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2,947,253

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2 Sheets-Sheet 1

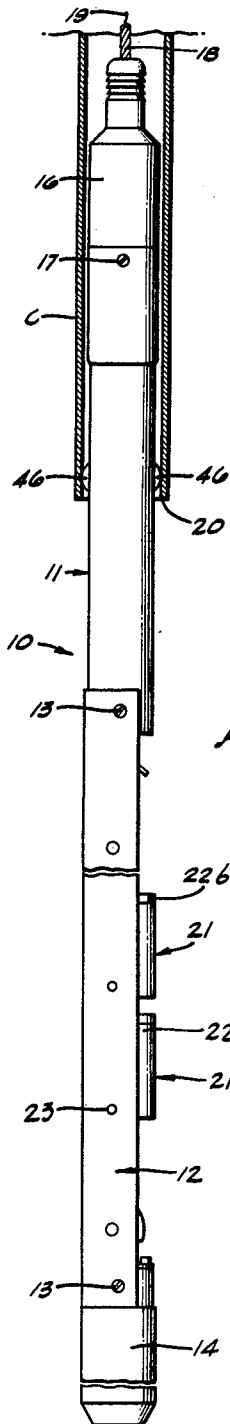


FIG. 1.

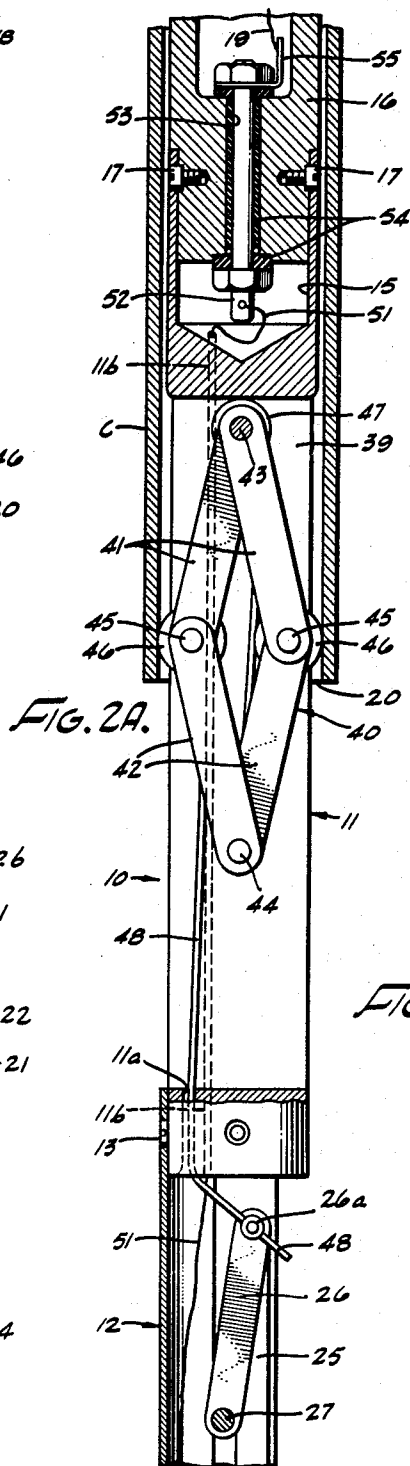


FIG. 2A.

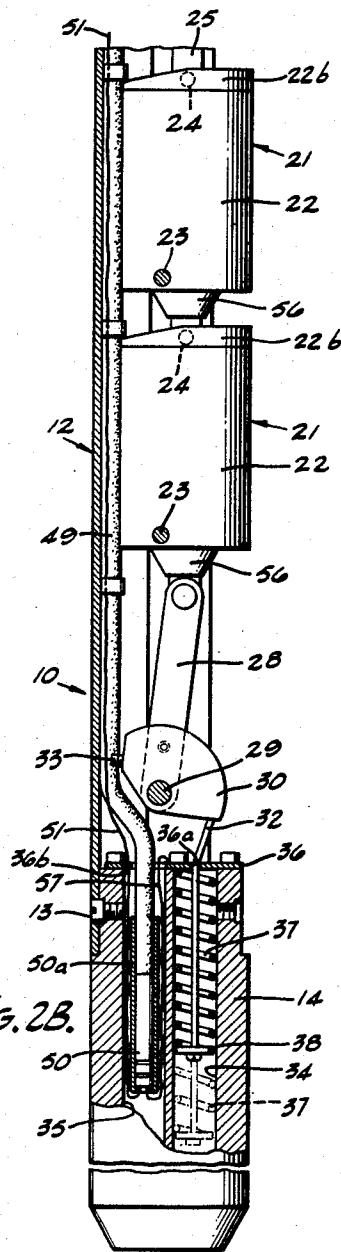


FIG. 2B.

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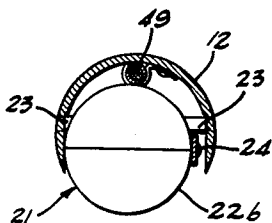
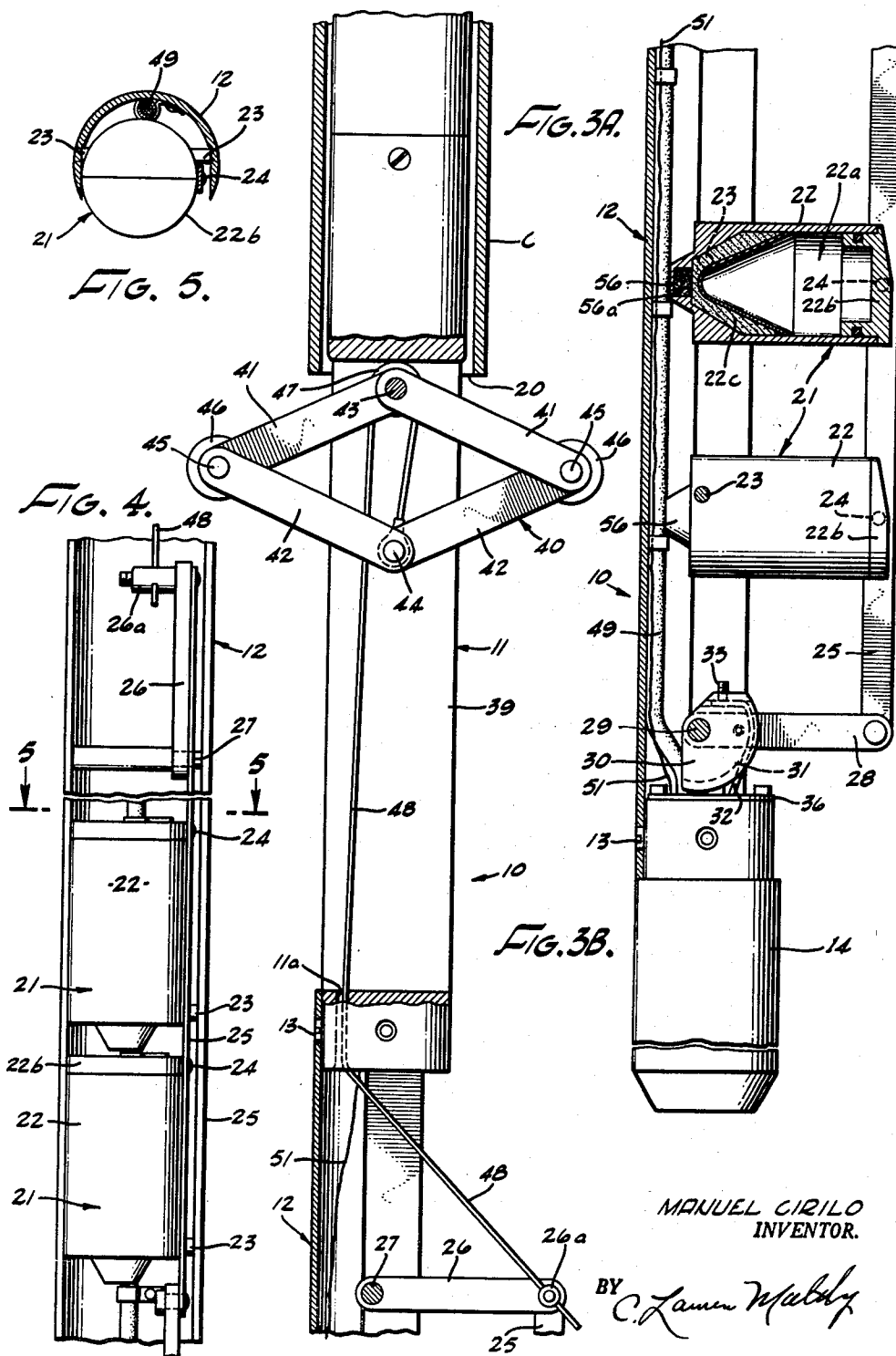


FIG. 5.



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4 Claims. (Cl. 102—20)

This invention relates to apparatus for perforating the walls or casing in earth boreholes such as oil or gas wells, and more particularly to perforating guns or the like devices which may be run through tubing in a well for perforating the well or casing below the lower end of the tubing.

The art of perforating casing in oil wells utilizing either bullet type guns or shaped charge types of perforating apparatus has become well known and well established in the industry. As with bullet type perforating guns, shaped charge guns are subject to the limitations of size and length when positioned for laterally directed firing within a well bore or casing. Where either bullet guns or shaped charges are used for perforating casing they have customarily been mounted in a substantially fixed position in a carriage or body member which is nearly as large in diameter as the well bore or casing in the well, to enable the use of a gun or shaped charge of maximum length, or to locate the shaped charge in the optimum position or stand-off distance relative to the well wall or casing. Even under the most favorable conditions perforation of oil well casing and surrounding formations to the desired depth is difficult to accomplish, and since the size of the gun or explosive is important, casing perforators have not usually been run into the well through tubing or other pipe smaller in diameter than the casing.

The present invention in an endeavor to obtain the advantages of explosive actuated perforating means, particularly shaped charged perforators, is directed to an arrangement whereby high explosive shaped charges can be lowered into a well bore or casing axially through a relatively small diameter pipe or tubing and then tilted into laterally directed firing positions to enable charges of maximum size and length to be used to obtain the maximum lateral penetration in the well.

It is, therefore, an object of the invention to provide an explosive actuated perforator means for shooting wells wherein a plurality of shaped charges may be lowered through tubing in a well bore for shooting the well where the perforator means is of greater length than the inside diameter of the tubing.

Another object of the invention is to provide a novel perforator which provides for the firing of high powered shaped charges with optimum standoff into surrounding oil well casing, the charges being run through relatively small size tubing and rotated to laterally directed position after passing out the lower open end of the tubing in the casing.

A further object of the invention is to provide a tilt-type perforator using shaped charges in which are incorporated improved features of safety by virtue of the fact that the shaped charge detonating means is maintained in an inoperative position during the running in stage of the operation.

A further object of the invention is to provide in a shaped charge perforator for oil well casing simple novel means for tilting the charges from a coaxially aligned longitudinal position to parallel positions normal to the

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longitudinal axis of the well for firing, upon the perforator being moved out the lower open end of the tubing.

A further object of the invention is to provide structure as set forth in the preceding object wherein the shaped charges may be realigned in coaxial positions for removal upwardly through the casing or tubing in the event it is desired to recover the perforator apparatus intact together with the unfired charges.

These and other objects, advantages and features of novelty of the present invention will be apparent from a consideration of the following specification when taken in conjunction with the accompanying drawings in which:

Fig. 1 is a view in elevation of a typical well perforating gun apparatus embodying features of the present invention shown as the gun is emerging from the lower open end of the tubing;

Fig. 2A is an enlarged view partly in section showing the upper portion of the apparatus of Fig. 1;

Fig. 2B is a view similar to that of Fig. 2A but showing the lower portion of the apparatus of Fig. 1;

Fig. 3A is a view similar to Fig. 2A showing the gun at a slightly lower position relative to the lower end of the tubing;

Fig. 3B is a view of the portion of the gun shown in 2B after rotation of the shaped charges to firing position;

Fig. 4 is an enlarged elevational view of a portion of the gun of Fig. 1; and

Fig. 5 is a cross-sectional view taken along the line 5—5 of Fig. 4.

Referring to the drawings, in more particularity, the numeral 10 indicates a gun perforator unit comprising an elongated frame or body member having an upper closed cylindrical portion or member 11 and a lower tubular portion or member 12 which is cut away or open along one side to form an elongated housing member which is U-shaped in cross-section. These members are secured together in any suitable manner, such as by screws 13. An elongated nosepiece 14 is secured to the lower end of tubular member 12 as by screws 13. The upper portion of upper cylindrical member 11 is formed with an end bore 15 (see Figs. 1 and 2A) in which is received the lower end of a cable head 16 which is secured thereto as by screws 17. Cable head 16 is supported by a conductor cable 18 having an electrical conductor 19 therein by which cable the gun perforator unit may be lowered through a tubing C which may be positioned in a well bore or casing (not shown), tubing C having a lower open end 20 out of which the perforator unit passes to operative position.

A plurality of shaped charge units 21 are carried by the lower U-shaped housing member 12 of the frame or body 10, each unit comprising a hollow shell or cylinder 22 containing a shaped charge. Cylinders 22 each have a central chamber 22a and an end closure 22b therefor, and a shaped charge explosive body 22c is positioned in the inner end of each chamber 22a. Each cylinder 22 is formed with a frusto-conical booster charge housing 22d containing a booster explosive charge 22e adjacent the inner end of the shaped charge 22c. Cylinders 22 each have pivots 23 on opposite sides thereof adjacent one end by which they are pivotally secured to and within the U-shaped housing 12 of the frame or body member 10 and each of the cylinder closures 22b have pivot pin connections 24 on one side thereof by which the cylinders 22 are pivotally secured to a longitudinally extending link or bar 25. The upper end of link or bar 25 is pivotally connected to a lateral link 26 which in turn is pivoted at 27 to a transverse pin extending between the sides of the U-shaped housing member 12. The lower end of the longitudinal link or bar 25 is similarly pivotally connected to a lateral link 28, the other end of which is pivotally supported on a transverse

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pivot pin 29 carried by the aforesaid side portions of the U-shaped housing member 12.

A sector plate 30 is suitably secured on the pivot pin 29 and to a link 28 and is formed with a peripheral groove 31 in the circular edge portion thereof. A flexible cable 32 has its upper end secured to sector plate 30 as by a lock screw 33 and is guided in groove 31 and has its lower end extended downwardly into a longitudinal bore 34 formed in nosepiece 14, which nosepiece also has another adjacent longitudinal bore 35 formed therein. A cover plate 36 is suitably secured to the upper end of nosepiece 14 and covers the upper ends of bores 34 and 35 except for an aperture 36a through which cable 32 extends, and an aperture 36b through which a later to be described fuse 49 extends. A compression spring 37 is positioned in bore 34, and the lower end of cable 32 is extended through the spring and suitably secured to a disc or plate 38 seated against the lower end of the spring. Spring 37 is thus held under compression between disc or plate 38 and cover plate 36 by tension in the cable 32.

Upper cylindrical member 11 of the frame or body 10 is formed with a longitudinal slot 39 in which is positioned a toggle mechanism designated generally by the numeral 40. This mechanism comprises pairs of toggle links 41 and 42, links 41 having their upper ends supported by pivot pin or shaft 43 extending transversely across slot 39, links 42 having their lower ends pivotally secured together through a pivot pin 44. The alternate pairs of links 41 and 42 have their other ends connected to pivot pins 45, each of which pins carries a roller 46, there also being a pulley 47 carried by pivot pin 43. A cable 48 has one end thereof secured to pivot pin 44 and is passed over pulley 47 and has its opposite end portion passed slidably through a drill hole or aperture 11a in the lower cylindrical portion of member 11, the lower end of the cable being connected to a pivot pin 26a which interconnects links 25 and 26.

An electric detonator cap 50 and the lower end of a fuse 49 are secured within a tubular fuse union 50a and contained in bore 35, fuse 49 extending the length of member 12 and being suitably secured along the inner rear wall portion thereof. An insulated conductor 51 is suitably secured to and along member 11 and 12 and is connected at its lower end to detonator cap 50 and has its upper end coarsed through a longitudinally extending bore 11b in member 11 and connected to the lower end of a terminal bolt 52 which extends through a bore 53 in the cable head 16 and is insulated from the cable head by suitable bushings 54.

A terminal 55 is secured to the upper end of terminal bolt 52, and cable conductor 19 is connected to terminal 55. The aforementioned booster charge-containing housing 56 extends downwardly or rearwardly from the shaped charge cylinders 22 in the charge units 21, as shown in Fig. 2B, the booster charges 56a therein being positioned closely adjacent fuse 49 as shown in Fig. 3B when the shaped charge units 21 are rotated to the horizontal or transverse firing position. The fuse 49 is of an explosive or detonating type, such as that known commercially as "P.E.T.N." Reenforced Primacord designated as "50GR/Ft."

In the operation of the invention the perforator 10 is lowered through a tubing string C as shown in Fig. 1, with the parts of the perforator in the collapsed condition shown in Figs. 1, 2A, 2B, 4 and 5. During this run-in movement the toggle mechanism 40 is fully collapsed with the rollers 46 engaging the inner wall of the tubing and with the shaped charge units retracted in coaxial alignment, spring 37 having been compressed by movement of the link or bar 25 to its uppermost and innermost position when the toggle mechanism is collapsed, which movement places a tension on cable 48 which swings the charge units to the before-mentioned aligned position and compresses spring 37. When the

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lower and central portion of the gun perforator emerges from the lower open end 20 of tubing C the toggle link mechanism is released and expanded by virtue of the spring tension on cable 48, the spring tension being transmitted through cable 32, sector plate 30, link 28 and bar 25 to the pivot pin 26a and thence to cable 48. This rotative movement of the shaped charge units 21 from the longitudinally aligned position of Figs. 1 and 2A rotates the charges to the horizontal or transverse firing position as shown in Fig. 3B, in which position the booster charge housings 56 are each brought into a position in contact with or adjacent fuse 49. When it is desired to detonate the shaped charges, an electrical current is delivered to igniter 50 through cable conductor 19, conductor 50 and through a suitable ground connection for the igniter, such as ground wire 57, thereby igniting the fuse which, upon igniting, detonates the several booster charges 56a and the associated shaped charges 22c contained in the cylinders 22. If for any reason after the gun perforator is positioned in the firing position shown in Figs. 3A and 3B, such as a failure of the electrical circuit or the fuse to ignite, or for a change in plan of the firing location or other similar reason and it is desired to remove the gun perforator, this can be done by an upward pull on the suspension cable 18. During such upward movement toggle mechanism 40 will be retracted upon the links 41 engaging the lower open end of the tubing C, and their further upward movement will cause the collapse of the mechanism and the return of the parts to the condition of Figs. 2A and 2B with the shaped charge units 21 axially aligned, and the perforator can then be raised through the tubing.

It is to be understood that the foregoing is illustrative only, and that the invention is not limited thereby, but may include various modifications and changes which may be made by those skilled in the art without departing from the spirit and scope of the invention as defined in the appended claims.

I claim:

1. Apparatus for perforating casing in oil wells below tubing suspended in said casing comprising in combination: an elongated frame adapted to be lowered in said well through and out the lower end of said tubing; a plurality of longitudinally coaxially aligned shaped charges pivotally mounted on said frame for rotation to laterally directed firing positions; arcuately shiftable means to rotate said charges from said coaxially aligned positions to laterally extending firing positions; means controlled by contact with the inside bore of said tubing to restrain said first means from actuation while said frame is in said tubing; and means to detonate said charges when in said laterally extended firing positions, said second means comprising a collapsible quadrilateral linkage having an upper pair of laterally extending links and a lower pair of laterally extending links, said upper pair having inner adjacent ends pivotally connected centrally of and to said frame by pivotal connection means; direction-reversing means associated with said pivotal connection means; said lower pair of links having adjacent ends pivotally connected together at an anchor point; the outer ends of said upper pair of links being pivotally connected to the outer ends of said lower pair of links; a cable connected to said anchor point and passing upwardly therefrom over said direction-reversing means and returning downwardly for connection to means associated with the mounting means for said shaped charges at the ends opposite the pivotal connections thereof to said body, said upper pair of links when said frame is being raised in said casing and into said lower end of said tubing, being engageable with said lower end of said tubing and actuatable thereby to tension said cable and shift said arcuately shiftable means to rotate said charges to their originally aligned coaxial positions.

2. Apparatus for perforating casing in oil wells below tubing suspended in said casing comprising in combination

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an elongated structure adapted to be lowered in said well through said tubing and out the lower end of said tubing, said structure including a channel member; a fuse positioned within and at the base of the channel of said channel member; a plurality of longitudinally aligned shaped charges pivoted adjacent one end thereof to and within said channel member; means pivotally connected to all of said shaped charges adjacent the other ends thereof to effect rotation thereof about axes transverse of said channel; a booster charge on each shaped charge at the lower portion thereof; means for rotating said shaped charges substantially 90° about said axes to laterally extending firing positions and said booster charges into positions adjacent said fuse; expansible means held in contracted condition while within said tubing for restraining said last means from actuation, said expansible means comprising a pantograph having a fixed link pivot on said structure, a link pivot movable toward and away from said fixed pivot, and a cable connected between said movable pivot and said first means, and means for igniting said fuse.

3. Apparatus for perforating casing in oil wells below tubing suspended in said casing comprising in combination: an elongated frame having a vertical axis and adapted to be lowered in said well through and out the lower end of said tubing; a shaped charge pivotally mounted on said frame and coaxially aligned therewith for rotation to laterally directed firing position; means resiliently biasing said shaped charge to rotate from said coaxially aligned position to said laterally directed firing position; means controlled by contact with the inside bore of said tubing to restrain said first means from actuation while said frame is in said tubing, said second means comprising a collapsible quadrilateral linkage having an upper pair of laterally extending links and a lower pair of laterally extending links, said upper pair of links having inner adjacent ends pivotally connected together at an upper point, said lower pair of links having inner adjacent ends pivotally connected together at a lower point, the outer ends of said upper pair of links being pivotally connected to the outer ends of said lower pair of links, means pivotally connecting said quadrilateral linkage to said frame at one of said upper and lower points, the other of said points being free, and means including a tension member connecting the free point of said quadrilateral linkage to said charge and arranged to urge said quadrilateral linkage to expand laterally as said charge rotates from said coaxially aligned position to said laterally directed firing position when said quadrilateral linkage emerges from the lower end of said tubing, said upper pair of links, when said frame is being raised in said casing and into the lower end of said tubing, being engageable with the

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lower end of said tubing and actuable thereby to laterally contract said quadrilateral linkage and tension said tension means to rotate said charge to its original coaxially aligned position; and means to detonate said charge when in said laterally extended firing position.

4. Apparatus for perforating casing in oil wells below tubing suspended in said casing comprising in combination: an elongated frame having a vertical axis and adapted to be lowered in said well through and out the lower end of said tubing; a shaped charge pivotally mounted on said frame and coaxially aligned therewith for rotation to laterally directed firing position; means resiliently biasing said shaped charge to rotate from said coaxially aligned position to said laterally directed firing position; means controlled by contact with the inside bore of said tubing to restrain said first means from actuation while said frame is in said tubing, said second means comprising a collapsible quadrilateral linkage having an upper pair of laterally extending links and a lower pair of laterally extending links, said upper pair of links having inner adjacent ends pivotally connected to said frame by pivotal connection means, said lower pair of links having inner adjacent ends pivotally connected together at an anchor point, the outer ends of said upper pair of links being pivotally connected to the outer ends of said lower pair of links, and means including a cable connecting said anchor point to said charge and arranged to urge said quadrilateral linkage to expand laterally as said charge rotates from said coaxially aligned position to said laterally directed firing position when said quadrilateral linkage emerges from the lower end of said tubing, said upper pair of links, when said frame is being raised in said casing and into the lower end of said tubing, being engageable with the lower end of said tubing and actuable thereby to laterally contract said quadrilateral linkage and tension said cable to rotate said charge to its original coaxially aligned position; and means to detonate said charge when in said laterally extended firing position.

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