Jan. 9, 1962 M. P. LEBOURG 3,016,014

PERFORATING APPARATUS

Filed May 23, 1955 3 Sheets-Sheet 1

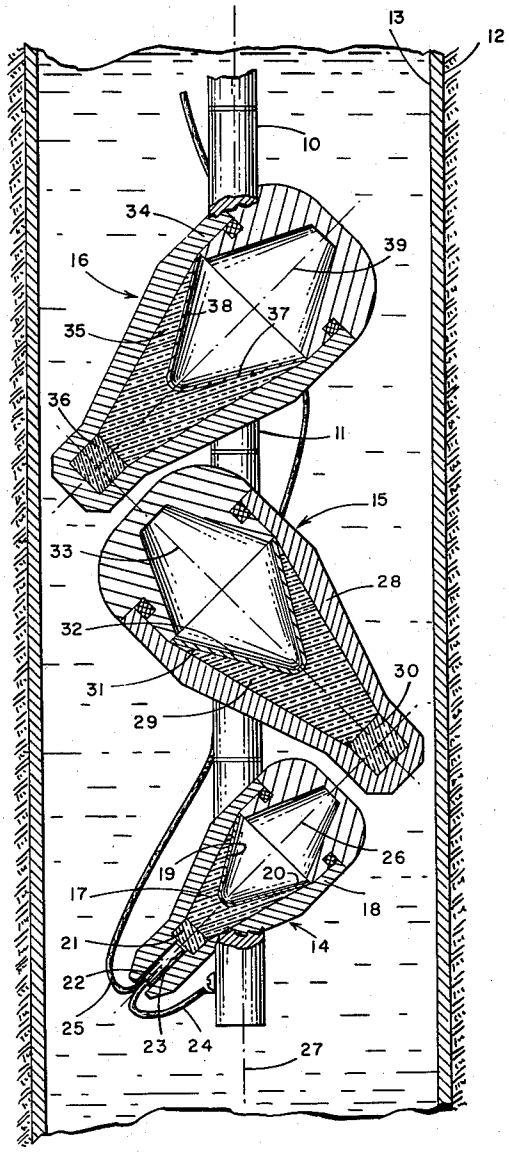


FIG. 1

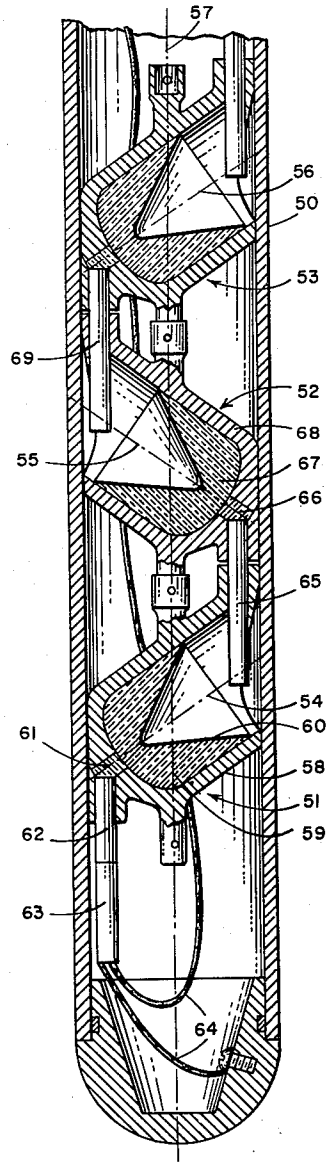


FIG. 2A

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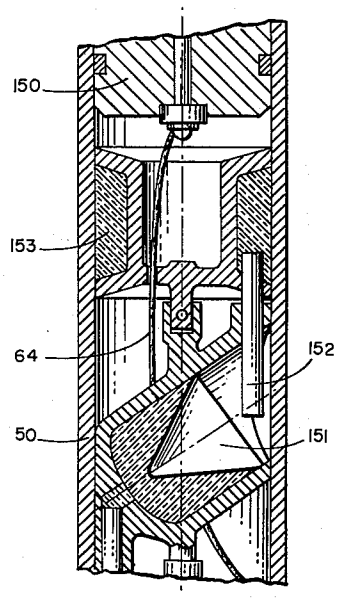


FIG.2B

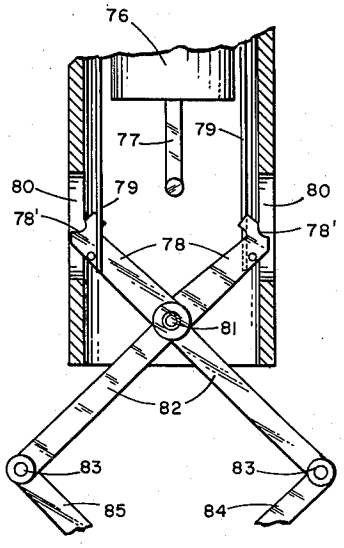


FIG.5

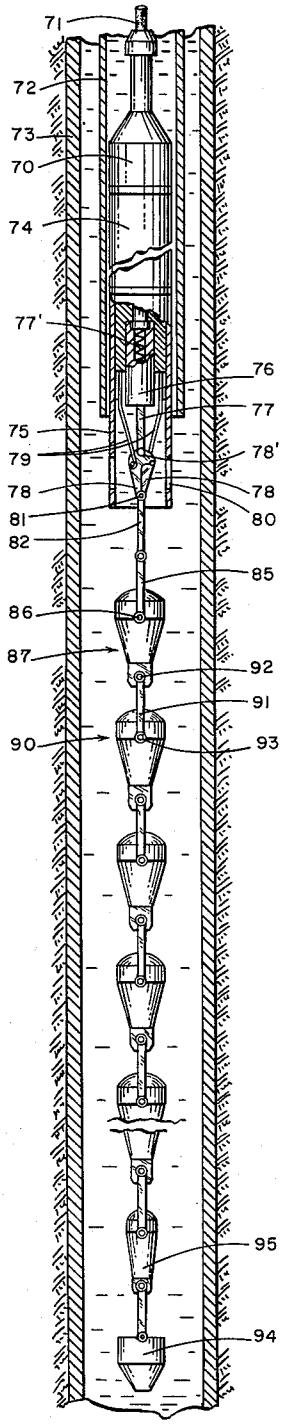


FIG.3

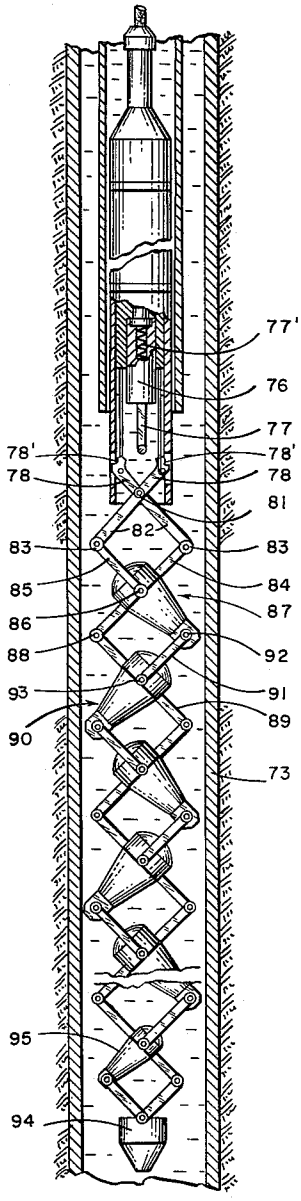


FIG.4

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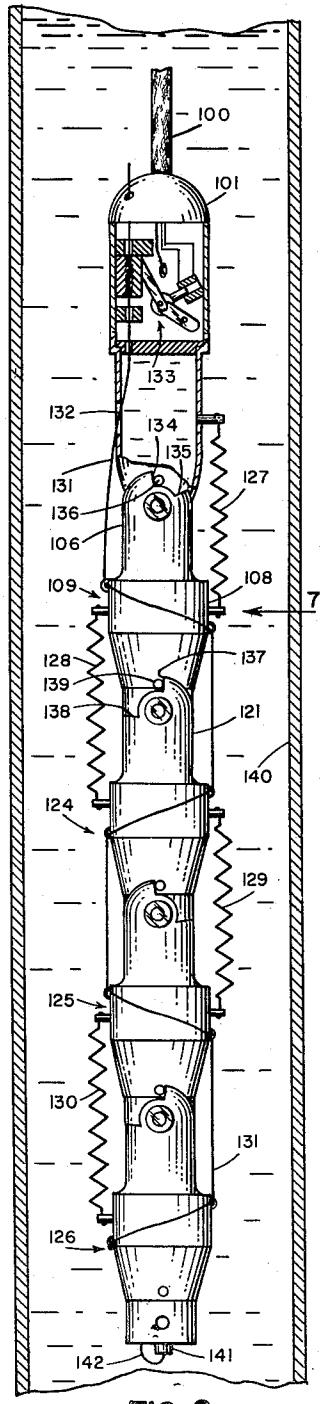


FIG. 6

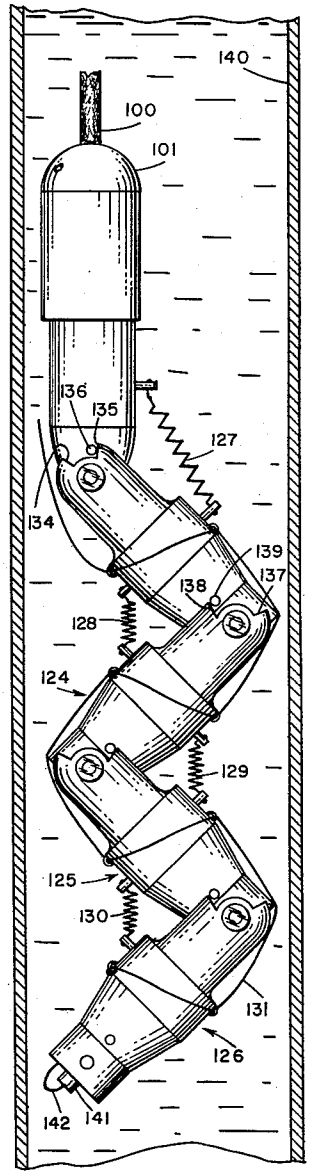


FIG. 8

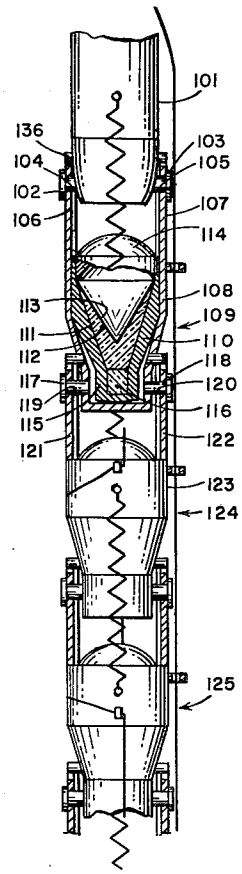


FIG. 7

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United States Patent Office

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PERFORATING APPARATUS

Maurice P. Lebourg, Houston, Tex., assignor, by mesne assignments, to Schlumberger Well Surveying Corporation, Houston, Tex., a corporation of Texas

Filed May 23, 1955, Ser. No. 510,129
15 Claims. (Cl. 102—20)

This invention relates to perforating apparatus and, more particularly, pertains to new and improved perforating apparatus which includes shaped explosive charges.

"Shaped" or "hollow" charges are widely and effectively used as cutting or perforating devices in many applications. For example, shaped charges have achieved great commercial success in perforating the casings of wells drilled into the earth. In such applications, a string of longitudinally spaced charges is lowered into a well, and at a desired depth the charges are ignited essentially simultaneously by firing a blasting cap attached to a Primacord that extends along the string of charges.

Although the foregoing arrangement has been successfully employed in a great many well perforating operations, in certain cases the use of a Primacord may be a handicap to the design of small, efficient shaped charge apparatus. For example, if the shaped charges are to be individually housed, the Primacord should be provided with a waterproof external jacket, and the charge housings should be provided with a very thin wall section adjacent the Primacord, at which initiation takes place. In an alternative arrangement where the charges are enclosed by a long cylindrical housing, the space needed for a Primacord may undesirably prevent a reduction in the size of the housing.

It is, therefore, an object of the present invention to provide new and improved shaped charge apparataus in which a Primacord is not required.

Another object of the present invention is to provide new and improved shaped charge perforating apparatus in which a plurality of charges may be efficiently and reliably initiated without any mechanical or electrical connection between the charges for firing purposes.

A further object of the present invention is to provide new and improved perforating apparatus employing a plurality of hollow charges fitted with a suitable liner wherein initiation of the charges is accomplished without the use of a Primacord and wherein harmful plugging effects of the slug usually formed of liner material are substantially reduced or entirely eliminated.

Perforating apparatus constructed in accordance with the present invention comprises a shaped explosive charge having a forward section from which a perforating jet emanates upon detonation of the charge. Another shaped explosive charge having a forward section from which a perforating jet emanates upon detonation thereof has a rearward section disposed in the path of material comprising the perforating jet of the first-mentioned charge. Accordingly, after the first-mentioned charge is initiated, its perforating jet initiates the last-mentioned charge.

The novel features of the present invention are set forth with particularity in the appended claims. The present invention, both as to its organization and manner of operation, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawings in which:

FIG. 1 is a view in longitudinal cross section of shaped explosive charge perforating apparatus constructed in accordance with the invention;

FIGS. 2A and 2B illustrate, in longitudinal cross section, the lower and upper portions respectively, of shaped charge perforating apparatus embodying another form of the present invention.

FIG. 3 is a view in longitudinal cross section of another type of perforating apparatus embodying the invention and shown in a retracted or closed condition of operation;

FIG. 4 represents the apparatus shown in FIG. 3, but illustrated in an extended or open condition;

FIG. 5 is an enlarged view of a portion of FIG. 4;

FIGS. 6 and 8 illustrate another type of apparatus embodying the invention, and represent the apparatus in closed and open conditions, respectively; and

FIG. 7 is a view of the apparatus of FIG. 6 taken in the direction of arrow 7 and shown partly in longitudinal cross section.

In FIG. 1 of the drawings there is shown a carrier comprised of a pair of laterally spaced supports **10** and **11**, which may be constructed of a frangible, electrically-conductive material. For example, a suitable alloy of aluminum may be employed. Means (not shown) are provided for lowering the carrier **10**, **11** into a borehole **12** provided with a casing **13** which is to be perforated.

A plurality of shaped explosive charge units **14**, **15** and **16** are mechanically connected to and supported between the members **10** and **11** of the carrier in vertically spaced relation. The lowermost charge unit **14** comprises a generally conically shaped explosive charge **17** encased in a housing **18**. The housing **18** may be constructed of any material, such as Bakelite, of sufficient strength to act as a retainer of the explosive material and protect charge material **17** from the liquid which usually fills the borehole.

The explosive **17** is formed with a conical, hollowed-out forward end **19** which receives a closely fitting liner **20** constructed, for example, of thin steel, copper or zinc. The rearward end of charge **17** preferably terminates in a cylindrical body **21** of explosive material associated with a blasting cap **22** that is positioned within a cylindrical recess **23** at the rear end of housing **18**. One electrical connection **24** extends between blasting cap **22** and carrier portion **11** and another electrical connection is completed by an insulated lead **25** which extends to the surface of the earth in the customary manner.

By connecting a source of electrical energy (not shown) between the upper end of lead **25** and a connection to carrier **10**, **11**, blasting cap **22** may be fired and it in turn detonates explosive material **21**, thereby to ignite the charge **17**. Thus, a jet is created which extends from forward section **19** along an axis represented by broken line **26**. Charge **14** is supported in such a position relative to carrier **10**, **11** that the jet axis **26** is inclined upwardly and at an angle other than 90° relative to a longitudinal axis, denoted by broken line **27**, for carrier **10**, **11**.

Charge unit **15** is enclosed by a housing **28** which may be similar to housing **18** in construction; however, charge **15** is somewhat larger than charge **14** so that it may perform a perforating function. It comprises a conically shaped body of explosive material **29** terminating at a section of reduced diameter in the form of a generally cylindrical primer **30**. Explosive material **29** includes a conical, hollowed, front end **31** fitted with a liner **32**. The primer **30** is positioned on axis **26** so that it is ignited by the jet from charge unit **14**. Thus, explosive material **29** is ignited and a perforating jet emanates along an axis defined by broken line **33**. Device **15** is supported by carrier **10**, **11** so that jet axis **33** is inclined upwardly and at an angle other than 90° relative to longitudinal axis **27** of the carrier.

Charge unit **16** is provided with a housing **34** which is similar to housing **28**. Enclosed by housing **34** is an explosive material **35** of generally conical configuration terminating in a cylindrical primer section **36** at the rear-

ward end of the charge. The forward end of explosive material 35 includes a conical, hollowed portion 37 fitted with a liner 38. Primer 36 is disposed in front of charge unit 15 and substantially on jet axis 33. In other words, end 36 is disposed in the path of material comprising the perforating jet of charge unit 15. Thus, primer end 36 is ignited thereby to ignite explosive material 35 and from forward section 37 a perforating jet emanates along an axis 39. Charge 16 is supported so that axis 39 is inclined upwardly relative to the longitudinal axis 27 of carrier 10, 11.

Although but two charges, 15 and 16, have been illustrated for perforating purposes, obviously, any desired additional number may be employed. The next charge, for example, may be positioned with its rearward end on jet axis 39 of charge 16. In general, all of the charges are supported with their jet axes inclined relative to longitudinal axis 27 and with their forward ends facing upwardly so that upwardly directed perforations may be produced in casing 13.

Returning to a discussion of the detonation of charge unit 15, as is well-known in the operation of a shaped explosive charge having a liner such as the one designated 32, a stream of flowing metal is created from the liner. This stream extends outwardly from charge unit 15 essentially along axis 33. While the collapse of liner 32 is involved in the creation of a high-speed perforating jet, a portion of the apex of the liner forms a relatively slowly moving slug which travels in the direction of the jet, but at a much lower velocity. This slug may plug the perforation made by the jet; however, section 36 of charge unit 16 is disposed in the path of the high velocity jet and is detonated thereby. The resulting explosive force created just prior to the arrival of the slug breaks the slug into small fragments. These are so distributed as to preclude plugging of the hole made by the high velocity jet. Of course, if rear portion 36 is disposed slightly off axis 33, but in the path of material comprising the high velocity jet, it will still be detonated by the jet. The explosive force, however, deflects the trajectory of the slug so that it cannot plug the hole made by the explosive jet.

The foregoing slug-eliminating feature is similar to the use for this purpose of an auxiliary explosive which may be positioned in igniting relation to the path of the perforating jet, as disclosed and claimed in the copending application of M. P. Lebourg, Serial No. 775,679, filed November 20, 1958, which is a continuation of an application (now abandoned) filed November 30, 1954, bearing the Serial Number 471,975, and assigned to the same assignee as the present invention.

In the perforating apparatus described hereinbefore, a portion of the explosive material of one charge unit is disposed in the path of material comprising the perforating jet of another charge unit and in this way a string of charges may be detonated, without the use of Primacord. Moreover, an organization of elements constructed in accordance with the present invention also features slug elimination; i.e., the plugging effects of the slug formed in the detonation of a charge having a liner are minimized.

Although the present invention has been described in connection with an arrangement in which the explosives are separately housed, usually referred to as "open hole" charges, the chain-firing and slug-eliminating features may be embodied in apparatus of the type illustrated in FIGS. 2A and 2B. As shown in FIG. 2A, supported within a hollow, cylindrical housing 50, which may be constructed of an alloy of aluminum, are a plurality of charge units 51, 52 and 53 having their respective jet axes 54, 55 and 56 inclined relative to longitudinal axis 57 for housing 50. Charge unit 51 includes a hollow cylindrical container 58 for an explosive material 59 having a liner 60 at its conical forward end and a primer 61 at its rearward end. A booster charge 62 for primer 61 is associated with a blasting cap 63 to which electrical

leads 64 are connected. A source (not shown) of electric current may be selectively connected to leads 64 to ignite blasting cap 63, in turn to ignite booster charge 62. The primer 61 is thus ignited and charge material 59 is thereby detonated.

A cylindrical booster charge 65 has one end disposed in the path of material comprising the jet from charge unit 51 which is formed along axis 54, and may actually intersect the axis 54 (as shown in FIG. 2A) or may terminate slightly off the axis of the perforating jet without intersecting the axis but in such relation as to be ignited thereby, as disclosed in greater detail in the aforementioned copending application of Maurice P. Lebourg. The other end of booster 65 is associated with a primer 66 at the rear end of charge material 67 contained by a housing 68 of charge unit 52. Consequently, the jet from charge unit 51 ignites the booster 65 which, in turn ignites primer 66 and charge material 67 is detonated. Similarly, a booster 69 for charge unit 53 is disposed in the path of material comprising the jet from charge unit 52. As a result, charge unit 53 is detonated and its perforating jet is formed along axis 56.

In order that housing 50 may be cleanly severed from head 150 shown in FIG. 2B, upon the detonation of the shaped charges within housing 50, the jet from uppermost charge 151 ignites booster 152 which in turn ignites annular explosive charge 153. The detonation of explosive charge 153 will cause housing 50 to be cleanly severed from head 150, which may then be readily withdrawn from the borehole by the cable (not shown).

It is, therefore, evident that in the perforating apparatus illustrated in FIGS. 2A and 3B charge units 52 and 53 have rearward sections effectively in the path of material comprising the perforating jets of charge units 51 and 52, respectively. Hence, the operation of this embodiment of the invention provides the detonaion and slug-elimination features ascribed to the arrangement shown in FIG. 1. Moreover, since a Primacord is not required, the housing 50 of the apparatus shown in FIGS. 2A and 2B may be substantially smaller in diameter than the housing of prior apparatus employing a Primacord.

The present invention may be embodied in perforating apparatus small enough to pass through tubing, in a closed condition as shown in FIG. 3, and yet giving maximum power when open in the casing in a perforating condition as shown in FIG. 4. The apparatus includes a cable attachment head 70 to which a cable 71 is connected so that the apparatus may be lowered through tubing 72 and out of the lower, open end of the tubing into the casing 73.

A casing collar locator section 74 is supported immediately below head 70 and may include any well-known arrangement for deriving a signal representing the casing joints which may be supplied to an indicator (not shown) at the surface of the earth via conductors (not shown) within cable 71. A cylindrical housing 75 extends downwardly from section 74 and encloses a solenoid 76 which receives a cylindrical armature or actuator 77. The lower end of armature 77 is biased by a spring 77' into recesses 78', best seen in FIG. 5, at upper ends of a pair of latch members 78. The latch members are thus held in closed positions against the outward bias of a pair of springs 79 which extend upwardly from the latch members and terminate at fixed points adjacent solenoid 76. Openings 80 in the vicinity of the lower end of housing 75 are provided to permit outward movement of the sections of latch 78.

Latch members 78 are disposed at the upper ends of a pair of arms 82 which are pivotally connected to the lowermost end of housing 75 by a common pin 81, and lower end portions of these arms are pivotally connected by pins 83 to a lever arm 84 and to a linkage 85, respectively. As seen in FIGS. 3 and 4, the free end of linkage 85 is connected by a pivot pin 86 to an upper, side portion of a shaped charge unit 87, and a central secuon

(not shown) of arm 84 is pivotally connected to charge unit 87 at a point opposite pin 86. A pin 88 pivotally connects the free end of arm 84 to a similar arm 89 having its central section (not shown) pivotally connected to an upper, side portion of a shaped explosive charge unit 90. A linkage 91 extends between a pivot pin 92 fixed to a rear, side portion of charge unit 87 and a pivot pin 93 on charge unit 90. A similar organization of linkages, lever arms and pivot pins connects the several shaped charge units shown in the representations of FIGS. 3–4 to form a construction of crossed levers usually referred to as "lazy tongs." The lowermost end of the string is terminated by a weight 94 disposed below the lowermost charge unit 95 which may be connected to a source of electric current (not shown) for initiating the string of charges.

In operation, the assembly is latched in its closed condition, as illustrated in FIG. 3, so that the charges are supported in positions with their jet axes aligned with the longitudinal axis of the tool. Accordingly, the apparatus may be easily lowered through tubing 72.

Upon reaching the level within casing 73 at which perforations are to be made, electromagnet 76 is energized and armature 77 is withdrawn from engagement with latches 78. Springs 79 are thus permitted to exert forces which pivot the various levers and linkages, and the apparatus is placed into its extended or open condition as shown in FIG. 4. It is, therefore, evident that the charge units are carried from their first positions in which their jet axes are aligned with the longitudinal axis of the perforating tool to their second positions with their jet axes inclined to the longitudinal axis. In the second positions, the rearward end portion of each of the charges is disposed in the path of material comprising the perforating jet from the charge below.

In order to produce perforations, the lowermost charge 95 is ignited, thereby to ignite the entire string in the same manner described in connection with FIG. 1. After the charges are expended, the latching system may be retrieved by withdrawing cable 71 upwardly.

In case of a misfire, the open tool may be drawn back through the tubing since the linkage system must close upon entering the lower end of the tubing.

Another arrangement for carrying explosive charges into a borehole with their jet axes in alignment along a longitudinal axis and subsequently permitting the charges to be displaced into firing positions in which their jet axes are inclined to the longitudinal axis is represented in FIGS. 6–8.

Connected to a supporting cable 100 is a cable attachment head 101 which encloses a cable-release mechanism whose function will be described hereinafter. As best seen in FIG. 7, a pair of pivot pins 102 and 103 extend in radially opposed directions from the lower end of head 101 and are received by respective openings 104 and 105 in extensions 106 and 107 of a housing 108. These extensions straddle the lower end of head 101.

Housing 108 is a part of a charge unit 109 and receives a container 110 for an explosive material 111 having a hollow, conical front end 112 fitted with a conical liner 113. The front end of container 110 is closed by a cap 114 and its rear end 115 encloses an extension of explosive material 111 in the form of a primer 116.

A pair of pivot pins 117 and 118 extend in radially opposite directions from the rear end of housing 108 and are received by respective openings 119 and 120 in extensions 121 and 122 which straddle the rear end of housing 108. The extensions 121 and 122 are part of a housing 123 for another charge unit 124 which may be constructed identically to charge unit 109.

The apparatus also includes charge units 125 and 126 which preferably are similar in construction to charge unit 109 and which are connected with one another and with charge unit 109 in the manner just described with respect to charge units 108 and 124.

As shown in FIG. 6, each of a plurality of tension springs 127–130 is connected between lateral projections of an adjacent pair of the members 101, 109, 124, 125 and 126. Specifically, spring 127 biases charge unit 109 about its pivots counterclockwise with respect to head 101, while spring 128 relatively biases charge units 109 and 124 in the opposite direction. Spring 129 biases charge unit 125 for pivotal movement in a counterclockwise direction with respect to charge unit 124, while charge unit 126 is biased clockwise relative to charge unit 125 by spring 130.

To maintain the charges in longitudinally aligned relation, a cable 131 is fixed at its lower end to charge unit 126 and passes through suitable guides along the several charge units so that it presents one of its sections directly opposite each of the tension springs 127–130. Thus, the charge units may be placed in longitudinally aligned positions and the upper end of cable 131 is passed through an opening 132 in head 101 and into operative relation with an electrically-actuated release mechanism 133 where it is releasably locked.

In order to limit movement of the charge units, each of the housing extensions is provided with a suitable cut-out portion cooperating with a locking pin. For example, extension 106 of housing 109 has a cut-out, defining shoulders 134 and 135 positioned to engage lateral pin 136. Accordingly, shoulder 134 upon engaging pin 136 limits movements of charge unit 109 so that despite the tension applied to wire 131, the charge unit may not pivot in a clockwise direction relative to head 101 beyond a longitudinally aligned position. Shoulder 135 is disposed so that upon engagement with pin 136, counterclockwise movement in response to the action of spring 127 is limited whereby charge unit 109 assumes a given angular position.

The remaining charge units are similarly equipped. For example, extension 121 of charge unit 124 is provided with shoulders 137 and 138 positioned to engage a pin 139 fixed to housing 108 of charge unit 109. Shoulder 137 and pin 135 act to restrain movement against the action of wire 131, while shoulder 137 and pin 135 act to restrain movement against the bias of spring 128.

In general, the shoulders, such as the ones designated 134 and 137 and their respective pins operate together with wire 131 to maintain the charge units 109, 124, 125 and 126 with the jet axes in longitudinally aligned relation. This alignment represented in FIG. 6 facilitates the passing of the apparatus through narrow well tubing and into casing 140. At a selected depth, locking mechanism 133 is actuated, thereby to release wire 131 and the various charge units are displaced about the several pivots by springs 127–130 to the positions shown in FIG. 7. In the latter positions, shoulders such as the ones designated 135 and 138 cooperate with the associated pins to limit movement so that the charges are inclined to the longitudinal axis of the apparatus with the rear portion of one charge on the jet axis of the charge below. For example, primer 116 (FIG. 7) of charge unit 109 is disposed on the jet axis of charge unit 124. A blasting cap 141 at the rear end of charge unit 126 may be electrically actuated by means of a current source (not shown) via an electric cable 142 that passes along the charge units and whose conductors traverse cable 100 en route to the surface of the earth. Accordingly, the perforating apparatus may be detonated and its operation is essentially the same as explained in connection with FIGS. 3 and 4.

While particular embodiments of the present invention have been shown and described, it is apparent that changes and modifications may be made without departing from this invention in its broader aspects, and, therefore, the aim in the appended claims is to cover all such changes and modifications as fall within the true spirit and scope of this invention.

I claim:

1. Perforating apparatus for use in a bore hole com-

prising a plurality of shaped explosive charge devices each having a rearward portion and a forward portion from which an explosive perforating jet is adapted to emanate along a jet axis upon ignition of said charge, individual igniting means coupled to said rearward portion of each of said charge devices, means mounting said charge devices in a zig-zag train with their jet axes disposed at acute angles to a reference axis for penetration of the borehole wall by the explosive jets, each of said igniting means extending forwardly of the forward portion of the preceding charge device and into igniting relation with the path of the explosive perforating jet emanating therefrom, said igniting means presenting a relatively small cross-sectional area to the forward portion of said charge device to avoid substantial impairment of the penetration of the perforating jet emanating therefrom, and means for initiating detonation of an explosive charge device in said train.

2. Perforating apparatus comprising a plurality of shaped explosive charge devices each having an ignitable rearward end portion and a forward portion from which an explosive perforating jet is adapted to emanate along a jet axis upon ignition of said rearward end portion, means linking said charge devices in the form of a chain while permitting movement of said charges to position the jet axes thereof at different acute angles with respect to a reference axis, means actuatable to move said linked charge devices to form a zig-zag train in which the jet axes are disposed at acute angles to said reference axis for penetration of a borehole by the explosive jets and with the ignitable rear end portion of each device extending into igniting relation with the path of the explosive perforating jet from the preceding charge device for ignition thereby, and means for initiating detonation of one of said explosive charge devices.

3. Perforating means as defined in claim 2 wherein said actuatable means includes means urging said linked charge devices to form said ziz-zag train, means locking said charge devices in said chain form, and means for actuating said locking means to permit movement of said charge devices to form said zig-zag train.

4. Perforating apparatus for use in a borehole comprising a plurality of shaped explosive charge devices each having a rearward portion and a forward portion from which an explosive perforating jet is adapted to emanate along a jet axis upon ignition of said charge, individual igniting means coupled to said rearward portion of each of said charge devices, means mounting said charge devices in stacked array with their jet axes oriented in different directions with respect to a reference axis for penetration of the borehole wall by the explosive jets, each of said igniting means extending forwardly of the forward portion of the preceding charge device and comprising a booster explosive charge extension extending substantially in the same direction as said reference axis into igniting relation with the path of the explosive jet emanating therefrom, said igniting means presenting a relatively small cross-sectional area to the forward portion of said charge device to avoid substantial impairment of the penetration of the perforating jet emanating therefrom, and means for initiating detonation of said explosive charge devices.

5. Perforating apparatus for use in a borehole comprising a plurality of shaped explosive charge devices each having a rearward portion and a forward portion from which an explosive perforating jet is adapted to emanate along a jet axis upon ignition of said charge, individual igniting means coupled to the rearward portion of each of said charge devices, individual fluid pressure-tight containers enclosing each of said shaped explosive charge devices, means mounting said containers and said charge devices in a zig-zag train with the jet axes of said charge devices disposed at acute angles to a reference axis and with the igniting means of each charge device extending into igniting relation with the path of the explosive perforating jet emanating therefrom, said igniting means presenting a relatively small cross-sectional area to the forward portion of said charge device to avoid substantial impairment of the penertation of the perforating jet emanating therefrom, and means for initating detonation of an explosive charge device in said train.

6. Perforating apparatus for use in a borehole comprising a plurality of shaped explosive charge devices each having a rearward portion and a forward portion from which an explosive perforating jet is adapted to emanate along a jet axis upon ignition of said charge, individual igniting means coupled to said rearward portion of each of said charge devices, each of said igniting means extending forwardly of the forward portion of the preceding charge device and comprising a booster explosive charge extension for each ignitable rear end, means mounting said charge devices in a zig-zag train with their jet axes disposed at acute angles to a reference axis and with the booster charge extension of each charge device extending into igniting relation with the path of the explosive perforating jet from the preceding charge, said booster charge presenting a relatively small cross-sectional area to the forward portion of said charge device to avoid substantial impairment of the penetration of the perforating jet emanating therefrom, and means for initiating detonation of an explosive charge device in said train.

7. Perforating apparatus for use in a borehole comprising an elongated fluid pressure-tight carrier, a retrievable support connected to said carrier, a plurality of shaped explosive charge devices each having an ignitable rearward end portion and a forward portion from which an explosive perforating jet is adapted to emanate along a jet axis upon ignition of said rearward end portion received by said carrier, means mounting said charge devices in a zig-zag train with their jet axes disposed at acute angles to a reference axis and with the ignitable rear end portion of each charge device extending into igniting relation with the path of the explosive perforating jet from the preceding charge device for ignition thereby, another explosive charge positioned at one end of said carrier and adjacent the periphery thereof for severing the same from said support, detonating means for said last-named charge extending into and transversely of the path of the explosive jet from an adjacent shaped explosive charge device in said train.

8. Perforating apparatus for use in a borehole comprising: an elongated housing; a plurality of explosive charge devices received by said housing, each having a rearward portion and forward portion from which an explosive perforating jet is adapted to emanate along a jet axis upon ignition of said charge; individual igniting means coupled to said rearward portion of each of said charge devices; means mounting said charge devices in a zig-zag train with their jet axes disposed at acute angles to a longitudinal axis of said housing for perforation of the borehole wall by the explosive jets; each of said igniting means comprising a booster explosive charge extending longitudinally of said train from said rearward portion of one of said shaped charge devices and forwardly of the forward portion of the preceding charge device into igniting relation with the path of the explosive perforating jet emanating therefrom, said booster explosive charge presenting a relatively small cross-sectional area to the forward portion of said charge device to avoid substantial impairment of the penetration of the perforating jet emanating therefrom, and means for initiating detonation of one of said explosive charge devices in said train.

9. Perforating apparatus for use in a bore-hole comprising: an elongated housing; a plurality of shaped explosive charge devices received by said housing, said devices including hollow containers, explosive charges received by said containers and means to space said containers from one another, said containers and said explosive charges being arranged to produce explosive perforating jets for perforation of the borehole wall, said perforat-

ing jets being generated along jet axes which are at an angle relative to a longitudinal axis of said housing, the angle of each jet axis and the spacing between adjacent containers being such that the explosive jet from one container will not intersect another container; means to chain fire said charge devices including booster explosive charges respectively in igniting relation with and extending from an explosive charge of one container into igniting relation with the path of the perforating jet of an explosive charge in an adjacent container, each of said booster explosive charges presenting a relatively small cross-sectional area to the charge device in said adjacent container to avoid substantial impairment of the penetration of the perforating jet emanating therefrom whereby, upon detonation of one of said explosive charges, the explosive jet of said one explosive charge is adapted to penetrate the borehole wall while also detonating a booster charge which serves to initiate the detonation of the succeeding charge device which continues the operation in a like manner; and means to initiate detonation of said one explosive charge.

10. Perforating apparatus for use in a borehole comprising: an elongated housing; a plurality of shaped explosive charge devices received by said housing, said devices including hollow containers, explosive charges received by said containers and means to space said containers from one another, said containers and said explosive charges being arranged to produce explosive perforating jets for perforation of the borehole wall, said perforating jets being generated along jet axes which are at an angle relative to a longitudinal axis of said housing, the angle of each jet axis and the spacing between adjacent containers being such that the explosive jet from one container will not intersect another container; means to chain fire said charge devices including booster explosive charges in igniting relation with and extending from an explosive charge of one container into igniting relation with the path of the perforating jet of an explosive charge in an adjacent container, said booster explosive charges presenting relatively small cross-sectional areas to said charge devices to avoid substantial impairment of the penetration of the perforating jets emanating therefrom, whereby, upon detonation of one of said explosive charges, the explosive jet of said one explosive charge is adapted to penetrate the borehole wall while also detonating a booster charge which serves to detonate the succeeding charge device which continues the operation in a like manner; and means to initiate detonation of said one explosive charge.

11. Perforating apparatus for use in a borehole comprising: an elongated housing; a plurality of shaped explosive charge devices received by said housing, said devices including hollow containers, explosive charges received by said containers and means to space said containers from one another, said containers and said explosive charges being arranged to produce respective explosive perforating jets in alternate directions for perforation of the borehole wall on opposite sides of a longitudinal axis of said housing, said perforating jets being generated along jet axes which are at an angle relative to said longitudinal axis of said housing, the angle of each jet axis and the spacing between said containers being such that the explosive jet from one container will not intersect another container; means to chain fire said charge devices including booster explosive charges respectively in igniting relation with and extending transversely from an explosive charge of one container so as to be in igniting relationship with the perforating jet of an explosive charge in an adjacent container, said booster explosive charge presenting a relatively small cross-sectional area to the forward portion of said charge device to avoid substantial impairment of the penetration of the perforating jet emanating therefrom, said booster charges terminating adjacent the jet axis of said explosive charge of the adjacent container whereby, upon detonation of one of said explosive charges, the explosive jet of said one explosive charge is adapted to penetrate the borehole wall while also detonating a booster charge which serves to detonate the succeeding charge device which continues the operation in a like manner; and means to initiate detonation of said one explosive charge.

12. Perforating apparatus for use in a borehole comprising: an elongated housing; a plurality of shaped explosive charge devices received by said housing, each having a rearward portion and a forward portion from which an explosive perforating jet is adapted to emanate along a jet axis upon ignition of said charge; individual igniting means coupled to said rearward portion of each of said charge devices; means mounting said charge devices in a zig-zag train with their jet axes, each disposed at acute angles to an axis extending longitudinally of said housing and in a common plane with said longitudinal axis, the forward portions of said charges alternately lying on opposite sides of said longitudinal axis whereby said explosive jets obtain perforation of the borehole wall on opposite sides of said longitudinal axis; a booster explosive charge for each of said charge devices lying in said common plane each of said igniting means comprising a booster explosive charge extending from the rearward portion of one charge device and forwardly of the forward portion of the preceding charge device into igniting relation with the path of the explosive perforating jet emanating therefrom; said booster explosive charge presenting a relatively small cross-sectional area to the forward portion of said charge device to avoid substantial impairment of the penetration of the perforating jet emanating therefrom; and means for initiating detonation of one of said explosive charge devices.

13. Perforating apparatus for use in a borehole comprising first and second shaped explosive charges each having an ignitable rearward explosive section and a hollowed-out forward section fitted with a liner from which a perforating jet emanates along a jet axis upon ignition of said rearward section, means for supporting said shaped charges in an elongated assembly for movement longitudinally through a well bore with the forward section of said first shaped charge adjacent the rearward section of said second shaped charge and with the jet axes of said shaped charges offset and at an angle to the longitudinal dimension of said supporting means so as to provide spaced, separate jet perforations in the bore wall, an elongated auxiliary charge spaced forwardly and overlying a portion only of the forward section of said first shaped charge in igniting and offset relation with the path of the perforating jet emanating therefrom for ignition thereby without substantially impairing its penetration, said auxiliary charge presenting a relatively small cross-sectional area to the forward section of said first shaped charge said auxiliary charge extending into igniting relation with the rearward section of said second shaped charge to ignite the same upon ignition by the perforating jet of said first shaped charge, and means for initiating the detonation of said first shaped charge.

14. Perforating apparatus for use in a borehole comprising an elongated housing, first and second shaped explosive charges in said housing each having an ignitable rearward explosive section and a hollowed-out forward section fitted with a liner from which a perforating jet emanates along a jet axis upon ignition of said rearward section, said shaped charges being supported in said housing for movement through a well bore with the forward section of said first shaped charge adjacent the rearward section of said second shaped charge and with the jet axes of said shaped charges offset and at an angle to the longitudinal axis of said housing to provide spaced, separate jet perforations in the bore wall upon detonation, an elongated auxiliary charge spaced forwardly of the forward section of said first shaped charge and extending in igniting and offset relation with the path of the perforating jet emanating from said first shaped charge for ignition thereby without substantially impairing its penetration,

said auxiliary charge presenting a relatively small cross-sectional area to the forward section of said first shaped charge said auxiliary charge extending longitudinally into igniting relation with the rearward section of said second shaped charge to ignite the same upon ignition by the perforating jet of said first shaped charge, and means for initiating the detonation of said first shaped charge.

15. Perforating apparatus for use in a borehole comprising a plurality of shaped explosive charges, each including a hollow container of generally cylindrical configuration for conforming with a cylindrical bore when said charges are mounted in axial alignment with respect to a mounting axis therealong, means for mounting said charges in alternately directed axial alignment, said container having therein an explosive material, a primer at its rearward end and a liner fitted in its hollowed-out forward end from which a perforating jet emanates along a jet axis at an angle to said mounting axis upon detonation of said explosive material by said primer, and an elongated booster charge for said primer extending from the rear end of said container at an angle to its jet axis and in a direction generally parallel to said mounting axis, said booster charge being of a length to terminate in igniting relation with the path of the perforating jet and near to but not on the jet axis of an adjacent shaped charge opposite its forward end and presenting a relatively small cross-sectional area to the forward end of said charge to avoid substantial impairment of the penetration of the perforating jet emanating therefrom.

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