Nov. 27, 1945. A. L. ARMENTROUT 2,389,711

WELL JAR

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Fig. 1.

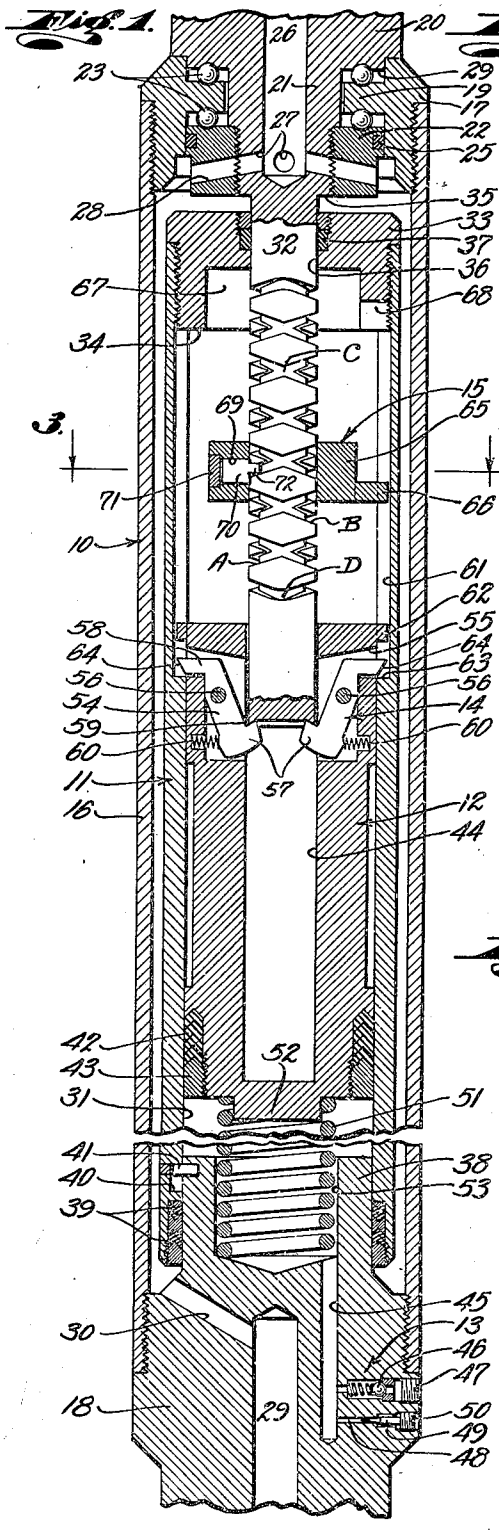


Fig. 2.

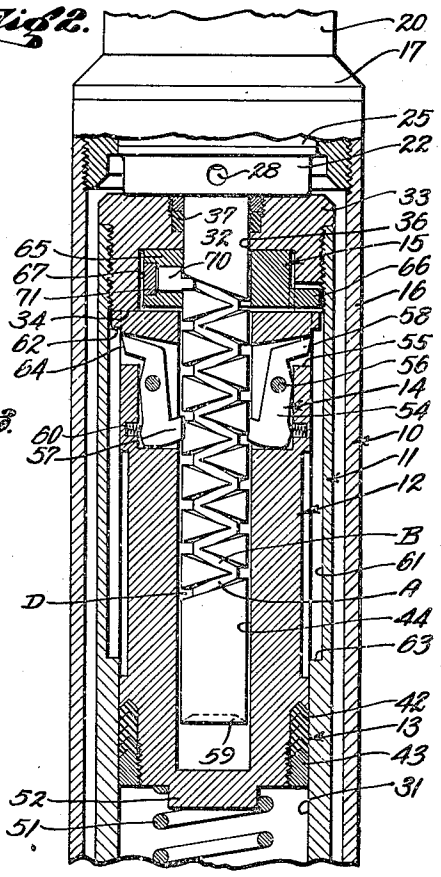
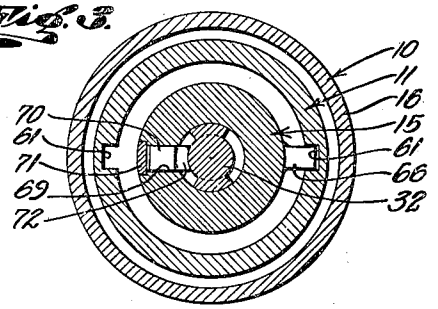


Fig. 3.



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Fig. 4.

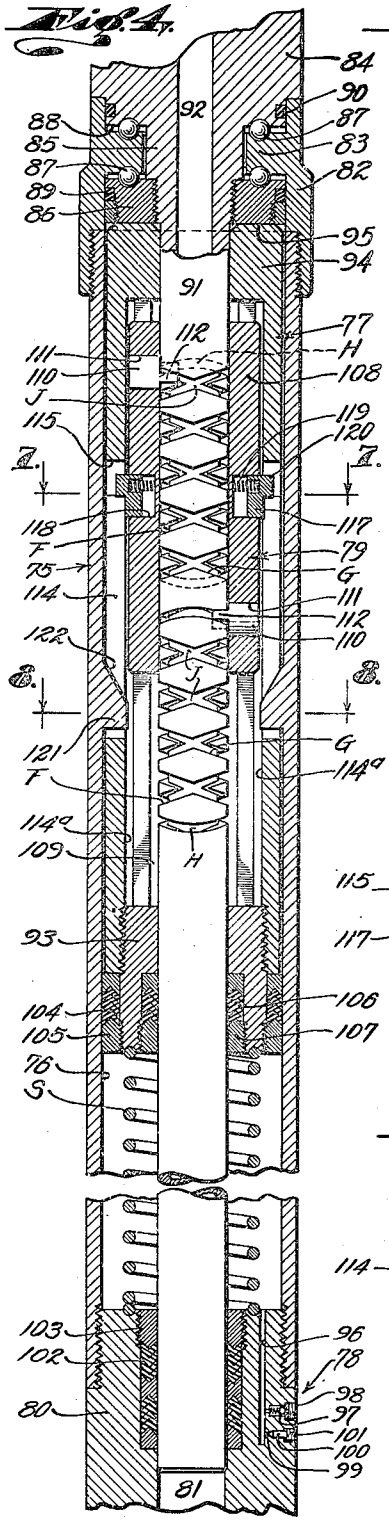


Fig. 5.

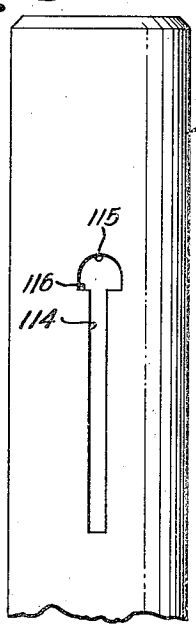


Fig. 6.

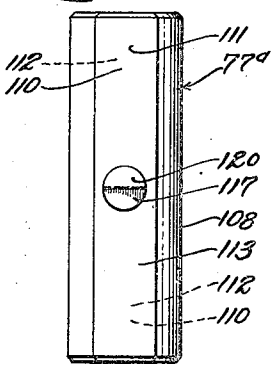


Fig. 7.

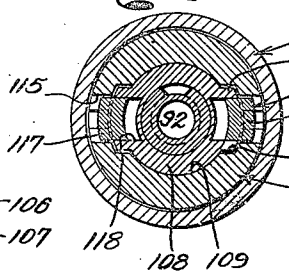


Fig. 8.

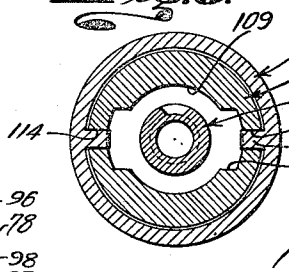
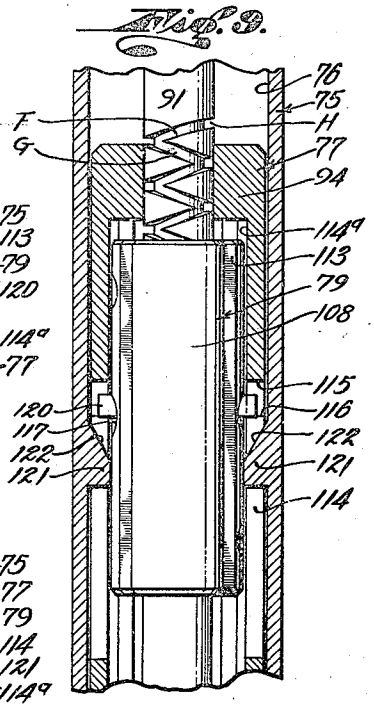


Fig. 9.



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Fig. 10.

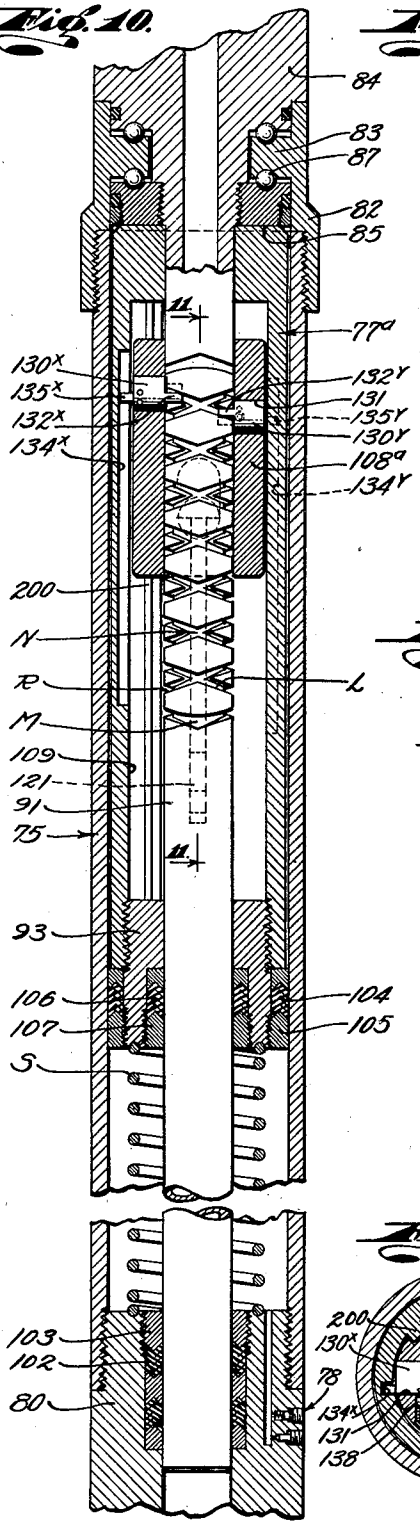


Fig. 11.

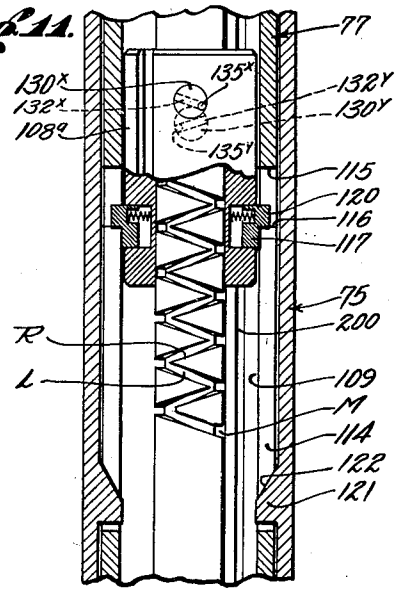


Fig. 12.

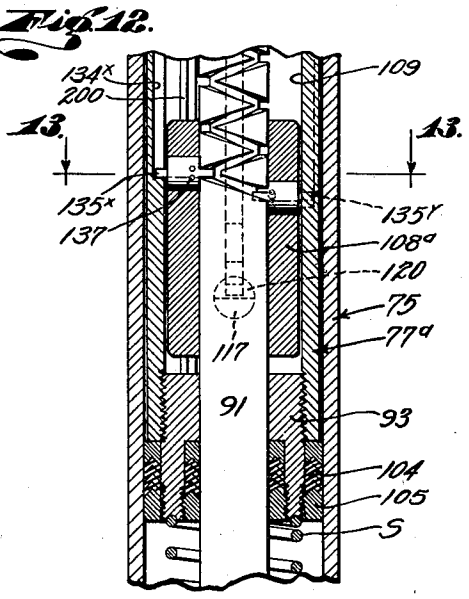
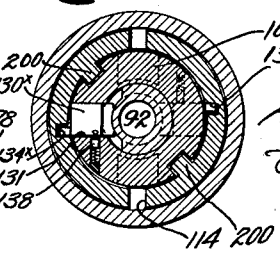


Fig. 13.



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UNITED STATES PATENT OFFICE

2,389,711

WELL JAR

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Application August 13, 1941, Serial No. 406,646

15 Claims. (Cl. 255—27)

This invention relates to well tools and relates more particularly to jars or jaring tools useful in removing objects from wells. A general object of this invention is to provide a practical effective jarring tool capable of producing very heavy jarring effects for freeing objects caught in wells.

Rotary jars of various types have been introduced but all have certain limitations of use or have certain disadvantages accompanying their operation. One type of jar now employed embodies a jarring hammer actuated by a spring. The spring is compressed to store up energy for the operation of the hammer, this compression either being accomplished by a pull on the fishing string or by a cam mechanism actuated by rotation of the string. The size and space limitations of a well tool, such as a jar, prevent the use of a heavy strong spring and, for this reason, the spring-hammer type jar is incapable of producing jarring blows of any substantial magnitude. Another general type of jar that has been introduced utilizes the "stretch" or resiliency of the fishing string to provide a jarring action, the string being put under heavy tensile strains in order to obtain the required "stretch." This subjects the string to excessive and dangerous strains and subjects the hoisting cables, etc. to excessive wear. Furthermore, it is impossible to strike the jarring blow while maintaining the tensile strain on the string because the sudden release of the tool momentarily relieves the string of its tension and the blow is struck during this interval of no-tension. A third general type of jar has been proposed which contemplates the use of the hydrostatic pressure in the deep well as the actuating force for the hammer. The hydraulic well pressure is very slow in its action and cannot develop sufficient dynamic inertia in the hammer to produce an effective jarring action.

Another object of this invention is to provide a well jar operable to produce a jarring action of great intensity. The tool of the present invention is operable to produce a jarring action of much greater intensity than previously introduced well jars.

Another object of this invention is to provide a well jar operable to provide a heavy strong jarring action without subjecting the fishing string to excessive or dangerous tensile strains. The tool of the present invention is operable to provide a jarring action of any desired or required magnitude without putting the string under tension, it being optional with the operator whether the string is to be maintained under tension and the tension, if applied, may be of selected or the required degree without varying the intensity of the jarring blows. In employing the tool of the present invention it is unnecessary to subject the fishing string to a "stretch" in order to obtain the jarring action and there is little or no danger of breaking the string during the fishing operations and the hoist lines, etc. are not subjected to excessive wear.

Another object of this invention is to provide a jarring tool of the character referred to in which jarring blows of great intensity may be imparted to the string and fish while maintaining an uninterrupted and unvarying pull or tension on the string. No relaxation in the tensile strain on the fishing string is required in the operation of the tool and a constant uniform or varied tension may be maintained on the fishing string without interruption to utilize the jarring action to the best advantage in freeing the fish.

Another object of this invention is to provide a well jar of the character referred to which is fully operable by simple rotation of the fishing string in either direction.

Another object of this invention is to provide a jarring tool of the character mentioned in which the hammer element is driven or moved at tremendous speed and with great force to provide a hammer blow or jarring blow of very great intensity.

Another object of this invention is to provide a jarring tool which utilizes the elasticity or sudden expansion of gas under pressure to operate the hammer for the production of the jarring blows. In the tool of the present invention the hammer-piston element is forced against a contained or sealed body of gas under pressure to further increase the pressure on the gas and is then released to be driven against the anvil at a high velocity by the sudden expansion of the gas.

Another and important object of this invention is to provide a jarring tool of the character just mentioned in which the hammer-piston element may have a long stroke or a stroke of any required extent. If the tool is constructed so that the hammer element has a long stroke the contained body of gas may be put under greatly increased pressure to operate the hammer with great speed and force. On the other hand, if the tool is constructed so that the hammer has a shorter stroke the gas is subjected to less compression and the hammer is actuated with less speed and force.

In my copending application entitled "Jarring tools," filed August 12, 1941, Serial No. 406,465, I have disclosed a jarring tool in which a hammer is forced against a body of gas under pressure by a cam means and is released to be driven against the anvil by the expanding gas upon the release or disengagement of the cam means. Certain prior jarring tools employ broken threads or cams for advancing a hammer against a spring and for providing relative longitudinal movement between the jar body parts. The cams employed in such tools can only provide a very short hammer stroke or a very short relative movement between the jar body parts, as the case may be, and the resultant jarring action is accordingly relatively weak. The tool of the present invention may be constructed to give the hammer or relatively movable parts a stroke of great length or of sufficient length to produce a very heavy jarring action.

Another object of this invention is to provide a well jar embodying novel hammer operating and controlling means capable of full operation by simple rotation of the fishing string in either direction.

Another object of this invention is to provide a jarring tool that may be easily prepared or set to produce a jarring action of any selected or required intensity or, if desired, may be conditioned to employ the high hydrostatic pressures in the well to increase the magnitude of the jar blows without a reduction in the velocity of movement of the hammer element.

A further object of this invention is to provide a jarring tool that is operable to produce a succession or series of heavy jarring blows by simple rotation of the operating string with or without tension on the string and which may be operated continuously or intermittently for a long period without a diminution in the magnitude of the jarring blows.

The various objects and features of my invention will be fully understood from the following detailed description of typical preferred forms and applications of the invention, throughout which description reference is made to the accompanying drawings, in which:

Fig. 1 is a central longitudinal detailed sectional view of one form of a jarring tool of the invention showing the hammer element latched in the retracted position. Fig. 2 is a fragmentary longitudinal detailed sectional view of the tool illustrated in Fig. 1 showing the latches released with the hammer element striking the anvil. Fig. 3 is a transverse detailed sectional view taken as indicated by line 3—3 on Fig. 1. Fig. 4 is a central longitudinal detailed sectional view of another form of the invention. Fig. 5 is a side elevation of the upper portion of the hammer element removed from the tool illustrating the latch slot. Fig. 6 is a side elevation of the travelling nut of the tool illustrated in Fig. 4 removed from the other elements. Figs. 7 and 8 are transverse detailed sectional views taken as indicated by line 7—7 and 8—8, respectively, on Fig. 4. Fig. 9 is a fragmentary longitudinal detailed sectional view showing the hammer element approaching the lower end of its downward stroke. Fig. 10 is a central longitudinal detailed sectional view of still another form of the invention. Fig. 11 is a fragmentary vertical detailed sectional view taken substantially as indicated by line 11—11 on Fig. 10. Fig. 12 is a fragmentary longitudinal detailed sectional view of the tool shown in Fig. 10 with the travelling nut at the lower end of its stroke and Fig. 13 is a transverse detailed sectional view taken as indicated by line 13—13 on Fig. 12.

The jarring tool of the invention illustrated in Figs. 1 to 3, inclusive, may be said to comprise, generally, a body 10, a cylinder 11 in the body 10, a movable or reciprocable hammer 12 in the cylinder 11, means 13 for providing and maintaining a body of gas under pressure under the hammer element 12, latch means 14 for releasably latching the hammer 12 in a position where it maintains the gas under increased pressure and means 15 for moving the hammer 12 to said position and for thereafter releasing the latch means 14.

The body 10 is an elongate hollow or tubular member to be interposed in a fishing string of drill pipe, or the like. In the particular case illustrated, the body 10 comprises an elongate tubular main section 16 having a cap 17 threaded in its upper end and a sub 18 threaded in its lower end, it being understood that the body may be varied considerably without departing from the invention. An internal annular flange 19 is provided on the cap 17 adjacent its upper end. A connecting member 20 having a suitable connection with the fishing string, not shown, has a reduced stem 21 extending downwardly through the flange 19 with suitable clearance. A nut or collar 22 is threaded or otherwise fixed on the stem 21 below the flange 19. Rows of anti-friction elements or balls 23 are engaged between the collar 22 and the lower side of the flange 19 and between the upper side of the flange 19 and a shoulder 24 on the member 20. The balls 23 operate in suitable races in the flange 19, the collar 22 and the shoulder 24. The nut or collar 22 turnably fits in the member 17 and carries packing 25 for sealing with the interior of the member. The structure just described constitutes a swivel connection between the member 20 on the fishing string and the body 10. The body 10 is in the nature of a shell and serves to conduct the circulation fluid downwardly around the cylinder 11. A passage 26 having communication with the fishing string extends downwardly through the member 20 to lateral ports 27 in the stem 21. The ports 27 in turn communicate with lateral ports 28 in the collar 22 which discharge into the interior of the body 10. A central longitudinal passage 29 is provided in the sub 18 and leads to the lower portion of the string or fish, not shown. One or more lateral ports 30 is provided in the sub 18 to place the interior of the body 10 in communication with the passage 29.

The cylinder 11 defines or provides the chamber 31 for containing the gas under pressure and for housing the reciprocable hammer 12. The cylinder 11 is supported in the body 10 for limited longitudinal movement and slidably or shiftably engages on a mandrel 32 depending from the stem 21 of the connecting member 20. The cylinder 11 may be varied considerably and, in the typical case illustrated, is an elongate tubular member provided at its upper end with a cap or head 33. The head 33 is preferably quite heavy and is threaded into the upper end of the cylinder 11 to provide a downwardly facing annular shoulder 34 in the cylinder. The upper end of the head 33 is flat and is adapted to bear or engage upwardly against the lower side of the collar 22 and the shoulder 35 of the stem 21 which lies in the same plane as the lower end of the collar. A central vertical opening 36 in the head 33 slidably passes the mandrel 32. Packing 37 is provided in the opening 36 to tightly seal with the

mandrel 32. The body of the cylinder 11 preferably has a rather heavy or thick wall. The cylinder 11, as just described, is centrally or coaxially arranged in the body 10 and is proportioned to leave an annular clearance space or passage between its periphery and the interior of the body 10 for conducting the circulation fluid.

The lower end of the cylinder 11 has packed sliding engagement with the sub 18. A boss 38 of reduced diameter is provided on the upper end of the sub 18 and is slidably received in the lower portion of the tubular cylinder 11. The means for slidably sealing between the cylinder 11 and the boss 38 may comprise packing 39 of the chevron type set in a recess in the cylinder 11 to slidably seal with the boss 38. The packing 39 preferably faces in both directions to prevent leakage from and into the cylinder. Means is provided for keying the cylinder 11 to the boss 38 and to limit longitudinal movement of the cylinder relative to the body 10. A keyway or groove 40 is formed in the interior of the cylinder 11 above the packing 39 and receives a key or pin 41 projecting from the boss 38. The keyway 40 is located and proportioned to allow the cylinder 11 to move upwardly until its head 33 engages the under side of the collar 22 and the shoulder 35. Fig. 1 of the drawings shows the cylinder 11 in its lowermost position where the upper end of the keyway 40 engages the pin 41 to stop the downward travel of the cylinder.

The hammer element 12 is movable or shiftable vertically in the cylinder 11, being operable in one direction by the means 15 and being moved or driven in the other direction with great force and speed by expansion of the confined gas under pressure contained in the lower portion of the cylinder. The hammer 12 is a weight element preferably formed and proportioned to have substantial weight and is a piston element being operable in the cylinder 11 to further compress the gas under pressure when moved in one direction and being operable in the other direction by the sudden expansion of the gas.

In the preferred construction, the hammer 12 is an elongate block-like part of cylindrical configuration having opposite end portions which slidably fit the cylinder 11. It is preferred to provide means on the hammer 12 for slidably sealing with the interior of the cylinder 11 to definitely separate the portions of the chamber 31 above and below the hammer. In the structure illustrated chevron type packing 42 is engaged on a reduced lower end portion of the hammer 12 and is actuated or compressed by a threaded-on nut or gland 43 to effectively seal with the internal surface of the cylinder 11. A central longitudinal opening or socket 44 enters the hammer 12 from its upper end and freely receives the mandrel 32. The socket 44 is of sufficient depth to entirely receive the mandrel 32. This allows the upper end of the hammer to directly strike against the shoulder 34.

The weight of the hammer 12 and the length of the hammer stroke are two important factors in determining the intensity of the jarring action produced by the tool. It is an important feature of the present invention that the stroke of the hammer 12 may be as long as required or desired, the means 15 being operable by simple rotation of the fishing string to feed the hammer 12 downwardly any required distance to give the hammer the necessary stroke. The cylinder 11 may be proportioned to provide for the selected or required hammer stroke with additional length for the length of the hammer 12 and for that portion of the cylinder chamber 31 below the hammer which contains the air or gas under pressure when the hammer is in its lowermost position. By increasing or decreasing the length of the hammer 12, its weight may be regulated or provided as desired and where the cylinder 11 may be of any selected length it will be seen that the hammer 12 may be given as great a weight as will be necessary under any conditions of operation.

The means 13 provides and maintains a body of air or other gas under pressure in the cylinder chamber 31 below the hammer 12 under super-atmospheric pressure. It is an important feature of the invention that the gas thus held under super-atmospheric pressure is operable to develop a greater hammer velocity and to impart a greater driving force to the hammer than any means employed in the jarring tools heretofore introduced. In accordance with the invention the hammer actuating gas is initially under substantial super-atmospheric pressure and this pressure is greatly increased or multiplied when the hammer 12 is forced down by the means 15 so that the gas is under a very high pressure at the time of release of the latch means 14 to throw the hammer 12 upwardly at a tremendous speed and with great force. It is preferred to construct the means 13 so that the gas pressure initially provided in the cylinder chamber 31 under the hammer 12 may be varied or changed to adapt the tool for any given operation and so that the high hydrostatic pressures in the well may be utilized to boost or increase the initial pressure on the gas. That portion of the cylinder chamber 31 below the hammer 12 constitutes the gas chamber, it being noted that the packing 39 seals off the lower end of this chamber by sealing between the cylinder 11 and the boss 38 and that the packing 42 seals off the upper end of the gas chamber by packing between the wall of the cylinder 11 and the hammer 12.

This sealed or packed off lower portion of the cylinder chamber 31 is pre-loaded or pre-charged with air or other gas under super-atmospheric pressure prior to running the tool into the well. The initial gas pressure provided in the lower portion of the cylinder chamber 31, that is, the gas pressure in the lower part of the cylinder with the hammer 12 in its uppermost position is one of the important factors in determining the intensity of the jarring blow produced by the device. The initial gas pressure may range from a few pounds per square inch to several thousand pounds per square inch depending upon the intensity of the jarring action desired and depending upon the length of stroke of the hammer 12. In general it may be said that when the hammer 12 is given a long stroke the initial gas pressure provided in the chamber 31 under the hammer 12 may be less than when the hammer is given a shorter stroke.

The means 13 preferably includes a ported valve structure for admitting air or gas under pressure to the cylinder chamber 31 and for bleeding or removing such pressure from the chamber. It is to be understood that the invention contemplates permanently sealing a body of gas under pressure in the chamber 31 under the hammer 12, in which case the valved means for admitting the gas to the chamber may not be required. In the construction illustrated a port 45 leads upwardly from the exterior of the sub 18 and through the boss 38 to communicate with the chamber 31. A spring loaded check valve 46 is provided in the

mouth portion of the port 45 and is arranged to close outwardly to retain the gas pressure in the cylinder chamber. The port 45 is equipped or formed to receive the nozzle or threading fitting of a pressure supply means, not shown. In the simple case illustrated, the outer end of the port 45 is threaded. A plug 47 is removably threaded in this outer portion of the port 45 to exclude the high hydrostatic pressure present in the well bore and to exclude the mud ladened well fluid. A second port is provided in the sub 18 to facilitate the leading or relieving of gas pressure from the cylinder chamber 31. In practice, this second port 48 may be a branch of the port 45. The port 48 is equipped with a normally closed valve 49 adapted to be opened or removed to permit bleeding of the chamber 31 or to relieve excess pressure from the chamber. The valve 49 may be in the nature of a needle valve carried by or actuated by a plug 50 threaded in the outer end of the port 48. It is to be understood that the valve 49 is normally closed and that the plug 50 is normally threaded in the port 48 so that gas cannot pass outwardly through the port and so that well fluids are excluded.

In conditioning or charging the lower portion of the cylinder chamber 31 the plug 47 is removed and the threaded fitting of a pump line or air pressure supply line is threaded in the port 45 to deliver the air or gas under pressure to the chamber 31. During this operation it is preferred to have the hammer 12 in its uppermost position to be later described. When selected gas or air pressure has been provided in the chamber 31 under the hammer 12 the plug 47 is returned to the port so that well fluids cannot leak into the well and so that the high external pressures that may be encountered in the well will not change the initial pressure provided in the chamber 31. In the event that it is desired to utilize the high hydrostatic pressures in the well to boost or increase the initial gas pressure provided in the chamber 31, under the hammer 12, the plug 47 is removed or left out of the port 45. In this case the valve 46 remains closed against the entrance of well fluids and pressures until the tool has reached a depth in the well where the hydrostatic pressures are greater than the initial gas pressure provided in the chamber 31, at which time the valve 46 opens inwardly to admit the well pressure to the lower end of the chamber 31. It is to be understood that the gas remains under high pressure in the cylinder chamber 31 under the hammer 12 and the liquid from the well occupies or enters only the lowermost part of the cylinder chamber. The use of the hydrostatic pressures to increase the initial gas pressure in the chamber 31 is not essential in every case and, in many uses of the tool, the plug 47 is left in the port 45 to exclude the well pressures from the chamber 31. The portion of the chamber 31 above the hammer 12 is sealed or closed by the previously described structure and when the hammer 12 is forced downwardly a reduced pressure is created above the hammer. This reduced pressure materially assists the expanding gas under pressure below the hammer 12 in driving the hammer upwardly with great velocity and force, as will be more fully described.

It may be desired to incorporate a spring 51 in the jar to assist the gas under pressure in driving the hammer 12 upwardly, it being understood that the spring is not essential to the tool or its operation and may be omitted if desired. In the drawings I have shown a coiled spring 51 arranged under compression between the lower end of the hammer 12 and the sub boss 38. A boss 52 on the lower end of the hammer 12 and a socket 53 formed in the boss 38 centralize and retain the spring 51. Where the spring 51 is employed it is preferred to construct it to be under compression when the hammer 12 is in its uppermost position in striking engagement with the collar 22 and to be under materially increased compression when the hammer 12 is in its lowermost position.

The latch means 14 is operable to hold the hammer 12 in its lowermost position, against the gas pressure and spring pressure which act upwardly against the hammer, and the latch means is released by the means 15 to allow the hammer 12 to be forcibly driven upwardly by the expanding gas and spring 51. The means 14 is such that it is automatically made operative or latched when the hammer 12 is moved to the lower end of its stroke by the means 15. The releasable latch means 14 includes one or more latches 54 carried by the hammer 12 for latching or cooperating with the mandrel 32. In the particular structure illustrated there are latches 54 arranged in two diametrically opposite slots 55 in the upper portion of the hammer 12. The latches 54 are alike, independent elements each pivoted on a transverse or horizontal pivot pin 56. The slots 55 extend longitudinally of the hammer 12 and have communication with the socket 44 throughout their lengths and extend outwardly to the exterior of the hammer 12 at their upper portions only. Each latch has a lower nose 57 and an upper nose 58. The lower noses 57 of the latches 54 are engageable with the lower end of the mandrel 32 to latch the hammer 12 against upward movement with respect to the mandrel body 10, etc. The lower end of the mandrel 32 may be provided with a downwardly projecting marginal lip 59 and the latch noses 57 are constructed to hook under this lip 59. Springs 60 are arranged under compression between the walls of the slots 55 and the lower portions of the latches 54 to urge the latch noses 57 inwardly for automatic cooperation with the lower end of the mandrel 32.

The upper noses 58 of the latches 54 project outwardly through the upper portions of the slots 55 to extend into longitudinal keyways or grooves 61 formed in the wall of the cylinder 11. The latch noses 58 engaged in the grooves 61 may key the hammer 12 against turning but it is preferred to provide keys 62 on the body of the hammer 12 to operate in the grooves 61 for this purpose. The lower ends of the keyways or grooves 61 terminate in abrupt upwardly facing shoulders 63 and the parts are proportioned so that these shoulders 63 occur immediately below or a very short distance below the noses 58 of the latches 54 when the cylinder 11 and the hammer 12 are both in their lowermost positions. Thus, as illustrated in Fig. 1 of the drawings, where the pin 41 is supporting the cylinder 11 in its lowermost position and where the latch noses 58 are engaged with the lower end of the mandrel 32 to hold the hammer 12 in its lowermost position the shoulders 63 are adjacent and below the latch noses 58. The outer ends of the latch noses 58 have upwardly and outwardly inclined surfaces 64 cooperable with the shoulders 63. As will be later described, the means 15 is operable to shift the cylinder 11 upwardly slightly subsequent to latching of the hammer 12 so that the shoulders

63 are made to cooperate with the surfaces 64 and pivot the latches 54 to release their noses 57 from the mandrel 32. Upon the release of the latch means 14 the hammer 12 is forcibly driven upwardly by the expanding gas and as the hammer travels upwardly the latches 54 remain in retracted positions such as illustrated in Fig. 2. The latches 54 also remain fully retracted during the downward or return movement of the hammer 12, the engagement of the faces of the noses 57 with the mandrel 32 holding the latches in the released position.

The means 15 serves to move the hammer 12 downwardly to its lowermost position where the latches 54 latch with the end of the mandrel 32 and where the gas is put under the maximum increased pressure and is operable thereafter to shift the cylinder 11 to cause the release of the latches 54 so that the hammer 12 may be driven upwardly by the rapidly expanding gas under super-atmospheric pressure. The means 15 is operable by simple rotation of the fishing string in either direction without regard to the vertical forces on the string, that is, the means 15 is fully and effectively operative with great or little tension on the string as desired. It is an important feature of the invention that the means 15 may be constructed to give the hammer 12 as long or as short a stroke as desired, thus distinguishing the present invention over prior jarring tools employing cam means operable by rotation of the string and capable of producing only a very short hammer stroke. The means 15 may force the hammer 12 against the contained gas under pressure for a substantial distance to greatly increase or multiply the gas pressure.

The means 15 is a thread means or screw means comprising a thread or groove in the mandrel 32 and a travelling nut 65 cooperating with the thread or groove. The thread of the mandrel 32 will be considered as a groove and, as illustrated, comprises two oppositely pitched portions A and B connected or joined at their ends to constitute a single continuous groove. The groove portions A and B may be termed the right and left hand portions, respectively, of the thread or groove having right and left hand pitches. The thread or groove portions A and B are of equal pitch or lead and are of equal uniform width and depth throughout their lengths. It is preferred to give the groove portions A and B a substantial pitch, as illustrated, to assure rapid travel of the nut 65. The groove portions A and B are square or rectangular in cross section having flat upper and lower walls and being of substantially the same width at their mouths and at their bases or inner walls. The portions A and B being pitched in opposite directions cross or intersect one another each 180° at the points or intersections C.

The right and left hand portions A and B of the continuous spiral groove or thread are joined at their upper and lower ends by what I will term reversing or connecting portions D formed to reverse the direction of travel of the nut 65. The reversing portions D have smoothly rounded or curved walls joining the oppositely pitched walls of the right and left hand groove portions A and B. Fig. 1 of the drawings clearly illustrate the manner in which the groove portions D connect the right and left hand groove portions A and B. The curvature of the groove walls in the portions D is such that the groove is slightly wider at these points for the purpose to be later described. The length of the above described thread or groove comprised of the oppositely pitched portions A and B determines the length of travel of the nut 65 and, therefore, determines the stroke of the hammer 12. It is important to note that the thread or groove A—B may be of any length required to give the hammer 12 the desired or necessary stroke. In the case illustrated, the groove A—B extends a substantial distance along the mandrel 32, it being understood that it may be made longer or shorter than illustrated.

The nut 65 is an annular or tubular member having a central opening slidably receiving the mandrel 32. The nut 65 is received in the chamber 31 with substantial clearance, being spaced a considerable distance from the internal wall of the cylinder. Means is provided for holding the nut 65 against rotation. A lug or ear 66 projects from the nut 65 and cooperates with one of the grooves 61 to hold the nut against turning. A recess 67 is provided in the under side of the cylinder head 33 to receive the nut 65 when the nut is in its uppermost position and the recess 67 has an extension or notch 68 for receiving the ear 66.

The nut 65 carries a follower for cooperating with the thread or groove A—B to produce up and down movement of the nut as the mandrel 32 rotates. A radial opening 69 is provided in the wall of the nut 65 to carry a block or rocker 70. The outer end of the opening 69 is closed by a plug 71 to prevent loss or displacement of the rocker 70. A lug or key 72 is provided on the inner end of the rocker 70 to cooperate with the groove A—B. The key 72 has flat upper and lower sides and is of such height or thickness that its sides readily ride on the upper and lower walls of the groove portions A and B. The width of the key 72 is substantial, being greater than the intersections C, that is, greater than the width of the spaces occurring where the portions A and B cross. This is important as it assures the continued movement of the key 72 through a given groove portion A or B and prevents the key from catching at an intersection C and from switching from one groove portion to the other at an intersection. However, the width of the key 72 is not so great that the key cannot be directed from one groove portion to the other at the reversing groove parts D. The curvatures of the groove walls at the reversing parts D are designed to direct the key 72 from one groove portion to the other. This direction or transference of the key 72 from one groove portion A or B to the other is accompanied by slight oscillation or turning of the rocker 70. It will be seen that with the grove and nut structure just described simple continued rotation of the mandrel 32 in a selected direction causes up and down movement of the nut 65 along the mandrel for a stroke or distance equal to the length of the groove A—B.

In the operation of the tool illustrated in Figs. 1 to 3, inclusive, it will be assumed that the tool is to be employed in jarring an object or fish caught in a deep well, such as an oil well or gas well. Prior to lowering the tool into the well air or other gas is supplied to the lower portion of the cylinder chamber 31 under the selected pressure. The threaded valved port 45 provides for the convenient delivery of the air under pressure to the lower portion of the cylinder chamber 31. The pressure employed may vary greatly and depends upon the nature of the jarring action, the capacity of the cylinder chamber 31, the stroke of the

hammer 12, etc. In most instances the plug 47 will be threaded in the port 45 following the delivery of the gas under pressure to the valve 31. The valve 49 remains closed. The jarring tool is connected in the fishing string, not shown, above the selected fishing tool and the string is run into the well to engage the fishing tool with the lost object or fish, all being in accordance with the usual practice. With the lower portion of the fishing string coupled with the object or fish by the fishing tool the equipment is in condition for jarring. In many instances it will be preferred or necessary to apply an up-pull or tension to the fishing string. It is a feature of the present invention that this tension may be continuously maintained throughout the jarring operations, may be of any selected intensity or may be varied and interrupted, if desired.

The tool is actuated to produce the jarring action by merely rotating the fishing string. This rotation may be continuous so long as the jarring action is required and may be as rapid or as slow as selected. Rotation of the fishing string causes up and down movement of the travelling nut 65. Assuming that the fishing string is rotated to the right the engagement of the key 72 in the left hand groove portion B causes downward travel of the nut 65. Further, assuming that the hammer 12 and the nut 65 are in their uppermost positions shown in Fig. 2 of the drawings the downward travel of the nut, just mentioned, results in downward movement of the hammer, the nut forcing the hammer down. The lug or key 72 engaged in the left hand groove portion B causes the nut 65 to move downwardly the full length of the groove A—B and the nut in turn forces the hammer 12 downwardly ahead of it. The downwardly travelling hammer 12 compresses the gas in the lower portion of the chamber 31. This gas is initially supplied to the chamber 31 under a super-atmospheric pressure and the downward travel of the hammer 12 greatly increases the pressure on the gas. The increase in pressure on the gas under the hammer 12 depends upon the length or volume of the cylinder chamber 31 and the stroke of the hammer 12. The downward movement of the hammer 12 also results in the creation of a vacuum or reduced pressure condition above the hammer. Accordingly, a very high gas pressure may exist below the hammer element 12 and a substantial negative pressure may exist above the hammer 12 by the time the hammer has reached the end of its downward movement. When the nut 65 approaches the lower end of its downward travel, that is, when the key 72 enters the lower reversing groove portion D the noses 57 of the latches 54 suddenly snap under the lower end of the mandrel 32 to assume positions such as illustrated in Fig. 1. This positively latches the hammer 12 in the down position where a greatly increased gas pressure condition exists under the hammer and a substantial negative pressure condition exists above the hammer.

The engagement of the key 72 in the lower reversing groove portion D causes the rocker 70 to turn slightly and directs the key 72 upwardly into the groove portion A. The engagement of the key 72 in the groove portion A of the rotating mandrel 32 causes the nut 65 to travel up on the mandrel. The nut travels upwardly on the mandrel until its upper end cooperates with the upper wall of the recess 67. This occurs before the key 72 is reversed or turned in the upper reversing groove portion D. Engagement of the upwardly travelling nut 65 with the wall of the recess 67 produces upward movement of the cylinder 11. This brings the shoulders 63 upwardly against the surfaces 64 and releases the latches 54 from the lower end of the mandrel 32. The release of the latches 54 just described occurs at a time when the nut 65 has raised the cylinder 11 to the position where the upper end of its head 33 is in engagement with the collar 22 and anvil shoulder 35 and at a time when the key 72 is in or entering the upper reversing portion D of the groove. When the latches 54 are released the hammer 12 is suddenly driven upwardly with great force by the instantaneous expansion of the high compressed gas under the hammer aided by the negative pressure above the hammer. The hammer 12 is forcibly driven upwardly at a high velocity and its upper end strikes the shoulder 34 with great force. The resultant impact or upward action is directly transmitted from the cylinder head 33 to the collar 22 and shoulder 35 in turn is transmitted to the string and the fish engaged by the fishing string.

The jarring impact generated depends upon several factors such as the weight of the hammer 12, the maximum pressure created under the hammer and the length of the hammer stroke. As pointed out above, the construction of the present invention permits the employment of a hammer 12 of any selected weight and makes it possible to give the hammer 12 a very long stroke or a shorter stroke, as desired.

As the rotation of the fishing string and mandrel 32 continue the key 72 travels through the upper reversing portion D of the groove to enter the down or left hand portion B of the thread or groove. The engagement of the key 72 in the groove portion B causes the nut 65 to travel down on the mandrel 32 and the nut forces the hammer 12 downwardly against the gas under pressure in the lower portion of the chamber 31 to further compress the gas. The nut and hammer move downwardly until the latches 54 again engage with the lower end of the mandrel 32 and the operations above described are repeated. It is important to note that the simple rotation of the operating string in either direction with any selected tension on the string will produce a series of heavy upward jarring blows so long as the rotation is continued, it being unnecessary to manipulate the fishing string in any way to provide for the repeated jarring actions. During the upward and downward travel of the hammer 12 the latches 54 remain in the retracted positions illustrated in Fig. 2. The inner sides of the latch noses 57 engage against the surface of the mandrel 32 to hold the latches in the retracted positions. Those portions of the noses 57 which contact the mandrel 32 are of such width or vertical extent that they cannot engage in the groove A—B.

The embodiment of the invention illustrated in Figs. 4 to 9, inclusive, may be said to comprise, generally, a body 75 having or providing a chamber 76, a hammer 77 operable in the chamber 76, means 78 for supplying and maintaining air or other gas under pressure in the lower portion of the chamber 76 and means 79 for forcing the hammer 77 against the gas under pressure contained in the chamber 76 and thereafter releasing the hammer to be driven against an end of the chamber by the expanding gas.

The body 75 is adapted to be interposed in a fishing string such as a string of well drill pipe and serves to house and carry the other elements

of the tool. As illustrated, the body 75 is an elongate hollow structure or tubular member provided at its opposite ends with means for facilitating its connection in the fishing string. In the case illustrated, a sub 80 is threaded in the lower end of the body 75 and may be considered as connected with the lower portion of the fishing string, not shown. A fluid passage 81 extends downwardly through the sub 80 to communicate with the lower part of the string. A connecting member 82 is threadedly connected with the upper end of the body 75. An internal annular flange 83 is provided in the connecting member 82 at a point between its ends. A member or sub 84 of the fishing string has a stem 85 which passes downwardly through the annular flange 83 with clearance. A nut or collar 86 is threaded or otherwise fixed to the stem 85 below the flange 83. Series of balls 87 are arranged in opposing races in the under side of the flange 83 and the upper side of the collar 86 and in the upper side of the flange 83 and a downwardly facing shoulder 88 on the sub 84. Packing 89 on the collar 86 seals with the interior of the member 82 below the flange 83 and similar packing 90 seals between the sub 84 and the member 82 above the flange 83. The structure just described constitutes a packed swivel connection between the jar body 75 and the fishing string.

In accordance with this form of the invention a mandrel 91 extends downwardly from the stem 85 and may pass completely through the body 75 to the sub 80. The mandrel 91 serves to carry certain elements of the means 79 and further serves to conduct the circulation fluid downwardly through the tool. The lower portion of the mandrel 91 is received in the passage 81 of the sub 80. A passage 92 extends downwardly through the sub 84 from the well string and continues down through the stem 85 and the mandrel 91 to discharge directly into the passage 81 of the sub 80. The mandrel 91 is preferably of uniform external diameter.

The hammer 77 is arranged in the body chamber 76 to travel longitudinally therein. The hammer 77 is in the nature of a piston operable to compress the gas under pressure when moved in one direction and adapted to be operated or driven in the other direction by the expanding gas and is in the nature of a hammer or weight element having substantial dynamic inertia for striking a part of the body when thus driven or actuated by the expanding gas. The hammer 77 is an elongate member received in the body chamber 76 with suitable clearance and is chambered or provided with an enlarged opening 109 between its ends to have its major portion entirely clear of the mandrel 91. A tubular head or plug 93 is threaded in the lower end of the hammer 77 to slidably ride on the mandrel 91. The hammer 77 is provided with a heavy or thickened upper wall portion 94 which likewise slidably rides on the mandrel 91. The upper end of the hammer 77 is flat and extensive and is adapted to strike upwardly against the face presented by the lower end of the collar 86 and the lower end of the stem 85, which face I will term the anvil 95. The hammer 77 just described, is of substantial length to house or contain various elements of the means 79. The weight of the hammer 77 may be varied to suit the tool for different operations. The weight of the hammer 77 is one of the elements or factors which governs the intensity of the jarring effect and this factor may be changed as conditions may require.

The means 78 provides for the supplying of air or other gas under pressure to the body chamber 76 below the hammer 77 and for maintaining a charge or body of gas under pressure in the chamber. In accordance with the invention the portion of the body chamber 76 below the hammer 77 is pre-charged or pre-loaded with gas or pressure prior to introducing the tool into the well. While the charge of gas under pressure may be permanently sealed in the chamber 76 it is preferred to construct the means 78 so that the tool may be supplied with a charge of air or gas under a selected pressure before running the tool into the well and so that the pressure on the gas may be increased or decreased as operating conditions may require. The means 78 includes a port 96 leading from the exterior of the sub 80 and extending upwardly to communicate with the lower end of the body chamber 76. The port 96 has a spring loaded check valve 97 which closes outwardly to prevent the discharge of the gas under pressure and which may be opened inwardly to admit fluid under pressure. The mouth of the port 96 is prepared to receive the fitting of a pressure supply means such as an air hose fitting or the fitting on a pump. A plug 98 is threaded in the outer portion or mouth of the port 96 and under most operating conditions is retained in the port to prevent the entrance of the well fluids to the port.

The means 78 further provides for the bleeding or discharge of gas under pressure from the body chamber 76. The port 96 may have a branch port 99 leading to the exterior of the sub 80. A valve, say a needle valve, 100 sets inwardly to close the port 99. The needle valve 100 is carried or actuated by a plug 101 threaded in the mouth of the port 99. The valve 100 is readily opened to permit the discharge of gas from the body chamber 76 for the purpose of reducing the pressure within the chamber and for the purpose of bleeding well liquid from the chamber if this becomes necessary.

The means 78 embodies packing structures for sealing off the opposite ends of the chamber 76 to prevent the escape of the air or gas under pressure therefrom. A socket is provided in the top of the sub 80 and contains packing 102 sealing about the mandrel. The packing 102 may be chevron type packing arranged to face in both directions and actuated or compressed by a follower 103 to effectively prevent the leakage of fluid in both directions. It will be observed that there is no relative longitudinal movement between the mandrel 91 and the sub 80 but that there is relative rotation between these parts and the packing 102 may be of a type which effectively seals between relatively rotating members. The means for packing up between the hammer 77 and the body 75 may comprise a body of chevron type packing 104 surrounding the plug 93 to seal with the wall of the chamber 76 and actuated by a threaded follower 105. The lower end of the plug 93 is relieved or recessed to carry packing 106 for sealing with the mandrel 91. The packing 106 may be of the chevron type and may be actuated by a threaded follower 107.

It will be observed that the cylinder chamber 76 is completely sealed at both ends and that the hammer 77 forms a closed piston sealing with the walls of the chamber 76 and with the mandrel 91 to partition or completely separate the upper and lower portions of the chamber. The lower portion of the chamber 76 contains the air or gas under pressure admitted by the means 78 and

operation of the hammer 77 produces a negative or reduced pressure condition in the upper portion of the chamber during certain phases of the operation. The lower portion of the chamber 76 is charged with the selected initial gas pressure, while the hammer 77 is in the uppermost position illustrated in Fig. 4. Upon downward movement of the hammer 77 the pressure below the hammer is greatly increased and a reduced pressure or negative pressure condition is created above the hammer.

If desired, a spring S may be provided to assist the expanding gas in driving the hammer 77 upwardly against the anvil 95. The spring S is arranged in the lower portion of the chamber 76 and is under compression between the sub 80 and the under side of the plug 93. The spring S is in surrounding relation to the mandrel 91 to be held against displacement thereby.

The hammer operating and controlling means 79 is a feature of the invention. The means 79 is operable by simple rotation of the fishing string in either direction to force the hammer 77 downwardly in the chamber 76 to increase the gas pressure below the hammer and to create a reduced pressure above the hammer and the means 79 then operates to release the hammer so that it is driven upwardly with great force and speed to strike against the anvil 95. The means 79 repeats these operations to provide a succession of heavy jarring blows so long as rotation of the fishing string and mandrel 91 continues.

The means 79 includes a travelling nut 108. The nut 108 is an elongate tubular member freely sliding on the mandrel 91 and received in the opening 109 of the hammer 77 with clearance. The means 79 further includes threads or spiral grooves in the mandrel 91 and parts on the nut 108 cooperating with the grooves. In the form of the invention being described there are two like double spiral grooves formed in the mandrel 91 and spaced a short distance apart to be entirely independent of one another. Each of these grooves includes a right hand groove portion F helically pitched or spiralled in the right hand direction, a left hand portion G spiralled in the left hand direction and connecting portions H connecting or joining the corresponding ends of the groove portions F and G. The oppositely pitched groove portions F and G cross at intersections J. The groove portions F and G are of uniform pitch and of equal width and depth throughout their lengths and connecting portions H join the corresponding ends of the right and left hand portions so that the grooves are continuous or without ends. The portions H are smoothly or gradually curved and may be slightly wider than the other parts of the grooves. The grooves F—G are formed so that the connecting portions H of one groove are at the opposite side of the mandrel 91 from the connecting portions H of the other groove F—G. The grooves are preferably square or rectangular in cross section having substantially flat upper and lower walls and have a steep or substantial lead. The length of the grooves F—G determines the stroke of the hammer 77. The length of the hammer stroke is one of the factors determining the intensity of the jarring action obtained and, in accordance with the invention, the length of the grooves F—G may be great or small, as desired, to give the hammer 77 the required stroke for the jarring action desired. This is a marked advantage over prior jarring tools employing cam means for actuating the hammers in which the hammer strokes are definitely limited.

In this form of the invention the hammer 77 carries a key part for cooperating with each of the two grooves F—G. Cylindrical pins or rockers 110 are turnably supported in radial openings 111 in the wall of the tubular hammer 108. The rockers 110 are held against displacement by the wall of the hammer opening 109 and the surface of the mandrel 91. The inner ends of the rockers 110 have lugs or keys 112 for cooperating with the grooves F—G. The keys 112 are diametric of the longitudinal axes of the respective rockers 110 and are elongate in transverse cross section having flat upper and lower sides of the substantial extent for cooperating with the upper and lower walls of the groove F—G. The width of the keys 112 is greater than the width of the intersections J so that the keys readily bridge or pass through the intersections J without being caught and without taking the wrong course. However, the keys 112 are not of such excessive width that they cannot move through the connecting portions H of the grooves and the substantial width of the keys is the reason for making the grooves H of slightly greater width than the other portions of the grooves F and G. When the keys 112 reach the connecting groove portions H they are directed by the portions H in such a way that their rockers 110 turn on their longitudinal axes and the groove portions H guide or direct the keys from one groove portion F or G to the other so that the keys may travel through, say the groove portions F and then enter and travel through the groove portions G.

The pins or rockers 110 are provided in diametrically opposite sides of the mandrel 91 and are preferably arranged in a common vertical plane but occupy vertically spaced horizontal planes so that one key 112 cooperates with the upper groove and the other key cooperates with the lower groove. The vertical spacing of the keys 112 is such that they cooperate with corresponding parts of the two grooves, that is, both keys may cooperate with the upper portions of the two grooves F—G when the parts are in the position shown in Fig. 4 and the spacing of the keys remains constant. The pins or rockers 110 are provided in the upper and lower portions of the nut 108 so that the nut is well balanced and will not bind on the mandrel 91. Further, it will be understood that the loads are equally divided between the two keys 112 relieving the individual keys to excessive loading. Upon rotation of the fishing string and mandrel 91 the keys 112 travel through the grooves F—G from their upper ends to their lower ends and then back to the upper ends and the downward movement of the nut 108 is transmitted to the hammer 77 by the releasable latch means to be presently described. The nut 108 has splines or keys 113 engaged in grooves 114a in the hammer 77 to be held against rotation relative to the hammer and the hammer 77 in turn is keyed to the body 75 by the latch means to be described below.

The hammer actuating means 79 further includes latch mechanisms for releasably connecting the nut 108 with the hammer 77 to transmit downward movement to the hammer and for releasing the hammer for free upward movement at the completion of the down stroke. The latch means includes one or more longitudinal slots 114 in the wall of the hammer 77. In the pre-

ferred arrangement illustrated, there are two diametrically opposite slots 114. The slots 114 are straight and are of uniform width and configuration except at their upper ends where they are provided with enlargements or openings 115. The slot enlargements or openings 115 provide upwardly facing shoulders 116 at the upper ends of the slots 114.

The nut 108 carries latches 117 for transmitting downward movement from the nut to the hammer 77. The latches 117 are set in radial sockets 118 in the hammer 108 and are urged outwardly by springs 119 arranged under compression between the inner sides of the latches and the bottoms of the sockets. The latches 117 are preferably located substantiially midway between the opposite ends of the nut 108. The lower portions of the latches 117 cooperate with the wall of the hammer opening 109 to limit the outward travel of the latches. The latches 117 are considerably wider than the slots 114 and cannot enter the slots. The upper portions of the latches 117 have noses or lugs 120 extending outwardly and adapted to enter the openings 115. The latches 117 may be cylindrical and the lugs 120 may be semi-cylindrical to have flat lower sides. When the latch lugs 120 are received in the openings 115 their flat lower sides are engageable downwardly against the shoulders 116. The sturdy latch lugs 120 cooperable with the flat shoulders 116 at opposite sides of the nut 108 are operable to dependably transmit the downward forces from the travelling nut 108 to the hammer 77.

Cam means is provided for releasing the latches 117 from the hammer 77 when the nut 108 approaches the lower end of its downward stroke. The cam means includes internal projections or cam parts 121 on the body 75. The cam parts 121 extend into the slots 114 of the hammer 77. The upper sides of the cam parts 121 present downwardly and inwardly pitched surfaces 122 engageable by the under sides of the latch lugs 120. The parts are proportioned and related so that the under sides of the latch lugs 120 cooperate with the surfaces 122 to retract the latches, and thus disengage the lugs from the openings 115, shortly before the keys 112 reach the lower ends of their respective grooves F—G, thus providing for over-travel of the nut 108 following the release of the hammer 77. This completely relieves the keys 112 of hammer-pushing forces when the keys are being directed by or passed by the groove portions H. Further, the parts are related and proportioned so that the nut 108 over-travels or begins its downward stroke before it starts to transmit downward movement to the hammer 77. Assuming the hammer 77 to be at its uppermost position against the anvil 95 and assuming that the nut 108 has reached the upper end of its stroke and the rotation of the mandrel 91 is continuing the keys 112 will travel through the upper connecting portions H of the grooves to be directed thereby to the right or left hand portions F or G, as the case may be, and will begin moving down through said groove portions before the latches 117 become effective in transmitting downward movement from the nut 108 to the hammer 77. When the nut 108 reaches the upper end of its stroke or slightly before, the latch lugs 120 move out into the openings 115. The openings 115 are of greater vertical extent than the lugs 120 and when the keys 112 pass through the upper connecting portions H of the grooves and start to travel down the spiral groove portions F or G the latch lugs 120 move down in the openings 115. The latch lugs 120 move down through the openings 115 a short distance before their lower ends strike the shoulders 116. This allows the keys 112 to fully enter the main groove portions F or G before assuming the transmission of downward forces from the nut to the hammer 77.

In operating the tool illustrated in Figs. 4 to 9, inclusive, the portion of the chamber 76 under the hammer 77 is charged with air or other gas under the selected pressure prior to introducing the tool into the well. This may be readily done by removing the plug 98 and securing a pressure hose in the mouth of the port 96 to deliver the gas under pressure to the chamber 76. The pressure initially provided in the chamber 76 may be varied to adapt the tool for the particular requirements of the operation. In most instances, the plug 98 will be replaced prior to introducing the tool into the well. The fishing string, not shown, in which the jarring tool is connected is run into the well and is connected with the fish or lost object by a fishing tool, not shown, in the usual manner. When this has been done a selected up strain is put on the string and the string is rotated either to the right or the left. It is to be understood that the tensile strain applied to the string may be constant throughout the jarring operations and may be of selected intensity or, if desired, may be varied in intensity.

Assuming that the hammer 77 is at the upper end of its stroke and that the fishing string is rotated to the right the keys 112 start down the left hand portions G of the spiral groove and as they begin their downward travel the latch lugs 120 move down in the openings 115. As the downward travel of the nut 18 continues the under side of the lugs engage the shoulders 116 for the transmission of downward movement from the nut to the hammer 77. The hammer 77 is forced downwardly against the gas under pressure in the lower portion of the chamber 76 to greatly increase the pressure. As the hammer 77 moves downwardly a reduced pressure or negative pressure is produced above the hammer. In practice, the down stroke of the hammer may be of such length that the gas pressure under the hammer is greatly multiplied before the hammer reaches the lower end of its stroke and so that a substantial negative pressure is developed above the hammer. Shortly before the nut 108 reaches the lower end of its downward travel the latch lugs 120 come into engagement with the cam surfaces 122 and the surfaces retract the lugs from the openings 115. Upon disengagement of the latch lugs 120 from the openings 115 the hammer 77 is released from the nut 108 and is suddenly driven upwardly with great force and at a high velocity by the expanding gas held at a very high pressure under the hammer. The negative pressure condition existing above the hammer 77 and the spring S, where used, assist in driving the hammer upwardly. The hammer moving upwardly at a high velocity and with great force strikes against the anvil 95 to impart a heavy upward blow to the body 75. The nut 108 may continue its downward travel while the hammer 77 is being driven upwardly and the keys 112 finally move through the lower groove portions H into the right hand groove portions F.

As rotation of the mandrel 91 is continued the keys 112 travel upwardly through the groove por-

tions F until the nut 108 reaches the end of its upward stroke. During this interval the hammer 77 is held against the anvil 95 by the spring S and the gas under pressure in the chamber 76. The keys 112 move through the groove portions H at the upper ends of the grooves and start back down through the groove portions G. During or prior to movement of the keys through the upper groove portions H the latch lugs 120 move out into the openings 115. When the nut 108 starts to move downwardly the latch lugs 120 move down in the openings 115. This downward movement of the latch lugs 120 in the openings 115 allows the keys 112 to fully engage in the groove portions F before the lugs engage the shoulders 116 for the transmission of downward force to the hammer 77.

So long as rotation of the fishing string and mandrel 91 continue, the above described operations are repeated, the hammer 77 being repeatedly driven upwardly against the mandrel 91 with great force to impart heavy jarring blows to the body 75. It is to be observed that in this form of the invention the hammer 77 moves downwardly with the nut when the nut approaches the end of its downward stroke and there is no delay or time interval during which the gas, put under increased pressure by downward movement of the hammer, may leak upwardly past the hammer into the upper portion of the chamber 76. This provides for more efficient operation of the tool.

If desired, the plug 98 may be left out of the port 96 when running the tool into the wall. In this case the valve 97 remains closed until the hydrostatic pressure in the well is greater than the gas pressure in the chamber 76. When the tool has reached a position where these conditions exist hydrostatic pressure is admitted from the well to boost or increase the gas pressure in the chamber 76 to provide for a heavier jarring action. It is to be noted that in this embodiment of the invention the nut 108 is balanced by the engagement of the vertically spaced oppositely directed keys 112 in the two spiralled grooves F—G and that the strains and wear are equally divided between the two keys.

Figs. 10 to 13, of the drawings, illustrate a modification of the general construction of Figs. 4 to 9, inclusive, in which the nut 108^a carries two keys for cooperating with a single double endless spiral groove in the mandrel 91. The body 75, the mandrel 91 and the means 78 may be the same as above described and the hammer 77^a may be substantially the same and corresponding reference numerals are applied to corresponding parts in the two forms of the invention.

The nut 108^a is substantially the same as the nut 108, being a tubular member freely slidable on the mandrel 91. The nut 108^a is keyed with the hammer 77^a, as at 200, and carries the latches 117 having lugs 120 cooperable with the openings 115 in the hammer 77^a and released by the cams 121 projecting into the grooves 114, all as above described. A single continuous double spiralled groove R—L is provided in the mandrel 91. The groove is comprised of the right and left hand portions R and L, respectively, joined at their opposite ends by connecting portions M. The right and left hand groove portions R and L intersect at intersections N. The groove R—L may be substantially the same as the groove A—B described above, and may be of the selected length. The connecting portions M may be slightly wider than the other parts of the groove.

The nut 108^a carries two tumbler blocks or rockers 130^x and 130^y, turnably carried in radial openings 131 in the wall of the nut 108^a. In accordance with the invention the rockers 130^x and 130^y are provided in diametrically opposite sides of the nut 108^a but for reasons which will later become apparent the rockers are offset vertically a distance equal to one-half the lead of the threads or double groove R—L. Keys 132^x and 132^y similar to the keys 112 described above are provided on the inner ends of the rockers 130^x and 130^y to cooperate with the groove R—L. The vertical offsetting of the rockers 130^x and 130^y relates the keys 132^x and 132^y so that the two keys may simultaneously cooperate with the same groove portion R or L.

Where the rockers 130^x and 130^y are vertically offset it will be seen that the rocker key 130^x will reach the upper end of the groove R—L before the key 132^y and that upon downward movement of the nut 108^a the key 132^y will reach the lower end of the groove before the key 132^x. The invention provides means for turning the rocker keys 132^x and 132^y to start them through another portion R or L of the groove when they do not get the opportunity to move through the connecting or reversing portions M of the groove. This means includes longitudinal slots 134^x and 134^y in the walls of the hammer 77^a in the vertical planes of the rockers 130^x and 130^y. Crank pins or control pins 135^x and 135^y are provided on the outer ends of the rockers 130^x and 130^y, respectively, to freely move through the grooves 134^x and 134^y, respectively. The slots 134^x and 134^y are vertically staggered, the slot 134^x having its upper end above the plane occupied by the upper end of the slot 135^y and the slot 135^y having its lower end in a plane below the plane occupied by the lower end of the slot 134^x.

Assuming that the string and mandrel 91 are being turned to the right and that the nut 108^a is approaching the upper end of its upward stroke the key 132^x will move upwardly from the groove portion R and through the connecting portion M to the left hand groove portion L to start the hammer on its downward movement. When the key 132^x is moving through the reversing portion M of the groove the pin 135^y is engaging with the upper end of the slot 134^y and this engagement turns or pivots the rocker 130^y in a direction to align the key 132^y with the left hand groove portion L. The intersection N in which the key 132^y turns may be slightly widened to permit this turning. Thus, when the key 132^x starts down the groove portion L the key 132^y is conditioned to likewise move down the groove portion L.

When the nut 108^a approaches the lower end of its downward movement with the mandrel 91 being turned to the right the key 132^y will move from the groove portion L into the lower connecting groove portion M and the groove portion M will direct it into the groove portion R. During the guiding or directing of the key 132^y through the lower groove portion M the pin 135^x is engaged with the lower wall of the slot 134^x and the slight downward movement of the nut 108^a is such that this engagement causes the rocker 130^x to turn. This turning of the rocker 130^x turns its key 132^x in the lower intersection N bringing the key in alignment with the groove portion R. The lower intersection N may be slightly widened to permit this turning of the key. When the nut 108^a starts upwardly through

cooperation with the key 132y with the groove portion R the key 132x is likewise engaged in the groove R so that the loads or forces are equally divided between the two keys.

Detent means are provided for releasably holding the rockers 130x and 130y in the positions where their keys 132x and 132y are set or positioned to cooperate with the right and left hand groove portions R and L. These detent means comprise spaced sockets or dimples 137 in the peripheries of the rockers 130x and 130y. Spring urged detents 138 (Fig. 13) are set in openings in the wall of the nut 108a to cooperate with the dimples 137. The dimples 137 are located to receive the detents 138 when the rockers 130x and 130y are in the positions where their keys 132x and 132y are pitched to move through the groove portions R and L.

The tool illustrated in Figs. 10 to 13 operates in substantially the same manner as the tool shown in Figs. 4 to 9, inclusive. With the tool in operative position in the well the fishing string is rotated while under a selected tensile strain. The engagement of the keys 132x and 132y in the groove R—L feeds the nut 108a up and down on the mandrel and the latch lugs 120 cooperating with the openings 115 drive the hammer 77 down during down strokes of the nut and the cams 121 release the latches 117 at the completion of the down strokes so that the hammer is forcibly driven upwardly at high speed and with great force to strike against the anvil 95.

While I have herein illustrated and described the several jarring tools of this invention as employed to create upward jarring actions it is to be understood that the invention contemplates inverting the tools to produce downward jarring actions. When downward jarring actions are desired the tool is connected in the fishing string in an inverted position from that shown in the drawings. The tool is operated substantially the same as above described, that is, the fishing string is rotated to produce a succession of jarring blows which, in this case, will be downwardly directed.

Having described typical preferred forms and applications of my invention, I do not wish to be limited or restricted to the specific details herein set forth, but wish to reserve to myself any variations or modifications that may appear to those skilled in the art or fall within the scope of the following claims:

Having described my invention, I claim:

1. In a well tool, two sections connected for relative turning and adapted to be interposed in a well string, one section having a longitudinal cylinder with a shoulder therein, a hammer shiftable in the cylinder, means maintaining a fluid-tight seal between the hammer and cylinder, the portion of the cylinder at one side of the hammer containing gas under pressure, and means operable by relative turning of the sections for moving the hammer against the gas under pressure to increase the pressure thereon and for then releasing the hammer to move in the other direction under the action of the expanding gas to strike against the shoulder.

2. In a well tool, two sections connected for relative turning and adapted to be interposed in a well string, one section having a longitudinal cylinder with a shoulder therein, a hammer shiftable in the cylinder, means maintaining a fluid-tight seal between the hammer and cylinder, means for introducing gas under pressure to the cylinder below the hammer, and means operable by relative turning of the sections for moving the hammer longitudinally against the gas under pressure to increase said pressure and produce a low pressure condition at the other side of the hammer and releasable by said relative turning following a given movement of the hammer to allow the hammer to move in the other direction under the action of the expanding gas and reduced pressure condition so that it strikes a jarring blow against the shoulder.

3. In a well tool, two sections connected for relative turning and adapted to be interposed in a well string, one section having a longitudinal cylinder with a shoulder therein, a hammer shiftable in the cylinder, means maintaining a fluid-tight seal between the hammer and cylinder, means for introducing gas under pressure to the cylinder below the hammer, means operable by relative turning of the sections for moving the hammer longitudinally against the gas under pressure to increase said pressure and produce a low pressure condition at the other side of the hammer and releasable by said relative turning following a given movement of the hammer to allow the hammer to move in the other direction under the action of the expanding gas and reduced pressure condition so that it strikes a jarring blow against the shoulder, and means for relieving the pressure at the first named side of the hammer.

4. In a well tool, two sections related for relative movement, one section having a sealed longitudinal cylinder with a shoulder therein, a hammer member slidable in the chamber, means maintaining a sealing connection between the hammer and the wall of the chamber, there being an initial charge of gas under pressure in the lower end portion of the cylinder, a spring in said lower end portion of the cylinder, and means operable by relative turning of the sections for moving the hammer member relative to a section to compress the gas and spring and for then releasing the hammer member to be forcibly driven against the shoulder by the expanding gas and spring.

5. In a well tool, two sections connected for relative turning and adapted to be interposed in a well string, one section having a longitudinal cylinder with a shoulder therein, a hammer shiftable in the cylinder, means maintaining a fluid-tight seal between the hammer and cylinder, the portion of the cylinder below the hammer normally containing gas under pressure, means for introducing gas under pressure to said side of the cylinder operable to exclude well pressure from the cylinder, and means operable by relative turning of the sections for moving the hammer against the gas under pressure to increase the pressure thereon and for then releasing the hammer to move in the other direction under the action of the expanding gas to strike against the shoulder.

6. In a well tool, two sections connected for relative turning and adapted to be interposed in a well string, one section having a longitudinal cylinder with a shoulder therein, a hammer shiftable in the cylinder, means maintaining a fluid-tight seal between the hammer and cylinder, the portion of the cylinder below the hammer normally containing gas under pressure, and means operable by relative turning of the sections while maintaining a selected tension on the string and sections for moving the hammer against the gas

pressure to increase the same and operable by said turning to release the hammer to move in the other direction under the action of the expanding gas to strike against the shoulder while said tension is maintained.

7. In a well tool, two sections connected for relative turning and adapted to be interposed in a well string, one section having a longitudinal cylinder, a hammer shiftable in the cylinder, the portion of the cylinder at one side of the hammer containing gas under pressure, and means operable by a plurality of relative revolutions between the sections for moving the hammer against the gas under pressure to increase the pressure thereon and for releasing the hammer to move in the other direction under the action of the expanding gas to jar against the section having the chamber.

8. In a well tool, two sections connected for relative rotation, one section having a chamber, a mandrel on the other section, a hammer slidably sealing in the chamber, the portion of the chamber at one side of the hammer containing gas under superatmospheric pressure, a nut adapted to travel along the mandrel, thread means operable to move the nut back and forth on the mandrel upon relative rotation between the sections, and means for connecting the nut with the hammer to move the same against the gas to increase pressure thereon during movement of the nut in one direction and releasable to allow the hammer to be forcibly driven against a section by the expanding gas.

9. In a well tool, two sections connected for relative rotation, one section having a chamber, a mandrel on the other section, a hammer slidably sealing in the chamber, the portion of the chamber at one side of the hammer containing gas under superatmospheric pressure, a nut adapted to travel along the mandrel, thread means operable to move the nut back and forth on the mandrel upon relative rotation between the sections, and means for connecting the nut with the hammer to move the same against the gas to increase pressure thereon during movement of the nut in one direction and releasable to allow the hammer to be forcibly driven against a section by the expanding gas, the last named means including a latch for releasably connecting the nut and hammer.

10. In a well tool, two sections connected for relative rotation, one section having a chamber, a mandrel on the other section, a hammer slidably sealing in the chamber, the portion of the chamber at one side of the hammer containing gas under superatmospheric pressure, a nut adapted to travel along the mandrel, thread means operable to move the nut back and forth on the mandrel upon relative rotation between the sections, and means for connecting the nut with the hammer to move the same against the gas to increase pressure thereon during movement of the nut in one direction and releasable to allow the hammer to be forcibly driven against a section by the expanding gas, the last named means including a latch for releasably connecting the nut and hammer, and means for releasing the latch when the nut approaches the end of its travel in said direction.

11. In a well tool, two sections connected for relative rotation, one section having a chamber, a mandrel on the other section, a hammer slidably sealing in the chamber, the portion of the chamber at one side of the hammer containing gas under superatmospheric pressure, a nut adapted to travel along the mandrel, thread means operable to move the nut back and forth on the mandrel upon relative rotation between the sections, and means for connecting the nut with the hammer to move the same against the gas to increase pressure thereon during movement of the nut in one direction and releasable to allow the hammer to be forcibly driven against a section by the expanding gas, the last named means including a latch for releasably connecting the nut and hammer, and means for releasing the latch during movement of the nut in the other direction.

12. In a well tool, two sections connected for relative rotation, one section having a chamber, a mandrel on the other section, a hammer slidably sealing in the chamber, the portion of the chamber at one side of the hammer containing gas under superatmospheric pressure, a nut adapted to travel along the mandrel, thread means operable to move the nut back and forth on the mandrel upon relative rotation between the sections, and means for connecting the nut with the hammer to move the same against the gas to increase pressure thereon during movement of the nut in one direction and releasable to allow the hammer to be forcibly driven against a section by the expanding gas, the last named means including a latch on the nut cooperable with the hammer, and a part on the first named section for releasing the latch when the nut approaches the end of its travel in said direction.

13. In a well tool, two sections connected for relative rotation, one section having a chamber, a mandrel on the other section, a hammer slidably sealing in the chamber, the portion of the chamber at one side of the hammer containing gas under superatmospheric pressure, a nut adapted to travel along the mandrel, a continuous groove in the mandrel having portions pitched in opposite directions and connected at their opposite ends, a part on the nut cooperable with the groove to cause the nut to travel back and forth on the mandrel upon relative rotation between the sections, and means operable by said back and forth movement of the nut for forcing the hammer against the gas to increase the pressure thereon and then releasing the hammer to be forcibly driven back against the end of the chamber by the expanding gas.

14. In a well tool, two sections connected for relative rotation, one section having a chamber, a mandrel on the other section, a hammer slidably sealing in the chamber, the portion of the chamber at one side of the hammer containing gas under superatmospheric pressure, a nut adapted to travel along the mandrel, a continuous groove in the mandrel having portions pitched in opposite directions and connected at their opposite ends, parts on the opposite sides of the nut cooperable with the groove to cause the nut to travel back and forth on the mandrel upon relative rotation between the sections, and means operable by said back and forth movement of the nut for forcing the hammer against the gas to increase the pressure thereon and then releasing the hammer to be forcibly driven back against the end of the chamber by the expanding gas.

15. In a well tool, two sections connected for relative rotation, one section having a chamber, a mandrel on the other section, a hammer slidably sealing in the chamber, the portion of the chamber at one side of the hammer containing

gas under superatmospheric pressure, a nut adapted to travel along the mandrel, two separate continuous grooves in the mandrel each having portions spiralled in opposite directions with said portions joined at their corresponding ends, parts on the nut cooperable with said grooves to cause the nut to travel back and forth on the mandrel when one section is rotated relative to the other, and means for transmitting movement of the nut in one direction to the hammer so that the hammer is forced against the gas and is then driven back by the compressed gas to jar against an end of the chamber.

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