

June 1, 1954

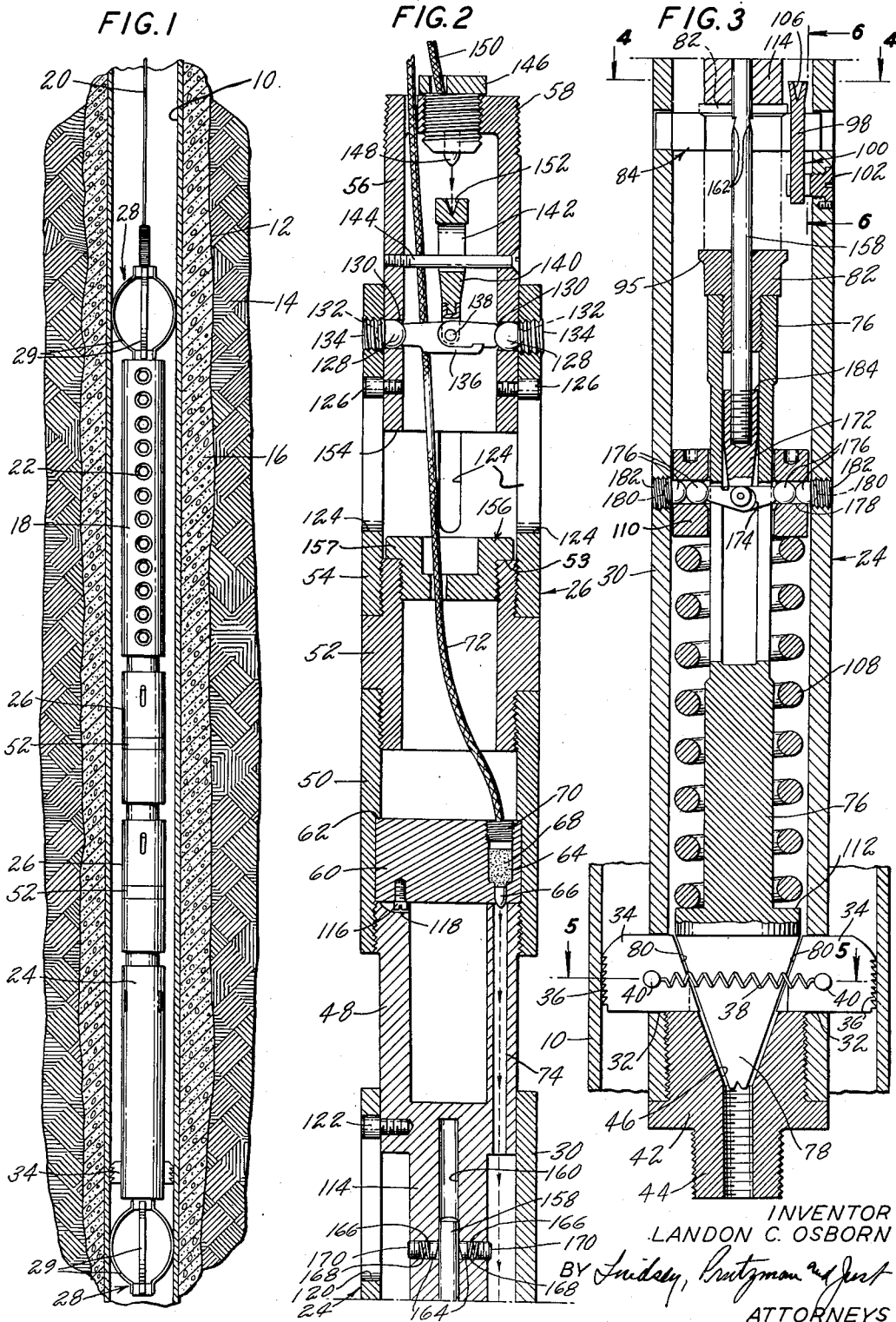
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MECHANISM FOR PERFORATING WELL CASINGS

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2 Sheets-Sheet 1



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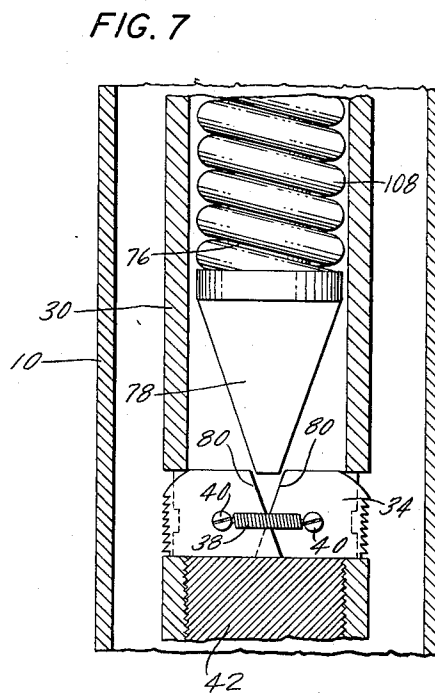
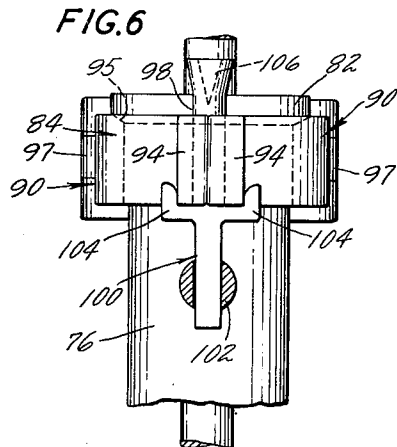
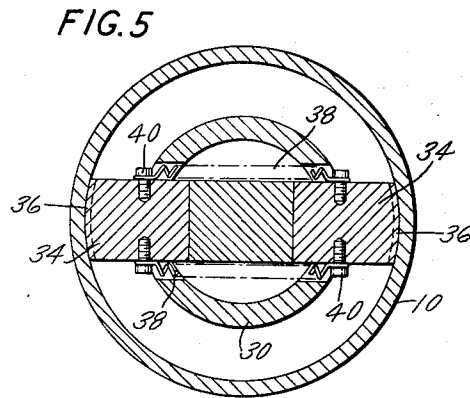
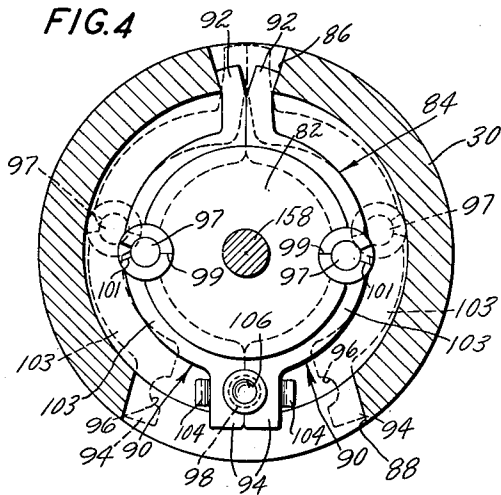
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2 Sheets-Sheet 2



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MECHANISM FOR PERFORATING WELL CASINGS

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6 Claims. (Cl. 164—0.5)

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This invention relates to improvements in mechanism for perforating well casings and, while not restricted thereto, said mechanism is especially adapted for perforating the casings of oil wells.

The oil-bearing formations that are drained by wells frequently are soft, unconsolidated sands. Under these conditions a well must be lined or cased with steel pipe in order to maintain the well hole open. Sometimes the oil pipe casing is run into the well without perforations and is perforated after the casing is mounted in place within the well hole. Such casing is also commonly used to keep water from entering the well from water-bearing strata either above or below those containing oil. The annular space between the casing and the strata formations usually is filled with cement. Sometimes, an oil stratum is cemented off in back of a string of casing pipes, or a number of strings of casing may be cemented together inside of one another. Later, if it is desired to open the well to such oil stratum, perforations are made through the casing or casings and the cement.

In modern well drilling, it has become a common practice to accomplish such aforementioned perforating by shooting small, hard projectiles of various shapes and sizes against the inner surface of such casings so as to penetrate the same and any cement which may be in back of the casing, as well as the stratum in back of the cement. The projectiles are driven by an explosive charge from a gun. Such operation is known as gun perforating and is accomplished by means of a gun made, for example, of a heavy cylindrical bar of steel of a size that can readily be introduced into the interior of the casing, supported by a cable from the upper end of the well or casing.

The cable usually includes insulated electrical conductors by means of which the shots or cartridges are selectively fired as desired. The gun is provided with a plurality of chambers or barrels which are spaced longitudinally of the gun relative to each other, the axes of the barrels being disposed transversely to the axes of the gun. Said chambers or barrels carry the explosive material and bullets or projectiles which may be hereinafter referred to as cartridges. Said chambers or barrels are fitted into recesses provided in the cylindrical bar of the gun by screw threads or otherwise.

A means is usually employed so that only one electrical conductor in the cable is required for the selective discharge of individual shots or projectiles from the gun perforator. One way in

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which this may be accomplished is by having progressively greater resistances in series with the live wire used for detonating and having all of these circuits in parallel with the insulating wire in the cable and the cable itself. At the surface adjacent the upper end of the well, a circuit runs from the cable through a source of current, an ammeter, a variable resistance, and then to the insulated line in the cable. Other suitable arrangements may be used.

In order to reach oil-bearing sands with projectiles fired from the barrels of said gun, said projectiles sometimes must penetrate through several strings of steel casing as stated above, disposed one outside of the other, in addition to cement between the casings and a considerable additional thickness of cement between the outermost casing and the formation of oil-bearing sands. In addition to the necessity of having the projectile pass through these considerable thicknesses of steel and cement, it is desirable to have the projectile penetrate as far as possible into the oil-bearing formation itself. A number of factors, and particularly the diameter of the bore hole of the well, place a practical limit upon the amount of explosive charge that may be used and therefore the amount of penetration that may be attempted with presently used perforators.

It is an object of the present invention to provide means which are attachable to one end of a multi-barrelled perforating gun and lowered therewith into a well casing, said means including positioning or support mechanism which is operable firmly to engage the inner surface of the well casing at a predetermined position therein, and gun shifting means operable following the initial firing of a cartridge from one or more of the barrels of said gun successively to position other barrels and cartridges opposite the penetration made by the initially fired projectile, whereby additional projectiles may successively be fired into and through said initial penetration to effect extended penetration of the well casing or casings, any cement associated therewith and the stratum in back of said cement.

It is another object of the invention to provide gun positioning and shifting means with actuating and control means which may be operated from the surface at the upper end of the well casing and, when so operated, effect the successive positionings of additional cartridges opposite an initially made penetration or penetrations, whereby said additional cartridges may be successively fired therethrough so as to make re-

peated attack at the same location in a well casing and thereby effect a satisfactory penetration into the stratum behind said casing.

A still further object of the invention is to so construct said gun positioning and shifting mechanism that it is simple in construction and operation, rugged and durable, adapted to the limited spaces within well casings, and may readily be disengaged from an oil well casing to permit movement of the positioning and shifting mechanism relative to said casing such as when it is desired to withdraw the same from the casing.

Details of these objects and of the invention, as well as other objects thereof, are set forth in the following specification and illustrated in the accompanying drawings forming a part thereof.

In the drawings,

Figure 1 is a fragmentary sectional view of part of a well hole lined with casing and cement and illustrating within said casing a multi-barrelled perforating gun connected to gun positioning and shifting mechanism embodying the principles of the present invention.

Fig. 2 is a longitudinal sectional view of the gun shifting mechanism secured to part of the upper portion of the gun positioning means of the invention and illustrated on a larger scale than in Fig. 1.

Fig. 3 is a longitudinal sectional view of the lower portion of the gun positioning means embodying the present invention, said figure, when considered in conjunction with and below Fig. 2, comprising a sectional view of the entire assembled gun shifting and positioning means of the invention. In Fig. 3, the lower end of the positioning means is shown secured to a fragmentary portion of a well casing.

Fig. 4 is a sectional view taken on the line 4—4 of Fig. 3 and shown on a larger scale than in the latter figure.

Fig. 5 is a sectional view taken on the line 5—5 of Fig. 3.

Fig. 6 is a vertical sectional view taken on line 6—6 of Fig. 3.

Fig. 7 is a vertical sectional view of the lower portion of the positioning means of the invention illustrated in the lower portion of Fig. 3 but showing the gripping members of the holding means in retracted position.

Referring to the drawings, a longitudinal sectional view of part of an oil well casing 10 is illustrated in Fig. 1, the same being disposed within a bore hole 12 formed in a section of stratum 14 which will be presumed to be oil-bearing. The exemplary casing 10 is secured within the bore hole 12 by cement 16 which fills the space between the walls of the bore hole 12 and the exterior surface of the casing 10. The cement is primarily for purposes of securing the casing 10 fixed within the bore hole 12. This illustration is merely exemplary of one type of well arrangement in which the present invention may be utilized. It is to be understood, as stated above, that it is not uncommon in oil well bore holes to have two or more strings of casings disposed within each other, the casings, of course, being of different sizes so that the smaller strings of casing may extend through those of larger size. Under such circumstances, it is customary practice to seal and hold the thus nested strings of casing in operative relationship by disposing cement between the pipes or tubes comprising the nested casings. It is contemplated that the pres-

ent invention be used with all such various arrangements which are customarily found in wells and especially oil wells.

As has also been stated above, oil-bearing strata of sands, shale, and the like, are sometimes drilled or bored through and sealed off by means of cement surrounding the oil well casing, as well as the casing per se which is imperforate. Subsequently, should it be desired to tap any of the said sealed-off strata in back of the well casing and cement, the present invention is utilized for purposes of perforating the casing or casings and cement which surround the casings so as to effect communication between such stratum and the interior of the innermost string of casing. Further, the present invention is used to perforate oil well casing or casings and cement surrounding the same which occurs at the lowermost levels of an oil well so as to render the normally imperforate section of casing in said lowermost levels capable of permitting the flow of oil into the casing by perforating the casing or casings and surrounding cement in addition to permitting the flow of oil up through the open lower end of the casing or through any filtering or straining device which is usually mounted in the lower end of said casing in an oil well.

The present invention comprises means for initially positioning and subsequently shifting a multi-barrelled casing perforating gun 18 relative to the casing 10. Guns of this nature usually comprise a heavy cylindrical bar of steel of a size which can readily be introduced into the casing 10, the gun being supported within the casing by having attached to the upper end of the gun a cable 20 by means of which the gun 18 is lowered from the upper end of the well into the casing 10. Such cable usually is a composite type and includes, in addition to the steel tension portion, insulated electrical conductors by means of which the explosives in the barrel or chamber units 22 in the gun casing are fired. The barrel or chamber units 22 may be secured to the gun casing 18 by threading said units laterally into suitable apertures provided in the casing 18. The units normally contain an axial barrel opening for supporting and directing a projectile, and a communicating cavity in the rear of the barrel which contains an explosive charge. The exemplary illustration of the gun 18 shown herein shows a longitudinal row of barrel units 22 spaced apart even distances, twelve of such units being illustrated herein with the barrels of the units extending laterally to the axis of the guns 18.

Well casings which are most frequently perforated are of the order of six or seven inches in diameter, for example. Successful perforation of such casings requires a relatively large charge of explosive material in order successfully to propel a projectile from a barrel unit with sufficient force to penetrate the well casing and, preferably, the cement lining 16 surrounding the casing and part of the stratum behind the cement. Various sizes and shapes of projectiles may be used, depending upon the thickness and kinds and combinations of casings and cement to be penetrated. The amount of explosive charge may be varied by using barrel units having suitable capacities for the charge, as well as barrel diameters suitable to accommodate the shape and size of the projectile. Relatively small sized cartridges generally are ineffective and only high powered, relatively large explosive charges are satisfactory to effect penetration

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with projectiles of substantial size. In view of the limited size within which the gun may be disposed within an oil well and also, in view of the fact that the projectiles and charges must be held within barrel units mounted within the gun casing, conventional specially designed units are used, the same not comprising part of the present invention and, therefore, further description thereof not being believed to be necessary.

In accordance with the present invention, a gun positioning means 24 is used in association with a multi-barrelled perforating gun 18 and one or more gun shifting units 26 are connected to and between the positioning means 24 and the perforating gun 18. When the gun, shifting units, and positioning means are assembled in a string arrangement as illustrated in Fig. 1, there is also preferably provided, adjacent the opposite ends of said assembly, centering means 28 which may comprise for example, a plurality of semi-elliptical leaf springs 29 of which the intermediate portions engage the interior surface of the casing 10 so as to maintain the axis of the assembled string of elements substantially in coincidence with the axis of the casing 10. The springs 29 may be supported at their ends by any suitable anchoring mechanism by which the springs may be attached to the ends of the assembled string of mechanisms.

Referring now particularly to Figs. 2 and 3, the gun positioning means 24 comprises a tubular body 30 which has a plurality of radially disposed openings or slots 32 formed in the lower portion thereof as shown in Fig. 3, the same slidably supporting for lateral movement relative to the body 30 a plurality of casing gripping members 34 shown in detail in Figs. 3 and 5. The outer ends of the gripping members 34 are provided with a row of hardened teeth 36 which engage and bite into the inner surface of the casing 10 when the gripping members 34 are moved radially outward from the slots 32 by means to be described.

In the present embodiment, only two diametrically opposed gripping members are illustrated, but it is to be understood that such number is not to be considered restrictive since other numbers of such units may readily be used. Said gripping members 34 are normally biased inward to their retracted position, illustrated in Fig. 7, by any suitable means such as a pair of coil springs 38 secured at their ends to opposite sides of the gripping members 34 by bolts or pins 40. The lower end of the casing 10 has a shouldered plug 42 which threads into said lower end of the casing until the shoulder preferably abuts the end thereof as shown in Fig. 3. A threaded extension 44 of a smaller diameter than the plug is integral with the lower end thereof for purposes of permitting attachment thereto of the lower centering means 28. The upper end of the plug is provided with a central conical or wedge-shaped recess 46 for purposes to be described.

Telescopically mounted for slidable movement relative to the upper end of tubular body 30 is a cylindrical member 48 which is detachably connected to the lower end of a sleeve 50 by means of threads as clearly shown in Fig. 2. The upper end of sleeve 50 is threadedly connected to the lower end of a coupling 52, the upper end of which is threadedly connected to a tube 54 comprising part of one gun shifting unit 26. Slidably mounted within and projecting

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beyond the upper end of tube 54 of the gun shifting unit is an inner sleeve 56, the upper end of which is provided with threads 58 to which the lower end of the casing of gun 18 is threadably secured. In the assembly shown in Fig. 1, two gun shifting units 26 are shown, while in Fig. 2, only one such shifting unit is shown for purposes of simplification. Assuming that the assembled gun, shifting units and positioning means have been lowered into the well by cable 20 until the gun 18 is opposite the position in the well where perforation is desired, the support or positioning means 24 is operated as follows:

An auxiliary gun 60 is positioned in the lower end of sleeve 50 between the upper end of cylindrical member 48 and an annular shoulder 62 formed on the interior of sleeve 50. The auxiliary gun 60 may simply be a cylindrical block having a breech chamber and barrel 64 in which is positioned a projectile 66 and a charge 68 of explosive material. An electrically controlled detonating member 70 is threaded into the upper end of barrel opening 64 and a firing cable 72 is connected to detonating member 70, said cable extending upward to the support cable 20 and the cable 72 may comprise part of the assembly of wires and other strands comprising cable 20 as described above. Thus, the upper end of the firing cable will be disposed at the upper end of the well so that the control for the operation of detonating member 70 may be performed by an attendant at the surface. The cylindrical member 48 is provided in one wall with a longitudinal hole 74 axially aligned with the barrel 64 of the auxiliary gun 60.

An actuating member 76 is disposed in the lower portion of the tubular body 30 for movement axially thereof as can be seen from Fig. 3. The lower end of the actuating member 76 is formed to comprise a wedge 78, the sides of which are engageable with surfaces 80 on the inner ends of gripping members 34, said surfaces being complementary to the inclined sides of wedge 78. Threaded into the upper end of actuating member 76 is an enlarged head 82 which is initially positioned with the actuating member 76 in the dotted line position of the head illustrated in Fig. 3. Said initial position of the lower end of actuating member 76 and wedge 78 is as illustrated in Fig. 7.

Latching means comprising a split clamp 84 cooperates with the head 82 to maintain the same in the elevated dotted line position thereof illustrated in Fig. 3 while the assembled mechanism shown in Fig. 1 is being lowered into operating position within the casing 10. Details of the clamping ring 84 are best shown in Fig. 4. The tubular body 30 is provided in opposite walls with a relatively small opening 86 and, in the opposite wall, a larger, segmentally shaped slot or opening 88 is provided. The clamping ring 84 comprises a pair of respectively articulate members 90 which are semi-circular and the ends thereof extend radially in opposite directions as clearly shown in Fig. 4. One end 92 of each member 90 is bent intermediate the ends thereof to provide angularly related portions. When the two members 90 are in position to clamp the head 82 of the actuating member as illustrated in Fig. 4, two of the angularly related portions of the ends 92 are in abutting position and will be held there by the ends 92 engaging the end walls of opening 86 as shown in Fig. 4. The opposite ends 94 of each of the members 90 have juxtapositioned concavities 96 cooperating to form a

bearing-like opening which receives the shaft 98 of a trigger-like locking member 100. When the members 90 are positioned to clamp the head 82, the ends 94 of the members abut.

The locking member is vertically movable relative to the opening formed by the concavities 96 and the lower end of the shaft 98 is slidably supported with some friction within a suitable bearing member 102 secured to the tubular body 30 as clearly shown in Fig. 3 and Fig. 6. Extending outward from the shaft 98 intermediate the ends thereof is a pair of L-shaped locking arms 104 which have legs extending upward to engage said opposite ends 94 of articulate clamping members 90 so as to hold them in juxtaposition as shown in Figs. 4 and 6 when the locking member 100 is disposed in its uppermost position shown in Fig. 6. The upper end of the locking member 100 is provided with a central conical cavity 106 in vertical alignment with the axis of hole 74.

When the assembly of mechanisms illustrated in Fig. 1 has been lowered into the casing 10 to the position wherein perforation of the casing is to take place, the lowering movement of the cable 20 is stopped. Suitable control mechanism at the surface is actuated by an attendant to detonate the charge 68 within auxiliary gun 60, whereupon the projectile 66 is fired downward through hole 74 and into engagement with cavity 106. The impact of the projectile with locking member 100 drives it downward and disengages locking arms 104 from said opposite ends 94 of the split clamp members 90. From Figs. 3 and 6 especially, it will be seen that the head 82 terminates at its upper end in an enlargement, the lower annular edge 95 of which is tapered inward and downward. The engaging curved edges of clamping members 90 are complementary to surface 95 on head 82. Thus, when locking member 100 is disengaged from said ends 94 of the clamp members 90, the weight of the head 82 and the mechanism depending therefrom, as well as another force to be described, immediately moves the surface 95 of head 82 against the complementary surfaces of clamp members 90 with a camming action and spreads the ends 94 of the clamp members apart as shown in dotted lines in Fig. 4.

The ends 94 of the clamp members will be limited in their outward movement by engaging the end walls of slot 88 in body 30. In order that the inner surfaces of clamp members 90 will permit passage therebetween of head 82 and especially the enlargement at the upper end thereof within the confined space afforded by the interior of tubular body 30, each clamp member 90 is articulated, each comprising a pair of curved sections pivotally connected by a hinge 97 as shown in Fig. 4. The hinges are so constructed that they have inner shoulders 99, which preferably abut when in clamped position as shown in full lines in Fig. 4. However, the hinges also have outer shoulders 101 which are spaced when the curved sections of members 90 are in clamped position as shown in full lines in Fig. 4, so as to permit further outward movement of sections 103 of the members 90 after the hinges 97 engage the inner surface of tubular body 30. Thus, it will be seen that sections 103 can be moved entirely out of obstructing positions relative to head 82, as is clearly illustrated in dotted lines in Fig. 4. When the clamp members 90 are moved to the released, dotted line position shown in Fig. 4, the other two angularly related portions of ends 92 of said members will be in abutting relation as

shown in dotted lines in Fig. 4. The ends 92 and 94 of the articulated clamping members 90 will always be disposed within slots 86 and 88, whereby they maintain the members against movement longitudinally of body 30.

Actuating member 76 having been released for movement downward relative to tubular body 30, such downward movement is not only induced by gravity but will also be assured and motivated by a compression spring 108 disposed between a collar 110, which is removably secured to the interior of tubular body 30, and an annular shoulder 112 immediately above wedge 78. Such downward thrust of the actuating member 76 and wedge 78 causes said wedge quickly and forcibly to move the gripping members 34 radially outward from the slots 32 in the body 30, whereupon the teeth 36 on the wedging members engage the inner surface of the casing 10 so as to somewhat bite into said surface and effect a fixing of the gun positioning means 24 relative to the casing 10.

After the firing of the projectile 66 has taken place and the fixing of gun positioning means 24 has been effected as aforesaid, the cable 20 is slackened off. Inasmuch as the lower portion 114 of cylindrical member 48 is smaller in diameter than the upper portion of said member, the lower end of portion 114 abuts the upper surface of head 82 of actuating member 76 when said head is secured in elevated position by split clamp 84 as shown in dotted and full lines in the upper end of Fig. 3. However, after the actuating member 76 and head 82 have been moved to their lower full line position in Fig. 3 following the firing of projectile 66 and due to the cable 20 having been slackened off, the member 48 and all of the interconnected mechanism including the gun 18 will quickly move by gravity downward so as to effect a sharp impact between the end of lower portion 114 of cylindrical member 48 and head 82 of actuating member 76. A very substantial heavy mass will thus be moved downward into impact with the actuating member 76 to drive said member farther downward and force farther outward the gripping members 34 into very firm frictional engagement with the inner surface of casing 10, the teeth 36 of the gripping members being well-embedded within said inner surfaces of the casing as a result. Thus, the weight of the members which engage the head 82 of wedging member 76, as well as the force exerted by spring 108, will serve to maintain the gripping members 34 firmly in engagement with the inner surface of casing 10 and effectively fix the gun positioning means 24, as well as the gun 18 and shifting units 26, relative to the casing 10.

Accurate positioning of auxiliary gun 60 relative to member 48, so as to axially align the barrel 64 of the auxiliary gun and hole 74 of member 48, is effected by any suitable means such as a positioning screw 116 in the auxiliary gun 60 which extends into a slot 118 formed in the upper end of member 48. Said positioning means thereby maintains said axial alignment while the gun 60 is being secured between the upper end of member 48 and shoulder 62 of sleeve 50. Cylindrical member 48 is also prevented from rotating axially relative to tubular body 30 during telescopic movement thereof by the provision of a plurality of slots 120 in the body 30 which receive the heads of guide bolts 122 secured to cylindrical member 48. The slots 120 are parallel to each other and the axis of body 30. Any

suitable number of such slots 120 and bolts 122 may be provided in circumferentially spaced relation about the tubular body 30.

The assembled gun 18, shifting units 26, and gun positioning means 24 are now secured within the casing 10 in position for having one or more of the charges within the barrel units 22 detonated in order to fire the projectile in each gun so detonated into the oil well casing so as to penetrate the same and the cement lining behind the casing. As stated hereinabove, either one projectile may be fired so as to penetrate the casing and cement or a plurality of initial projectiles may be fired simultaneously or in quick succession to penetrate the casing and cement at a plurality of spaced positions. The exemplary gun shown herein is illustrated as having twelve barrels or chambers 22. Assume that barrels 1, 4, 7 and 10, counting the barrels upward from the bottom of the gun, are fired initially. Four spaced penetrations are thereby formed through the casing and cement which may possibly extend into the strata 14 behind the cement. A greater depth of penetration may now be effected by selectively actuating the gun units 26 in a manner to be described so as to place additional loaded barrels 22 radially opposite the penetrations effected by firing barrels 1, 4, 7 and 10 as described.

Details of the electrical means for detonating the charges in the various barrels is not illustrated in detail herein as the same may be any conventional mechanism. For example, one means frequently employed involves only one electrical conductor in the cable 20. Selective discharge of individual projectiles from the perforator gun 18 may be effected by providing progressively greater resistances in series with the live wire used for detonating and placing all these circuits in parallel with an insulating wire in the cable and the cable itself. A source of current is connected in the circuit, together with an ammeter and a variable resistance. By manipulation of the mechanism in said circuit, selective firing of the charge in any desired barrel 22 of the perforator gun 18 may be effected.

Following the initial firing of one or more projectiles into the casing initially to penetrate the same, one of the gun shifting units 26 may be actuated to dispose another loaded barrel and projectile opposite each initial penetration by the following mechanism:

Each of the gun shifting units 26 comprises a cylindrical tube 54 secured at its lower end to the upper end of the coupling 52 as shown in Fig. 2. The tube 54 is provided intermediately of its ends with a plurality of circumferentially spaced slots 124 which extend parallel to each other and the axis of tube 54. The inner sleeve 56 is provided with radially extending bolts or threaded guide pins 126 which are slidably disposed in slots 124, thus preventing axial rotation between the inner sleeve 56 and tube 54 and also limiting in at least one direction longitudinal movement between the sleeve 56 and tube 54.

In its initial position in which the gun shifting unit 26 is lowered into the casing 10, the guide pins 126 are disposed in the upper ends of slots 124 and are held in such position by locking means comprising a plurality of ball locks 128 disposed in holes 130 formed in inner sleeve 56. The ball locks 128 also extend into concavities 132 formed in the inner ends of threaded plugs 134. The ball locks 128 are held in the locked position thereof illustrated in Fig. 2 by means of

a collapsible toggle 136 comprising a pair of members pivotally connected together at their inner ends by a pin 138 which also secures said members to the lower end of a vertically movable yoke 140. The yoke is provided with a longitudinally extending slot 142 which is disposed between the ends of the yoke, the slot accommodating a retaining bolt 144 extending between opposite walls of inner sleeve 56 as clearly shown in Fig. 2. In the locked position of the toggle 136, the lower end of slot 142 is opposed adjacent retaining bolt 144.

Another auxiliary gun 146 is threadably fixed to the upper end of inner sleeve 56, said auxiliary gun having a barrel opening extending vertically and containing a projectile 148 and a suitable charge of explosive. A firing cable 150 is connected to the detonating means of the gun 146, said cable extending upward so as to comprise part of or merge with supporting cable 20. The upper end of yoke 140 is provided with a central cavity 152. The charge within the auxiliary gun 146 is detonated by control means at the surface, the projectile 148 thereby being discharged into cavity 152 of yoke 140 to move the same downward and effect collapsing of toggle 136, whereupon ball locks 128 may move out of the concavities 132 and permit telescopically slidable movement between the lower portion of inner sleeve 56 and the upper portion of tube 54, such movement being guided by pins 126 within the slots 124.

Downward movement of the inner sleeve 56 and the perforating gun 18 connected thereto, as well as any other intermediate gun shifting units 26, is limited by engagement of the lower end 154 of inner sleeve 56 with the upper surface of a plug 156 threadably connected to the upper end of coupling 52. The plug 56 has a flange portion 157 which seats on the upper rim 53 of coupling 52. The thickness of flange 157 is made such that the upper surface thereof extends below the lower end 154 of sleeve 56, when sleeve 56 is in its uppermost position a distance exactly equal to the space between the parallel axes of the barrels 22 in perforating gun 18. The gun shifting units are thus capable of being used with various kinds of perforating guns in which the spacing between adjacent barrels may vary relative to the spacing between adjacent barrels of another gun. It is only necessary to provide a suitable substitute plug 156 within the gun shifting unit 26 having a flange 157 of the required thickness, in order to be able to adjust the movement of inner sleeve 56 relative to tube 54 of the gun shifting unit to an amount equal to the spacing between the axes of adjacent barrels in the gun.

In view of the secure fixing of gun positioning means 24 relative to the casing 10 as described hereinabove, the impact of inner sleeve 56 against plug 156 of the gun shifting units will not effect movement of the gun positioning means 24 relative to the casing. The slots 124 and guide pins 126 will insure axial alignment in a horizontal direction of another barrel or sets of barrels 22 with the initially made penetrations in the casing 10, and the engagement of the lower end 154 of inner sleeve 56 with the plug 156 will insure such axial alignment in a vertical direction. The projectile in another barrel or projectiles in another set of barrels of the perforating gun 18 will thus accurately be aligned with the initially made penetrations in the casing 10, whereby the charges within said another barrel or set of barrels may now be detonated to discharge a second

projectile into each initially made penetration in the casing 10.

The above-described gun shifting units will accurately position the barrels exactly opposite such initial penetrations, whereby the subsequent discharge of additional projectiles into said initially formed penetrations will have greatest effect for purposes of extending the penetration within the casing 10 or the cement lining 16 and the stratum 14 as well as any additional casings or cement linings which may surround the innermost casing or lining. During such secondary firing, and assuming that barrels 1, 4, 7 and 10 are initially fired, the barrels 2, 5, 8 and 11 can be fired to effect such second penetrations.

Assuming that an additional gun shifting unit 26 is connected in the series of mechanisms and units illustrated in Fig. 1, said second gun shifting unit may now be actuated in order that a third barrel or set of barrels may be disposed radially opposite the penetrations which were initially made and through which second projectiles have been fired. Such actuation of said second gun shifting unit 26 is effected by discharging the auxiliary gun 146 thereof in order to permit telescopic collapsing of the inner sleeve 56 relative to the tube 54 thereof until such telescopic movement is stopped by engagement of the lower end 154 of sleeve 56 with the plug 156 of said second gun shifting unit. The control for the detonating mechanism may then be operated to discharge a third cartridge or set of cartridges through the aforementioned penetrations, thus still further extending or enlarging said penetration.

After all barrels of the gun have been discharged as desired or as many of the barrels as desired have been discharged, the gun and positioning and shifting means are withdrawn from the casing 10 by elevating cable 20. In order to permit such elevation, it is necessary to disengage the gripping members 34 from engagement with the casing 10. Such disengagement is effected as follows:

As elevation of the cable 20 is commenced, elevation of the penetrating gun is effected and such movement of the gun causes upward movement of inner sleeve 56 of the uppermost gun shifting unit 26 relative to the tube 54 thereof until the guide pins 125 are disposed at the upper ends of slots 124. While the positioning means 24 has been fixed relative to the casing 10 during the various firings of the penetrating gun 18, the lower portion 114 of cylindrical member 48 adjacent the upper end of said positioning means has been disposed against the upper surface of head 82 of the actuating member 76 as described above. When said lower portion 114 moved downward into engagement with the head 82, it also moved downward relative to a vertical shaft 158 projecting upward from actuating member 76 and extending into a central elongated aperture 160 formed in said lower portion 114 of member 48.

Intermediate the ends of the shaft 158 is a plurality of notches 162 which are disposed on opposite surfaces of the shaft 158. The lower portion 114 supports a pair of inwardly biased locking dogs 164 which are slidably disposed in transversely extending apertures 166 formed in said lower portion 114 and accommodating compression springs 168 which are held in operative position by threaded plugs 170. The locking dogs 164 will slide relative to the exterior surface of shaft 158 while the cylindrical member 48 is moving downward relative to tubular body 30. When the

lower end of lower portion 114 abuts the upper end of head 82, the locking dogs 164 will be disposed either opposite or below the notches 162 in shaft 158. Thus, during the removal of the mechanism from the well, when cylindrical member 48 is moved upward by the elevation of the gun shifting units 26, the guide bolts 122 will be moved against the upper ends of slots 120 and, during such movement of member 48, the locking dogs 164 will be disposed within notches 162 in shaft 158 and cause elevation of said shaft relative to tubular body 30.

Fixed to the lower end of shaft 158 is a yoke 172, the lower end of which is pivotally connected to another collapsible toggle 174 comprising a pair of members pivotally connected at their inner ends and extending outward in opposite directions to hold one or more locking balls 176 within radially extending holes 178 formed in collar 110. The outermost locking balls 176 are disposed in concavities 180 formed in screw plugs 182 which are threadably connected to the walls of tubular body 30. The toggle 174 thus holds the locking balls 176 in engagement with the concavities 180 of plugs 182 releasably to secure the collar 110 relative to the inner surface of tubular body 30. Said collar 110 serves as an abutment as aforesaid for the upper end of compression spring 108 which maintains the actuating member 76 in its lower or depressed position for purposes of maintaining the gripping members 34 in their extended position illustrated in Fig. 3.

Upward movement of shaft 158 by the means described above therefore serves to collapse toggle 174 so as to remove it from engagement with the innermost locking balls 176 and thereby permit the outermost balls to be removed from the locking concavities 180. Thereupon, the force of the compression spring 108 moves the collar 110 upward within body 30 until the energy of the spring is expended. Continued movement of shaft 158 will bring the upper end 184 of yoke 172 into abutting relation with the lower end of head 82 fixed to the upper end of actuating member 76. Further upward movement of shaft 158 will therefore effect corresponding upward movement of actuating member 76 so as to withdraw the wedge 78 from locking engagement with gripping members 34. Springs 38 then operate to retract the gripping members 34 from their locked position illustrated in Fig. 3 to their retracted position shown in Fig. 7.

The foregoing retraction of actuating member 76 takes place while the guide bolts 122 are being moved upward into slots 120. Upon the bolts 122 reaching the end of slots 120, the tubular body 30 will be moved upward as the other mechanism is elevated by cable 20. In the event the teeth 36 of the gripping members 34 are embedded within the well casing to such an extent that the springs 38 cannot readily retract the gripping members 34, the shape of the teeth 36 is such that upward movement of the gripping members 34 by the tubular body 30 will cam the teeth out of their gripping notches formed upon the embedding of the teeth within the inner surface of the casing 10 and thus free the gripping members 34 from the casing. The gun and its attached mechanisms are then free to be entirely removed from the casing 10.

The entire assembly of gun and mechanism illustrated in Fig. 1 is completely removed from the casing 10 for purposes of reloading the barrels of the gun and resetting the various locking

and holding means such as clamp 84, toggle 136 and toggle 174, as well as replacing all of the other relatively movable members in their initial position so as to place the gun in readiness for again being lowered into the well to effect further penetration where and when desired.

It will thus be seen that the present mechanism comprises a relatively simple, accurate and effective means for securing a multi-barrelled perforating gun at any desired position within an oil well casing, said means being operable to establish and hold the gun at a predetermined initial position where an initial penetration or set of penetrations may be made in the casing, the cement lining, and the stratum behind said lining as well as any other casings and linings which might surround the innermost casing and lining. The positioning means of the present invention comprises gripping members which are projectible outward from a supporting body, such outward projection being effected by means which will effectively cause teeth on the gripping members to bite into the inner surface of the casing sufficiently to firmly anchor the positioning means to the casing. The projection of said gripping members is effected by foolproof mechanism comprising an auxiliary gun from which a light powered projectile is fired to release locking mechanism which normally holds the gripping member projecting device in retracted position. Thereafter, simply by discharging another single light powered projectile from another auxiliary gun, one of the gun shifting units in the string of mechanism lowered into the well casing is operated to effect movement of the multi-barrelled gun longitudinally within the well exactly the distance between two adjacent barrels of the gun so as to dispose a second cartridge or set of cartridges opposite the penetration or set of penetrations initially made within the casing 10. Then, said second cartridge or set of cartridges may be discharged into or through the initially made penetrations to extend the same. Such second discharge or discharges may be followed by even additional discharges, depending upon the number of barrels in the gun and the number of gun shifting units connected in the string of units attached to the gun.

The device is also provided with simple and rugged means for effectively withdrawing the gripping members of the positioning means as well as the entire mechanism attached to and including the gun from the well at the completion of a penetration operation, regardless of whether it is a single or sequential penetration operation. The various movable parts and members of the mechanism may quickly and easily be restored to their initial operative position so as to render the positioning and gun shifting units reuseable at another position within a previously penetrated well or in another well. When elevated to the surface, the gun may be reloaded in accordance with conventional practice.

The gun shifting units are also provided with means which may variably be calibrated in order to adapt the gun positioning means for use with guns having uniform distances between barrels which are different from the uniform distances between barrels of another gun. The gun shifting units and positioning means are also useable in a wide range of diameters of oil well casings, the gripping members of the holding means being capable of a relatively wide range of lateral movement so as to be engageable with the inner surface of casings of different diameters. How-

ever, in the event an unusually small or large diameter casing is to be penetrated, additional gripping members of appropriate length may be substituted for those presently in the positioning means in order to permit the positioning means to be operable within said casings. The entire mechanism for positioning and shifting a multi-barrelled gun within a well is of such nature that it is rugged and effective yet of a slender, elongated nature so as readily to adapt the mechanism to the inherently limited spaces within well casings and particularly oil well casings in wide use at the present time.

While the invention has been illustrated and described in its preferred embodiment and has included certain details, it should be understood that the invention is not to be limited to the precise details herein illustrated and described since the same may be carried out in other ways, falling within the scope of the invention as claimed.

I claim as my invention:

1. Mechanism for use with a multi-barrelled casing perforating gun and firing means capable of operation to discharge selectively a casing penetrating cartridge from each barrel of said gun, said mechanism comprising in combination, positioning means arranged to be disposed at a predetermined position within a well casing and including locking members movable into firm engagement with the interior of said casing to position said gun for discharging the initial cartridge in a barrel of the gun to effect a penetration of said casing, gun shifting means attachable to said gun and having a portion telescopically and slidably associated with a portion of said positioning means, slots extending longitudinally of one of said portions and pins fixed to the other portion and slidable within said slots to guide the relative movement of said means in one direction, a calibrated stop member carried by one of said means and engageable by the other means to limit the relative movement thereof in the other direction, releasable locking mechanism carried by one of said means and engageable with the other means releasably to hold one of said means so that the pins are disposed in one of the ends of said slots, and means operable to release said locking mechanism to permit movement of said gun and telescoping portion of said shifting means downward longitudinally of said casing and relative to said positioning means and into engagement with said calibrated stop member and position another barrel and cartridge of the gun opposite said casing penetration to permit discharge of said another cartridge into said penetration.

2. Mechanism for use with a multi-barrelled casing perforating gun and firing means capable of operation to discharge selectively a casing penetrating cartridge from each barrel of said gun, said mechanism comprising in combination, positioning means arranged to be disposed at a predetermined position within a well casing and including locking members movable into firm engagement with the interior of said casing to position said gun for discharging the initial cartridge in a barrel of the gun to effect a penetration of said casing, gun shifting means associated with said positioning means and attachable to said gun, releasable locking mechanism interengaging said positioning and shifting means and operable to hold them in one position relative to each other during the discharge of said initial cartridge, and an auxiliary gun carried by one of said means and operable to discharge a pro-

jectile into contact with said locking mechanism to release it to permit said shifting means to effect movement of said gun longitudinally of said casing and relative to said positioning means accurately to position another barrel and cartridge of the gun opposite said casing penetration to permit the discharge of said another cartridge into said penetration.

3. Mechanism for use with a multi-barrelled casing perforating gun and firing means capable of operation to discharge selectively a casing penetrating cartridge from each barrel of said gun, said mechanism comprising in combination, positioning means including a body and a plurality of gripping members supported by said body for guided movement laterally outward therefrom into gripping engagement with the interior of said casing to position said gun for discharging a cartridge in a barrel of the gun to effect a penetration of said casing, an actuating member movable longitudinally relative to said body and engageable with said gripping members to effect lateral outward movement thereof into engagement with the interior of said casing, latching means operable releasably to hold said actuating member in its elevated position, an auxiliary gun supported relative to and aimed at said latching means and operable to discharge a projectile against said latching means and release it from said actuating member to permit movement thereof into engagement with said gripping members as aforesaid, and gun shifting means including movement limiting means operable to permit movement of said gun a predetermined fixed distance to position another barrel and cartridge of the gun opposite said casing penetration to permit the discharge of said another cartridge into said penetration.

4. Mechanism for use with a multi-barrelled casing perforating gun and firing means capable of operation to discharge selectively a casing penetrating cartridge from each barrel of said gun, said mechanism comprising in combination, positioning means arranged to be disposed at a predetermined position within a well casing and including locking members movable into firm engagement with the interior of said casing to position said gun for discharging a cartridge in a barrel of the gun to effect a penetration of said casing, and a series of gun shifting units connected in longitudinal alignment within said casing and one end of said series being connected to said positioning means and the other end of said series being attachable to said gun, said shifting units being operable selectively to move said gun longitudinally of said casing and relative to said positioning means to position in sequence other barrels and cartridges of the gun radially opposite said casing penetration to permit the successive discharge of said other cartridges into said penetration.

5. Mechanism for use with a multi-barrelled casing perforating gun and firing means capable of operation to discharge selectively a casing penetrating cartridge from each barrel of said gun, said mechanism comprising in combination,

positioning means arranged to be disposed at a predetermined position within a well casing and including locking members movable into firm engagement with the interior of said casing to position said gun for discharging a cartridge in a barrel of the gun to effect a penetration of said casing, a series of gun shifting units connected in longitudinal alignment within said casing and one end of said series being connected to the upper end of said positioning means and the other end of said series being attachable to the lower end of said gun, control means associated with each of said units and selectively operable from the upper end of said casing to actuate sequentially said units to effect movement of said gun longitudinally of said casing and relative to said positioning means to position in sequence other barrels and cartridges of the gun radially opposite said casing penetration to permit the successive discharge of said other cartridges into said penetration.

6. Mechanism for use with a multi-barrelled casing perforating gun and firing means capable of operation to discharge selectively a casing penetrating cartridge from each barrel of said gun, said mechanism comprising in combination, positioning means including a body and a plurality of gripping members supported by said body for guided movement laterally outward therefrom into gripping engagement with the inside surface of a casing to position said gun for discharging a cartridge in a barrel of the gun laterally to effect a penetration of said casing, an actuating member movable longitudinally relative to said body and engageable with said gripping members to effect lateral outward movement thereof into said gripping engagement with the interior of said casing, means urging said actuating member to move longitudinally into forceful engagement with said gripping members, latching means operable releasably to hold said actuating member from forceful engagement with said gripping members, combustion means operable when ignited to actuate said latching means to release said actuating member to permit movement of the actuating member into forceful engagement with said gripping members as aforesaid, and gun shifting means including movement limiting means interconnecting said gun and said positioning means and operable to permit longitudinal movement of said gun relative to said positioning means a predetermined fixed distance such as to position another barrel and cartridge of the gun opposite said casing penetration to permit the discharge of said another cartridge into said penetration.

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