body, a cutter movable vertically and transversely relative to the body and having an external formation adapted to cause downward and inward movement of the cutter when it is moved upwardly against the lower end of a well casing, and yielding means urging the cutter upwardly; the combination of a cutter expanding plunger movable vertically relative to the body, and having a downwardly and outwardly facing wedge surface adapted to engage the cutter on downward movement and move the cutter outwardly and adapted to transmit upward vertical movement from the cutter to the plunger, and means for applying pressure to the plunger to move it down.

6. In an expansive reamer having a body, a cutter movable vertically and transversely relative to the body and having an external formation adapted to cause downward and inward movement of the cutter when it is moved upwardly against the lower end of a well casing, and yielding means urging the cutter upwardly; the combination of a cutter expanding plunger movable vertically relative to the body and having a cutter engaging wedge surface which makes an angle of approximately 30° to 45° to the horizontal, and means for applying pressure to the plunger to move it down.

7. In an expansive reamer having a body, a cutter movable vertically and transversely relative to the body and having an external formation adapted to cause downward and inward movement of the cutter when it is moved upwardly against the lower end of a well casing, and yielding means urging the cutter upwardly; the combination of a cutter expander movable vertically relative to the body and having a cutter engaging surface which makes an angle of approximately 30° to 45° to the horizontal, and controllable means for moving the expander down with relation to the body and the cutter.

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