July 4, 1967 W. T. BELL 3,329,218

APPARATUS FOR DETONATING SHAPED CHARGES

Filed Feb. 12, 1965 3 Sheets-Sheet 1

Fig. 1

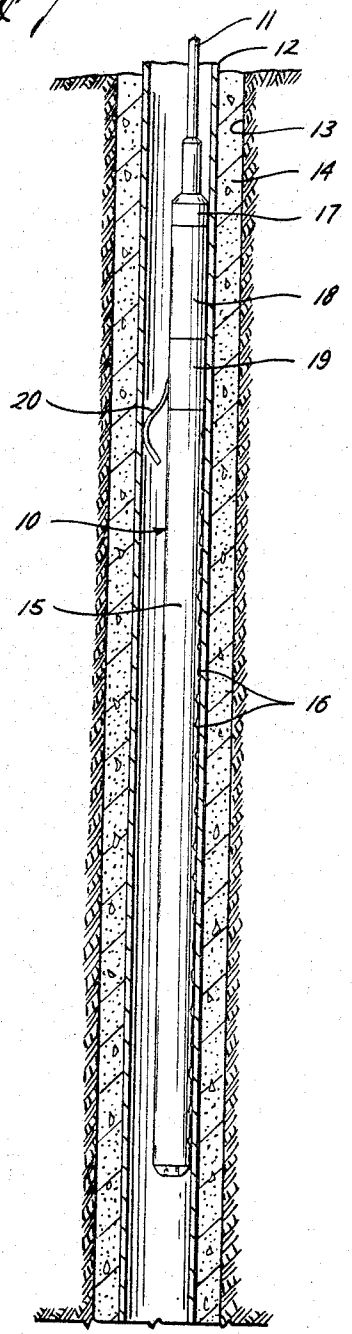
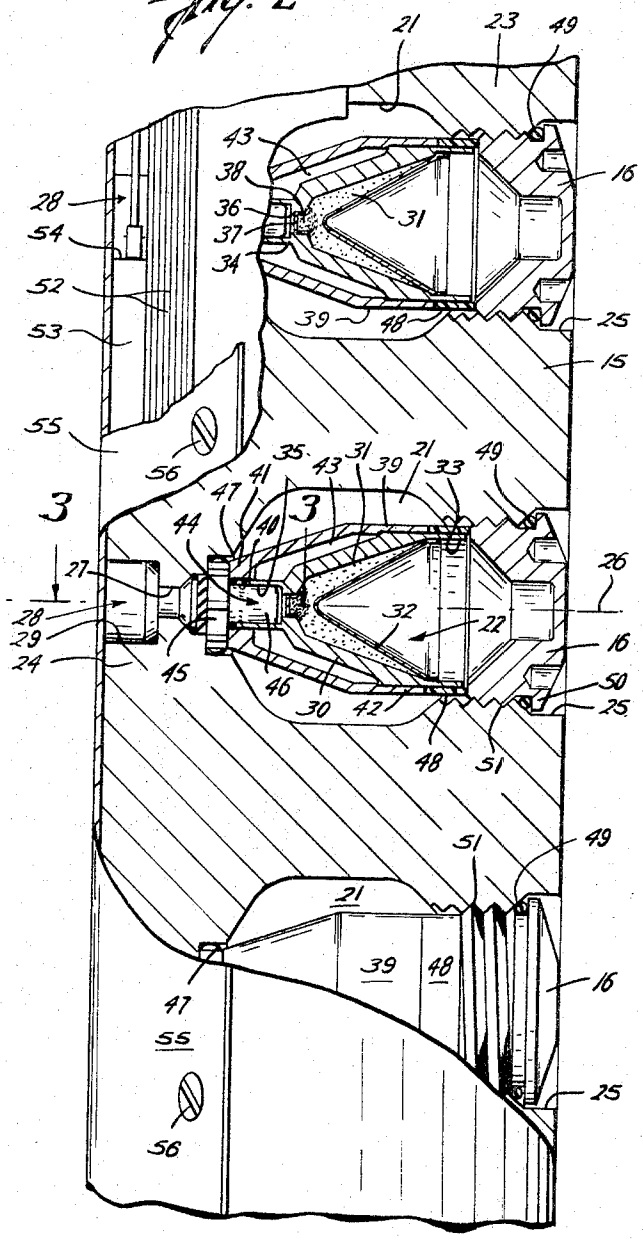


Fig. 2



William T. Bell
INVENTOR.

BY

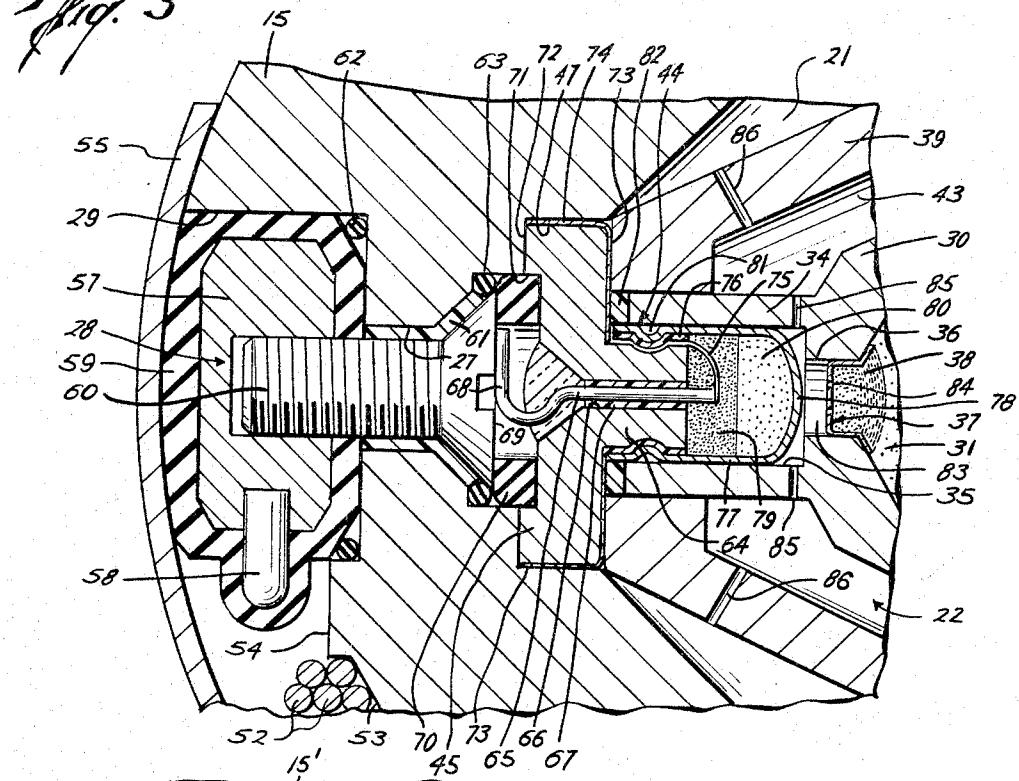
Ernest F. Schumbeau, Jr.
ATTORNEY

July 4, 1967 W. T. BELL 3,329,218

APPARATUS FOR DETONATING SHAPED CHARGES

Filed Feb. 12, 1965 3 Sheets-Sheet 2

Fig. 3



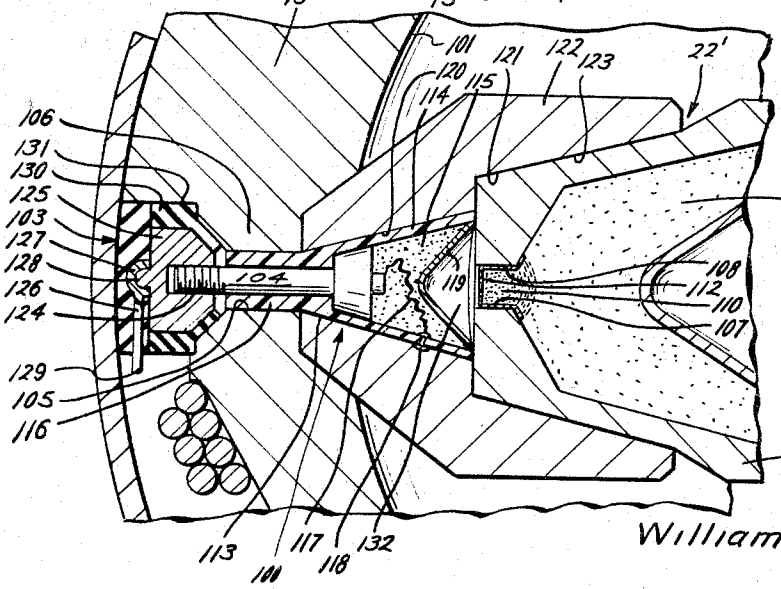


Fig. 4

William T. Bell
INVENTOR.

BY

Ernest L. Archambeau, Jr.
ATTORNEY

July 4, 1967 W. T. BELL 3,329,218

APPARATUS FOR DETONATING SHAPED CHARGES

Filed Feb. 12, 1965 3 Sheets-Sheet 3

Fig. 5

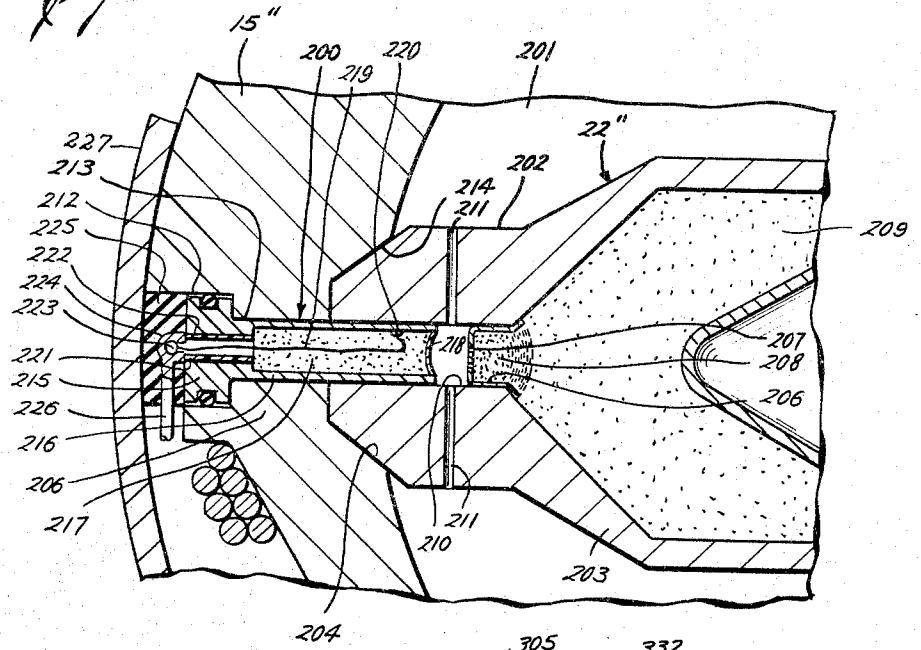
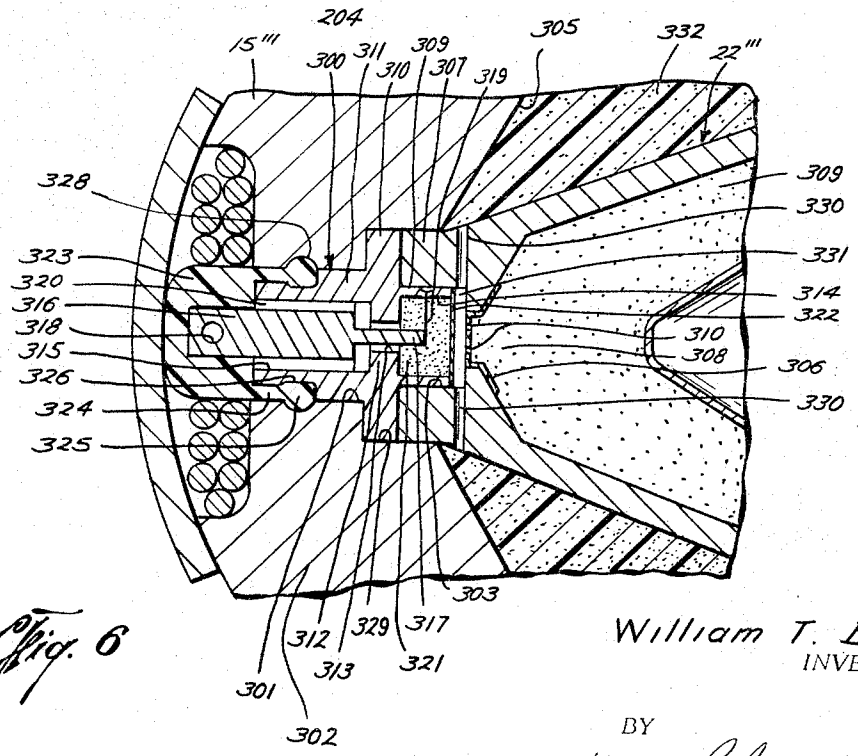


Fig. 6



William T. Bell
INVENTOR.

BY

Ernest F. Archambeau, Jr.
ATTORNEY

United States Patent Office 3,329,218
Patented July 4, 1967

3,329,218

APPARATUS FOR DETONATING SHAPED CHARGES

William T. Bell, Houston, Tex., assignor to Schlumberger Well Surveying Corporation, Houston, Tex., a corporation of Texas

Filed Feb. 12, 1965, Ser. No. 432,086
23 Claims. (Cl. 175—4.54)

ABSTRACT OF THE DISCLOSURE

This disclosure describes selectively operated perforating apparatus having a plurality of perforating devices that are each capable of individual detonation. By arranging the perforating devices in separate compartments and with individual detonators for each, the perforating devices can be selectively detonated without affecting the others. Means are also provided for selectively deactivating those of the perforating devices into whose compartments well fluids have inadvertently leaked.

Accordingly, as will subsequently become apparent, it will be seen that this invention relates to apparatus for detonating explosives for perforating oil wells; and, more particularly, to apparatus for reliably detonating individual shaped charges in an enclosed well-perforating carrier.

Rather than, as heretofore, indiscriminately scattering a large number of perforations along a wide interval, the present trend in well-perforating techniques is to place only one or, at most, a very few perforations at carefully selected and predetermined points in a well. To perforate a well in this latter manner, apparatus suspended from a cable and carrying a number of shaped charges is lowered into the well to a particular depth where a perforation is to be placed and the first of these shaped charges is detonated. Thereafter, the perforating apparatus is repositioned to another selected depth and another charge is fired. This procedure is repeated until all of the desired perforations have been made.

Such selectively fired shaped charge apparatus may be comprised of a number of shaped charges that are mounted and spaced at intervals within a sealed, retrievable carrier. The perforating apparatus is generally suspended in the well bore from a so-called "monocable" having a single electrical conductor enclosed within a conductive armored sheath which serves as the other conductor in the firing circuit. It will be realized, of course, that where a group of shaped charges are to be individually detonated, each of these charges must have separate detonating means. The detonating means for each shaped charge is typically comprised of a short length of detonating cord coupled from the shaped charge to an electrically initiated blasting cap which, by means of an electrical control system, is connected in a predetermined sequence through the monocable to an electrical source at the surface of the ground.

A typical electrical control system for such perforating apparatus quite often employs a solenoid-actuated, multiposition rotary selector switch for sequentially connecting each of the blasting caps in turn into the firing circuit. Thus, by alternately energizing and de-energizing the solenoid actuator, a rotatable contact arm is successively advanced to connect one blasting cap at a time

into the firing circuit for individual detonation of each shaped charge as desired. A typical control system also generally includes a pair of semi-conductor diodes that are oppositely poled and separately connected from the solenoid actuator and the rotatable contact arm to a common connection on the central conductor of the monocable. Accordingly, whenever a direct current voltage of one polarity is applied to the central conductor of the monocable, only the solenoid actuator will be operated. Similarly, the application of voltage of the opposite polarity to the central conductor will only detonate whatever blasting cap is connected at that time into the firing circuit. Thus, by alternately applying voltages of opposite polarities to the central conductor, the selector switch will be successively advanced to connect the blasting caps into the firing circuit one at a time so that they may be individually detonated upon each reversal of the voltage polarity.

The typical non-expendable or so-called "retrievable carrier" is an elongated, thick-walled, tubular, fluid-tight body that is capable of withstanding extreme well bore pressures as well as internal explosive forces. The shaped charges are mounted at spaced intervals within the carrier, with the forward end of each charge facing a lateral access port that is fluidly sealed by an expendable port-closure member. An air space must, of course, be provided around the shaped charges for attenuating laterally directed explosive forces and thereby minimizing distention of the carrier.

It is well-known, moreover, that should this air space become filled with liquid, the lateral explosive forces will blow out the closure member and possibly rupture the carrier or at least swell it to a great extent. Thus, in selectively fired shaped charge apparatus, it is essential to isolate the shaped charges from one another to prevent liquids in the well from entering through a perforated port-closure member and filling the air space around the remaining unfired shaped charges. Accordingly, it is apparent that each shaped charge must be maintained in a separate air-tight compartment until it is detonated. This is usually accomplished by disposing a blasting cap and detonating cord in each compartment with their associated shaped charge and introducing at least one electrical lead from the electrical control system into the compartment through a fluid-tight and electrically insulated connector.

It will be appreciated that such carriers for selectively fired perforating apparatus must be made of either a number of short, easily coupled compartmented subs or in a single elongated body with individual compartments. In the former instance, although it is relatively simple to separately install the explosive elements into each compartmented sub before coupling them into a unitary assembly, a great number of electrical connections must be made in some manner after the carrier has been assembled. Moreover, each inter-sub coupling will require a separate fluid seal; some provision must be made to maintain the assembled subs in a predetermined angular alignment with one another; and the couplings will represent a substantial part of the overall length of the assembled apparatus. If the latter course is pursued, it is usually necessary to make up some, if not all, of the connections to the detonating cord as well as the electrical connections by either extending the members to be connected out of the lateral access ports and then replacing the connected members into the chambers or by

working through the ports to make the connections inside of the separated chambers. In either case, there is a distinct possibility that improper connections will be made which can subsequently cause malfunction. It will be further realized, of course, that once the shaped charges are in place and these above-mentioned connections have been completed, testing of the connections is severely limited. In either event, some provisions must also be made to prevent detonation of shaped charges should liquid leak into the chamber containing it.

Accordingly, it will be understood that an optimum selectively fired shaped charge apparatus should at least (1) be reliable and safe in both loading and operation; (2) carry a maximum number of shaped charges for a given length of carrier; (3) be capable of withstanding high external pressures encountered in a well bore and severe explosive forces from inside of the carrier; (4) maintain the integrity of the fluid sealing of each air-tight compartment until the shaped charge therein has been detonated; (5) have a minimum number of connections that must be made to prepare the shaped charges for selective detonation; (6) have a minimum number of components requiring replacement following a perforating operation; (7) include means for deactivating a shaped charge should liquids leak into the compartment containing that charge; and (8) include means for safety testing as many components in an assembled apparatus as possible.

It is, therefore, an object of the present invention to provide reliable and substantially mistake-proof arrangements for mounting and detonating individual shaped charges in a non-expendable carrier that will accomplish the above criteria for an optimum selectively fired perforator.

This and other objects of the present invention are obtained by mounting a plurality of shaped charges in separate fluid-tight compartments in a perforating carrier with a receptor detonating explosive in each charge being spaced away from but within detonating proximity of a donor detonating explosive. Releasably connected conductor means are fluidly sealed within separate transverse passages through a wall of the carrier into each compartment to provide individual electrical connections from outside of the carrier to a filament arranged to selectively ignite each of the donor explosives. Deactivating means are also provided to prevent detonation of a receptor explosive should fluid somehow leak into a compartment containing that receptor explosive and its shaped charge by placing each receptor explosive in fluid communication with the compartment.

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 way of illustration and example of certain embodiments when taken in conjunction with the accompanying drawings, in which:

FIG. 1 depicts selectively fired shaped charge apparatus employing the principles of the present invention as it might appear within a well bore;

FIG. 2 is an enlarged elevational view, partially in cross-section, of a portion of the apparatus of FIG. 1;

FIG. 3 is a still further enlarged plan view, partially in cross-section, taken along the lines 3—3 of FIG. 2;

FIG. 4 is a view similar to FIG. 3, but depicting an alternate embodiment of apparatus incorporating the principles of the present invention;

FIG. 5 is a view similar to FIG. 3 of still another embodiment of apparatus incorporating the principles of the present invention; and

FIG. 6 is a view similar to FIG. 3 of yet a further embodiment of apparatus incorporating the principles of the present invention.

Turning now to FIG. 1, perforating apparatus **10** employing the principles of the present invention is shown suspended in the typical manner from a monocable **11** within a casing **12** secured within a borehole **13** by a column of cement **14**. As will be subsequently explained by reference to the succeeding figures, the perforating apparatus **10** includes a plurality of shaped charges that are mounted within separate fluid-tight compartments provided at closely spaced intervals in a carrier **15**, with the forward ends of the charges facing longitudinally aligned lateral ports (not shown) through a sidewall of the carriers. Expendable port-closure members **16** are fluidly sealed and secured within each of these ports. Whenever a shaped charge is detonated, however, the resulting perforating jet will, of course, easily penetrate the port-closure member **16** in front of it.

In addition to the carrier **15**, the perforating apparatus **10** includes a conventional cable-connector head **17**, suitable depth-indicating means such as a casing-collar locator **18**, a housed electrical control system **19**, and some positioning means such as a bowed spring **20** for laterally shifting the carrier to maintain the port-closure members **16** against the inner wall of the casing **12**.

Turning now to FIG. 2, to illustrate the principles of the present invention, an enlarged elevational view, partially in cross-section, is shown of a portion of a carrier **15** such as that depicted in FIG. 1. The carrier **15** is an elongated cylindrical member, preferably of steel, with a plurality of longitudinally-spaced chambers **21** being formed therein at close intervals. These chambers **21** are suitably proportioned to receive shaped charges **22** of a predetermined size and configuration and still leave sufficiently thick walls, such as at **23** and **24**, enclosing each chamber to withstand the explosive forces that are developed upon detonation of the shaped charges. Access is provided through the wall **23** of the carrier **15** into each of the chambers **21** by enlarged lateral ports **25** that are preferably aligned with the transverse central axes **26** of the chambers. Multi-stepped coaxial lateral bores **27** are provided through the opposite wall **24** of the carrier **15**, with the axis of these bores also preferably being in coincidence with the central axes **26** of the chambers **21**. Electrical contactors **28** are fluidly sealed within an enlarged outer portion **29** of the stepped bores **27** to provide a semi-permanent, electrical through-wall connection from the exterior of the carrier **15** into each of the chambers **21**.

Each of the shaped charges **22** is comprised of a hollowed, generally frusto-conical container **30** which receives a compressed pellet **31** of a suitable high explosive. A hollowed frusto-conical liner **32** of a suitable metal is complementarily fitted into a forwardly directed conical cavity in the explosive charge **31**, with the base of this liner terminating near the forward peripheral edge **33** of the shaped charge container **30**. A cylindrical extension **34** at the rear of the charge container **30** is counter-bored to provide an enlarged diameter axial socket **35** and a reduced-diameter axial bore **36** between the socket and interior of the container. A cup **37** of thin metal disposed within the forward end of the axial bore **36** closes the bore and confines a suitable primer explosive charge **38** within a recess into the apex of the explosive pellet **31**.

A hollowed, generally frusto-conical outer case **39** is coaxially mounted around the shaped charge container **30** for confining the lateral explosive forces upon detonation of the shaped charge **22** as well as possible. The rearward extension **34** of the charge container **30** is received within an axial bore **40** through a reduced-diameter portion **41** at the rear of the outer case **39**; and the forward portion **33** of the charge container is extended beyond the enlarged-diameter forward portion **42** of the outer case, with an annular space **43** being left between the case and the container.

As will be subsequently explained in greater detail, an encapsulated electrically actuated initiator **44** having an enlarged base portion **45** and a forward portion **46** is provided to detonate each of the shaped charges **22**. The for-

ward portion 46 of the initiator 44 is suitably arranged for reception within the socket 35 in the rearward extension 34 of the charge container 30; and the base portion 45 is arranged to be received with an inner enlarged portion 47 of the stepped bore 27. A cylindrical ring 48, preferably of a resilient plastic material, is slipped over the forward end 33 of the charge container 30 and abutted against the forward end 42 of the outer case 39.

Once assembled, the shaped charges 22, initiators 44, outer cases 39 and cylindrical rings 48 are then inserted through the lateral ports 25 into their respective chambers 21 within the carrier 15. After an assembly has been correctly positioned within its chamber 21, a port-closure member 16, is threaded into each port 25 and fluidly sealed therein by means of an O-ring 49 between the enlarged head portion 50 of the port-closure member and the carrier 15. As shown in FIG. 2, the cylindrical rings 48 project slightly beyond the forward ends 33 of the shaped charges 22 and are received within the threads 51 of the ports 25. Thus, as the port-closure members 16 are being threaded into the ports 25, they will engage the forward ends of the cylindrical rings 48 and urge the rings rearwardly against the forward ends 23 of the outer cases 39. Accordingly, once a port-closure member 16 is fully threaded into place, the outer case 39 will be forced against the forward face of the enlarged base portion 45 of the initiator 44 to position the shaped charge 22 and hold the initiator firmly into recess 47 and against the electrical contactor 28. It should be noted that in addition to supporting the forward end of the shaped charges 22, the rings 48 also protect the exposed threads 51 in the ports 25 from explosive forces.

For carrying the many individual wires 52 leading from the electrical control system 19 (FIG. 1) to each of the electrical contactors 28, a longitudinal groove 53 is provided along the exterior of the carrier 15 to one side of the contactors, with a branch groove 54 being provided between the longitudinal groove to each contactor recess 29. An elongated arcuate cover plate 55 is fastened by screws 56 to the exterior of the carrier 15 to enclose the electrical wires 51 and contactors 28 within their respective grooves 53 and recesses 29.

Turning now to FIG. 3, an enlarged cross-sectional view is taken along the lines 3—3 of FIG. 2 to further illustrate the principles of the present invention. The exterior portion of the electrical contactor 28 is comprised of a threaded terminal nut 57 having an outwardly projecting electrical lead 58 connected to one of the electrical conductors 52 from the electrical control system 19 (FIG. 1). The exterior of the terminal nut 57 and a portion of its projecting lead 58 are covered with a suitable fluid-proof electrical insulating material 59 such as rubber. The terminal nut 57 is disposed within the outer enlarged portion 29 of the stepped bore 27 with the projecting lead 58 extending into the adjacent lateral branch groove 54 leading to the longitudinal wire-confining groove 53 along the exterior of the carrier 15. To secure the electrical contactor 28 in place, a screw 60 extending through a complementary insulating sleeve 61 is inserted from inside of the chamber 21 through the stepped bore 27 and threadedly engaged with the terminal nut 57. As the screw 60 is drawn up, O-rings 62, 63 around the terminal nut 57 and the head of the screw, respectively, are sealingly engaged against the body of the carrier 15 to provide a fluid-tight seal. This, not only is the contactor 28 fluidly sealed from the exterior, but it is also sealed against the fluid leakage from the chamber 21 into the bore 27 after the shaped charge 22 has been detonated.

The body of the initiator 44 is preferably formed of steel with a short, reduced-diameter shank portion 64 projecting from the enlarged base portion 45. An electrical conductor 65 is extended through a central bore 66 in the body of the initiator 44 and tightly sealed therein by a suitable electrical insulator 67 such as epoxy resin, fused glass, or other similar materials. The outer end 68 of the conductor 65 is bent over in such a manner as to be deflected slightly when the initiator 44 is positioned correctly in the recess 47 and maintain electrical contact with the forward face 69 of the contactor screw 60. An annular sealing member 70 is partially received within a recess 71 in the rearward face 72 of the initiator base portion 45 to prevent so-called "blow-by" of explosive products into the stepped bore 27 upon detonation of shaped charge 22.

To ensure that the body of the initiator 44 makes good electrical contact with the body of the carrier 15, a thin, annular electrically-conductive member 73 having radially projecting fingers 74 is disposed against the forward face of the enlarged base portion 45 with these fingers being bent over the periphery of the base and extended rearwardly thereon. Thus, when the enlarged base portion 45 of the initiator 44 is correctly positioned within the inner enlarged portion 47 of the stepped bore 27, the fingers 74 will be maintained in electrical contact with the body of the carrier 15.

A suitable filament wire 75 is electrically connected to the forward end of the insulated central conductor 65 and extended rearwardy along the shank portion 64 and terminated after being bent outwardly across the conductive annular member 73. A sealing sleeve 76 of suitable sealing material is shrink-fitted over the shank portion 64 of the initiator 44 to hold the filament 75 in electrical contact with the shank.

A tubular closure member 77 having a closed forward end 78 is partially filled with the proper quantities of a suitable match composition 79 and a primary explosive 80 and disposed over the shank portion 64 of the initiator 44 where it is secured as by crimping 81. Thus, whenever a sufficient electrical current is passed from the contactor 28, through the conductor 65 and filament 75 and back to the carrier 15, the match composition 79 will be ignited to detonate the highly sensitive primer explosive 80.

An annular sealing member 82 disposed around the tubular closure member 77 serves as a pliable retainer to hold the initiator 44 within the socket 34 in the rearwardmost end of the extension 34 projecting from the base of the shaped charge container 30. It should also be noted that the thick enlarged base portion 45 of the initiator 44 completely covers the face of the screw 60 of the contactor 28. Thus, the mass of the base portion 45 will prevent rearwardly directed explosive forces from damaging the contactor 28 so that a great number of shaped charges 22 can be detonated before it is necessary to replace a particular contactor.

When the shaped charges 22, initiators 44, port-closure members 16 and electrical contactors 28 have been positioned as illustrated in FIGS. 2 and 3, it will be noted that the chambers 21 are fluidly sealed. Thus, the unless one or more of the O-rings 49 and 62 should fail for some reason, the chambers 21 will be fluid-tight until the shaped charge 22 in that chamber has perforated the port-closure member 16.

It will be appreciated, however, that fluid seals do fail upon occasion. It will also be recognized that should liquid leak into a chamber 21, detonation of that shaped charge 22 in the liquid-filled chamber will most likely blow out the port-closure member 16 and either rupture the carrier 15 or at least partially distend it. Accordingly, to prevent such an undesirable occurrence, it is a particular additional feature of the present invention to provide means for deactivating a shaped charge 22 in a reliable and positive manner should liquid somehow enter the sealed chamber 21 containing the charge.

As best seen in FIG. 3, the closed end 78 of each tubular initiator closure member 77 is separated a slight distance away from the metal cup 37 disposed in the axial bore 36 in the rear of the shaped charge container 30 to

leave an intervening space 83 between the closure member 77 and cup 37. The length of this intervening space 83 is, of course, well within the distance that the primary explosive 80 in the initiator 44 can reliably detonate the primer charge 38 in the shaped charge 22. One or more holes 84 are provided through the base of the cup 37; and lateral passages 85 and 86 are respectively provided through the wall of the extended rear portion 34 of the charge container 22 and the wall of the outer case 39.

Thus, it will be appreciated that should liquid fill the chamber 21 sufficiently, liquid will be forced through the lateral passages 86 and 85 into the socket 35 between the initiator 44 and primer explosive 38. Accordingly, even a slight amount of liquid in the air gap 83 will seep through these holes 84 and so permeate the primer explosive 38 that it is totally desensitized. It has been found, moreover, that when this air gap 83 becomes filled with liquid, the detonation of the initiator 44 will be so greatly attenuated that the primer charge 38 will not be detonated.

As is well-recognized by those skilled in the art, the maximum length of the air space 83 between these two explosives 38, 80 can be easily and quickly determined by routine experimentation with whatever quantities of the explosive materials 31, 38 79 and 80 that are to be used in the practice of the present invention. Thus, by routine experimentation, the maximum length of this air gap 83 may be easily determined and the shaped charge 22 and initiator 44 may be suitably arranged to maintain this length well within the maximum allowable dimension to ensure reliable high-order detonation of the primer charge 38 by the initiator so long as no liquid has entered the sealed chamber 21.

Turning now to FIG. 4, an enlarged cross-sectional view is shown of an alternate embodiment of the present invention. In this embodiment, the initiators 100 are installed in their respective chambers 101 in the carrier 15' before the shaped charges 22'. Then, after the shaped charges 22' and port-closure members (not shown) have been installed, the electrical contactors 103 outside of the carrier 15' may be connected to rearwardly directed conductors 104 extending from within the initiators 100 through lateral bores 105 in a wall 106 of the carrier 15'.

The shaped charge 22' depicted in FIG. 4 is generally similar to the shaped charges 22 previously described with reference to FIGS. 2–3. Inasmuch as the forward end of the shaped charge 22' may be suitably positioned in facing relation to the lateral port (not shown) by conventional means, only the rearward portion of the charge has been shown. A metal cup 107, similar to that shown at 37 in FIGS. 2 and 3, is disposed within an axial bore 108 through the rear of the charge container 109 to confine the primer charge 110 adjacent to the pressed explosive pellet 111 of the shaped charge 22'. One or more small holes 112 are provided through the base of the cup 107 for the same purposes as those at 84, previously described, to allow liquid to permeate into the primer charge 112.

The initiator 100 is comprised of a case 113 having a hollow, generally frusto-conical forward portion 114 in which a suitable primary explosive 115, such as lead azide, is confined and a generally tubular rearward portion 116 that is fluidly sealed around the electrical conductor 104. The case 113 is preferably made of a plastic, non-conductive material to electrically insulate the electrical conductor 104 and thereby eliminate insulating sleeves. A so-called "bridge wire" or filament 117 is connected between a terminal 118 in the wall of the case 113 and the forward end of the electrical conductor 104.

Although a flat disc would be equally suitable, a dished metal liner 119 is secured within the forward case portion 114 to confine the primary explosive therein. Thus, it will be realized that by suitably arranging this liner 119, initiator 100 will be a miniature shaped charge.

The frusto-conical forward portion 114 of the initiator case 113 is confined in the rearward portion 120 of a socket 121 in a fairly massive base member 122, with the forward portion 123 of the socket being adapted to receive the base of the shaped charge container 109. Thus, it will be appreciated that upon detonation of the initiator 100 and shaped charge 22', the mass of the base member 122 will tend to absorb much of the resultant rearwardly directed and lateral explosive forces.

The tubular initiator case portion 116 projects beyond the base member 122 and extends through the bore 105 in the wall 106 of the carrier 15' and is connected, as by threads 124, to an electrically conductive terminal nut 125. A suitably insulated electrical contact member 126 is adapted for connection as by mating socket 127 and plug 128, to the outside of the terminal nut 125 to connect an electrical wire 129 from the electrical system (not shown) to the initiator 100.

When the carrier 15' is being prepared for a perforating operation, the initiators 100 and their respective base members 122 are first inserted through the lateral ports (not shown) and positioned within the chambers 101 as shown in FIG. 4. A terminal nut 125 is threaded onto the projecting end of each conductor 104 until an elastomeric sleeve 130 around the nut has been drawn up into sealing engagement within an exterior recess 131 in the wall of the carrier 15'.

It will be appreciated that should an appreciable amount of liquid somehow enter a sealed charge chamber 101, it will be forced through socket 121 into the air gap 132 between the forward end of the initiator 100 and the cup 107 in the rear of the shaped charge container 109. Thus, as previously described with reference to FIGS. 2 and 3, the holes 112 in the base of the cup 107 will allow liquid entering the air gap 132 to permeate the primer charge 110. Similarly, filling of the air gap 132 with liquid will prevent detonation of the shaped charge 22' by the initiator 100.

Turning now to FIG. 5, still another embodiment employing the principles of the present invention is shown in which an initiator 200 can be inserted from the exterior of the carrier 15'' into the rear of a shaped charge 22'' disposed within a chamber 201 therein. Hereagain, since the forward end of the shaped charge 22'' may be held in position relative to the lateral port (not shown) by any of several conventional means, only the rearwardmost portion of the shaped charge has been shown for purposes of greater clarity. A rearward axial extension 202 from the rear of the shaped charge container 203 is adapted for reception within a complementary interior recess 204 in the wall 205 of the carrier 15''. A metal cup 206 with holes 207 in its base is provided to confine a suitable primer explosive 208 in the apex of the explosive charge pellet 209 and closes off the forward end of an axial bore 210 in the rearward extension 202 of the shaped charge container 203. One or more lateral passages 211 are provided to enable any liquid that may leak into the carrier chamber 201 to enter the axial bore 210. An exterior recess 212 and a lateral bore 213 are provided in the wall 205 of the carrier 15'' and coaxially aligned with an inner recess 214 and the axial bore 210 in the shaped charge container 203.

The initiator 200 is comprised of a tubular member having an enlarged-diameter head portion 215 adapted for reception in the exterior recess 212 in the carrier wall 205 and an elongated reduced-diameter body 216 adapted to project through the lateral bore 213 and extend partially into the axial bore 210 through the rearward extension 202 of the shaped charge container 203. The forward end of the body 216 of the initiator 200 is filled with a suitable primary explosive 217, such as lead azide, and enclosed therein by some suitable closure member 218. A suitable filament 219 is connected from a terminal 220

on the body **216** of the initiator **200** and extended through a suitable insulator, such as a sleeve **221**, disposed within a reduced-diamater bore **222** through the enlarged head portion **215** and terminated in a suitable electrical connector **223**. An electrical contactor **224** that is covered with a suitable fluid-tight electrical insulating material **225**, such as rubber, connected to the electrical connector **223** is provided with a wire **226** leading to the electrical control system **19**.

It will be realized that fluid pressure will hold the initiators **200** in place before they are detonated. Upon detonation, however, the resultant explosive pressure will tend to drive fragments of the initiators **200** outwardly. Accordingly, if it is desired not to leave fragments of initiators **200** in the well bore, the initiators may be held in place by either an arcuate cover plate **227** or by securing the initiators to the carrier **15''** by some suitable fastening means such as threads (not shown). It will also be realized that the lateral passages **211** in the rearward extension **202** of the shaped charge container **203** will permit whatever liquid that might enter the shaped charge chamber **201** to leak into the axial bore on air gap **210** between the initiator **200** and the metal cup **207** to prevent detonation of the shaped charge **22'** in the same manner as previously described.

Turning now to FIG. 6, yet another embodiment is shown of apparatus employing the principles of the present invention. An initiator **300** is sealingly received within a multi-stepped lateral bore **301** through a wall **302** of a carrier **15'''** and projected into an axial bore **303** into the rear of a shaped charge **22'''** mounted within a sealed chamber **305** within the carrier **15'''**.

In a manner similar to the arrangements of the previously described embodiments, a metal cup **306** closes off the axial bore **303** in a rearward extension **307** of the shaped charge **22'''** and confines a primer explosive charge **308** within a recess in the rear of the compressed explosive pellet **309**. One or more holes **310** through the cup **306** will permit any liquid leaking into the bore **303** to thoroughly permeate the primer charge **308** and desensitize it. Inasmuch as comparison with the previous figures will readily show the similarity of the shaped charges there with shaped charges **22'''**, it is believed unnecessary to devote further attention to a description of the shaped charge **22'''**.

The initiator **300** has a generally tubular metal body with a reduced-diameter forward portion **309** separated by an enlarged-diameter flange **310** from the rearward portion **311**. An internal partition **312** having an axial bore **313** of a reduced-diameter divides the internal bore of the initiator **300** into a forward portion **314** and a rearward portion **315**. An electrical conductor **316** disposed within the bore portion **315** has a reduced-diameter extension **317** projecting through the reduced bore **314**. The conductor **316** extends a short distance beyond the rearward body portion **311**, with a lateral hole **318** being drilled near the exposed projecting end of the conductor.

A suitable filament **319** is electrically connected between the tip of the conductor extension **317** and the wall of the forward body portion **309**. The conductor **316** and its extension **317** are insulated from the body of the initiator **300** by a suitable electrical insulating material **320** filling the annulus within the rearward bore portion **315** and reduced-diameter bore **313**. The forward bore portion **314** is filled with a suitable primary explosive **321** and the explosive is confined therein by a closure disc body **322** over the forward end of the body of the initiator **300**. Thus, it will be understood that the passage of sufficient electrical current through the filament **319** will detonate the explosive **321**.

The rearward end of the conductor **316** is covered with a cup-like elastomeric sealing member **323** having a skirt **324** that extends over the rearward end of the rearward body portion **311**. The internal surface of a peripheral bead **315** around the skirt **324** is received within a circumferential groove **326** around the rearward body portion **311**.

To prepare for a perforating operation, the initiator **300** is inserted from inside of a chamber **305** into the multi-stepped lateral bore **301**. The covered rearward portion **311** is forced into the bore **301** until the peripheral bead **325** of the sealing member **323** enters a complementary groove **328** in the bore **301** and the flange **310** is disposed in the enlarged-diameter portion **329** of the bore. Then, the shaped charge **22'''** is inserted into the chamber **305** and its rearward extension **307** is telescoped over the forward portion **309** of the initiator **300** to support the rear of the shaped charge. The forward portion of the shaped charge **22'''** is, of course, supported in some usual manner and usual lateral port (not shown) closed with a port-closure member (not shown).

When the shaped charge **22'''** and initiator **300** have been mounted and the lateral port closed, it will be understood that the chamber **305** is fluid-tight with the port-closure member sealing the port and the peripheral bead **325** sealing the multi-stepped bore **301**. Then, a wire (not shown) from the control system **19** (FIG. 1) is inserted into and sealed in the hole **318** to complete the electrical circuit.

As previously described, fluid seals can fail. If this should happen and liquid somehow enters the chamber **305**, it will enter via lateral passages **330** through the extension **308** of shaped charge **22'''** and fill the air gap **331** between the cup cup **307** and disc **322**. Thus, as previously described, the initiator **300** will be unable to detonate the desensitized primer charge **308**.

It should also be realized that a loose fill of plastic **332** can be placed in the chamber **305** to absorb an appreciable amount of the lateral explosive forces from the shaped charge **22'''**.

Thus, it will be appreciated that the various embodiments of the present invention have provided safeguards against the objectionable entry of fluid into the sealed charge chambers of a non-expendable shaped charge carrier. Should liquid enter one of these chambers, however, the liquid will enter an air space in fluid communication with the primer charge of the shaped charge and desensitize the primer explosive. Moreover, if this air space becomes filled with liquid, the shock wave induced by the detonation of the initiator will be so attenuated that it will be unable to detonate the shaped charge.

It will be realized, of course, that even should one or more of the shaped charges in a carrier become desensitized, only the charges in those chambers in which liquid has actually entered will be affected. Thus, the remaining shaped charges that are still fluidly sealed will be capable of detonation as usual. Moreover, by virtue of the extremely close longitudinal spacing which the present invention allows, the subsequently fired charges will not result in the perforations being appreciably off depth.

Another feature of the present invention is that the electrical wiring and conrtol system can be permanently assembled. This will, of course, permit the control circuitry and wiring to be thoroughly checked with complete safety to ensure the reliability of the electrical connections throughout the system. Then, to install the shaped charges in the carrier, only those expendable items, i.e., the initiators, the shaped charges and the port-closure members need to be installed. It should also be noted that the initiators of the present invention are fluidly sealed and are, therefore, capable of being stored without requiring special care to prevent moisture from desensitizing the usually more-sensitive explosives used therein.

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.

What is claimed is:

1. Perforating apparatus for perforating earth formations traversed by a well bore comprising: a sealed, hollow carrier having opposed side walls with a passage extending from an opening in the exterior of said carrier along an axis through one of said side walls and into the interior of said carrier; shaped charge means in said carrier and including a body of explosive material having a hollowed forward end and a receptor detonating explosive at the rearward end of said body, said passage axis passing within detonating proximity of said receptor explosive; means for actuating said shaped charge means including electrically-responsive initiating means between said exterior passage opening and said receptor explosive and having electrical conductor means extending through said passage and said exterior passage opening, a donor detonating explosive within detonating proximity of said initiating means and said receptor explosive, means for enclosing said donor explosive including a tubular container, and means for fluidly sealing said electrical conductor means in said passage; and means for permitting liquid to wet said receptor explosive for disabling said shaped charge means whenever liquid contacts said shaped charge means.

2. The perforating apparatus of claim 1 further including: a case around the rearward end of said body and having an opening therethrough, and wherein said receptor detonating explosive is disposed in said case opening and the forward end of said tubular container and said donor detonating explosive extend to said case opening.

3. Shaped charge means for a sealed, hollow carrier comprising: a body of explosive material having a hollowed forward end, a case around the rearward end of said body and having an opening therethrough, and a receptor detonating explosive disposed in said opening; and means for detonating said receptor explosive including a tubular container having a closed forward end adjacent to said opening, electrically responsive igniting means in said container, and a donor detonating explosive adjacent to said igniting means and sealingly enclosed in said container within detonating proximity of said receptor explosive.

4. Perforating apparatus for perforating earth formations traversed by a well bore comprising: a sealed, hollow carrier having opposed side walls with a transverse passage through one of said opposed side walls thereof opening into the interior of said carrier; shaped charge means mounted in the interior of said carrier and including a body of explosive material having a hollowed forward end facing the other of said opposed side walls, a case around the rearward end of said body and having an opening therethrough, and a receptor detonating explosive disposed in said opening; means for detonating said receptor explosive including a tubular container having a closed forward end aligned with said opening, electrically responsive igniting means in said container, a donor detonating explosive adjacent to said igniting means and in said closed container end within detonating proximity of said receptor explosive, and conductor means releasably connected to said lighting means extending through said transverse passage; sealing means fluidly sealing said conductor means relative to said one side wall; and passage means for admitting liquid into wetting engagement with said receptor explosive to disable said shaped charge means should liquid enter the interior of said carrier and contact said shaped charge means.

5. Perforating apparatus for perforating earth formations traversed by a well bore comprising: a sealed, hollow carrier having opposed side walls with a transverse passage through one of said opposed side walls opening into the interior of said carrier; shaped charge means including a body of explosive material having a hollowed forward end and adapted to develop a perforating jet along a perforating axis, said shaped charge means being disposed in the interior of said carrier with its perforating axis coincidental with the axis of said transverse passage and its forward end facing the other of said opposed side walls, a case around the rearward end of said explosive body and having a substantially axial opening therethrough, and a receptor detonating explosive disposed in said axial opening; means for detonating said receptor explosive including a tubular container coincidentally aligned with said axis and having a closed forward end adjacent to said axial opening and a rearward end extending into said transverse passage, electrically responsive igniting means in said container, a donor detonating explosive adjacent to said igniting means and in said closed container end within detonating proximity of said receptor explosive, and conductor means releasably connected to said igniting means extending from said container through said transverse passage and fluidly sealed and secured relative to said one side wall; means securing said shaped charge means to said carrier and in alignment with said transverse passage; and passage means for admitting liquid into wetting engagement with said receptor explosive to disable said shaped charge means should liquid enter the interior of said carrier and contact said shaped charge.

6. Shaped charge means for a sealed, hollow carrier comprising: a body of explosive material having a hollowed forward end and adapted to develop a perforating jet along a perforating axis, a case around the rearward end of said explosive body and having a rearward extension with a substantially axial opening therethrough, and a receptor detonating explosive disposed in said opening; means for detonating said receptor explosive including a tubular container having a closed forward end extending into said opening and spaced apart from said receptor explosive, electrically responsive igniting means in said container, and a donor detonating explosive adjacent to said igniting means and sealingly enclosed in said closed container end within detonating proximity of said receptor explosive; and passage means for admitting liquid into said space intermediate of said detonating explosives and into wetting engagement with said receptor explosive to disable said shaped charge means should liquid contact said shaped charge means.

7. Perforating apparatus adapted for perforating earth formations traversed by a well bore comprising: a sealed, hollow carrier having opposed side walls with a transverse passage through one of said opposed side walls thereof opening into the interior of said carrier; shaped charge means mounted in the interior of said carrier and including a body of explosive material having a hollowed forward end facing the other of said opposed side walls and adapted to develop a perforating jet along a perforating axis, a case around the rearward end of said body and having a rearward extension with a substantially axial opening therethrough, and a receptor detonating explosive disposed in the forward portion of said opening; means for detonating said receptor explosive including a tubular container having a closed forward end extending into said opening and spaced apart from said receptor explosive, electrically responsive igniting means in said container, and a donor detonating explosive adjacent to said igniting means sealingly enclosed in said closed container and within detonating proximity of said receptor explosive; conductor means releasably connected to said igniting means and extending rearwardly from said container through said passage in said one side wall; sealing means fluidly sealing said conductor means relative to said one side wall; and passage means for admitting liquid into said space intermediate of said detonating explosives and into wetting engagement with said receptor explosive to disable said shaped charge means should liquid enter the interior of said carrier and contact said shaped charge means.

8. Perforating apparatus for perforating earth formations traversed by a well bore comprising: a sealed, hollow carrier having opposed side walls with a trans-

verse passage through one of aid opposed side walls opening into the interior of said carrier; shaped charge means including a body of explosive material having a hollowed forward end and adapted to develop a perforating jet along a perforating axis, said shaped charge means being disposed in the interior of said carrier with its perforating axis coincidental with the axis of said transverse passage and its forward end facing the other of said opposed side walls, a case around the rearward end of said explosive body and having a substantially axial opening therethrough; and a receptor detonating explosive disposed in said axial opening; means for detonating said receptor explosive including a tubular container coincidentally aligned with said axis and having a closed forward end extending into said axial opening and spaced apart from said receptor explosive and a rearward end extending into said transverse passage, electrically responsive igniting means in said container, a donor detonating explosive adjacent to said igniting means and in said closed container end within detonating proximity of said receptor explosive, and conductor means releasably connected to said igniting means and extending rearwardly therefrom through said transverse passage and fluidly sealed and secured relative to said one side wall; means securing said shaped charge means to said carrier and in alignment with said transverse passage; and passage means for admitting liquid into said space intermediate of said detonating explosives and into wetting engagement with said receptor explosive to disable said shaped charge means should liquid enter the interior of said carrier and contact said shaped charge means.

9. Shaped charge means for a sealed, hollow carrier comprising: a body of explosive material having a hollowed forward end, a case around the rearward end of said body and having a rearward opening therethrough, and a receptor detonating explosive disposed in the forward portion of said opening; means for detonating said receptor explosive including a tubular container having a reduced forward portion with a closed end extending into said opening and spaced apart from said receptor explosive and an enlarged base portion adapted to engage said case around said rearward opening, electrically responsive igniting means in said container, a donor detonating explosive adjacent to said igniting means and in said closed container end within detonating proximity of said receptor explosive, and conductor means connected to said igniting means fluidly sealed within said container and extending from said container; and passage means for admitting liquid into said space intermediate of said detonating explosives and into wetting engagement with said receptor explosive to disable said shaped charge means should liquid contact said shaped charge means.

10. Shaped charge means for a sealed, hollow carrier comprising: a body of explosive material having a hollowed forward end, a case around the rearward end of said body and having a substantially axial opening therethrough, and a receptor detonating explosive disposed in the forward portion of said axial opening; means for detonating said receptor explosive including a tubular container having a reduced forward portion with a closed end extending into said opening and spaced apart from said receptor explosive and an enlarged base portion adapted to engage said case around said axial opening, electrically responsive igniting means in said container, a donor detonating explosive adjacent to said igniting means and in said closed container end within detonating proximity of said receptor explosive, and conductor means connected to said igniting means fluidly sealed within said container and extending from said container; means releasably securing said container to said case; and passage means for admitting liquid into said space intermediate of said detonating explosives and into wetting engagement with said receptor explosive to disable said shaped charge means should liquid contact said shaped charge means.

11. The shaped charge means of claim **10** further comprising means for attenuating lateral explosive forces of said shaped charge means including a tubular outer case coaxially mounted around said shaped charge means and defining an annular space therebetween.

12. Perforating apparatus for perforating earth formations traversed by a well bore comprising: a sealed, hollow carrier having opposed side walls with a transverse passage through one of said opposed side walls and providing a recess opening into the interior of said carrier; shaped charge means including a body of explosive material having a hollowed forward end and disposed in the interior of said carrier with its rearward end facing said side wall recess and its forward end facing the other of said opposed side walls, a case around the rearward end of said explosive body and having a rearward extension with a substantially axial opening therethrough, and a receptor detonating explosive disposed in the forward portion of said axial opening; means for detonating said receptor explosive including a tubular container having a reduced forward portion with a closed end extending into said axial opening and an enlarged base portion received within said side wall recess, electrically responsive igniting means in said container, a donor detonating explosive adjacent to said igniting means and in said closed container end within detonating proximity of said receptor explosive, and first conductor means connected to said igniting means and extending from said container base portion; second conductor means releasably connected to said first conductor means and extending rearwardly therefrom through said transverse passage in said one side wall and fluidly sealed and secured within said passage; and passage means for admitting liquid into said axial opening intermediate of said detonating explosives and into wetting engagement with said receptor explosive to disable said shaped charge means should liquid enter the interior of said carrier and contact said shaped charge means.

13. Perforating apparatus for perforating earth formation traversed by a well bore comprising: a sealed, hollow carrier having opposed side walls with a transverse passage through one of said opposed side walls and counterbored for providing a recess opening into the interior of said carrier; shaped charge means including a body of explosive material having a hollowered forward end and adapted to develop a perforating jet along a perforating axis, said shaped charge means being disposed in the interior of said carrier with its perforating axis coincidental with the axis of said transverse passage and recess and its forward end facing the other of said opposed side walls, a case around the rearward end of said explosive body and having a rearward extension with a substantially axial opening threthrough, and a receptor detonating explosive disposed in the forward portion of said axial opening; means for detonating said receptor explosive including a tubular container coincidentally aligned with said axis and having a reduced forward portion with a closed end extending into said axial opening and spaced apart from said receptor explosive and an enlarged base portion received within said side wall recess and adapted to engage said rearward extension around said axial opening, electrically responsive igniting means in said container, a donor detonating explosive adjacent to said igniting means and in said closed container end within detonating proximity of said receptor explosive, and first conductor means connected to said igniting means and extending from said container base portion; means releasably securing said container to said rearward extension; second conductor means releasably connected to said first conductor means and extending rearwardly therefrom through said transverse passage in said one side wall and fluidly sealed and secured within said passage; and passage means for ad-

mitting liquid into said space intermediate of said detonating explosives and into wetting engagement with said receptor explosive to disable said shaped charge means should liquid enter the interior of said carrier and contact said shaped charge means.

14. Perforating apparatus for perforating earth formations traversed by a well bore comprising: a sealed, hollow carrier having opposed side walls with a transverse passage through one of said opposed side walls and counter-bored at each end thereof for providing a first recess in the exterior of said carrier and a second recess opening into the interior of said carrier; shaped charge means including a body of explosive material having a hollowed forward end and adapted to develop a perforating jet along a perforating axis, said shaped charge means being disposed in the interior of said carrier with its perforating axis coincidental with the axis of said transverse passage and recesses and its forward end facing the other of said opposed side walls, a case around the rearward end of said explosive body and having a rearward extension with a substantially axial opening therethrough, and a receptor detonating explosive disposed in the forward portion of said axial opening; means for detonating said receptor explosive including a tubular container coincidentally aligned with said axis and having a reduced forward portion with a closed end extending into said axial opening and spaced apart from said receptor explosive and an enlarged base portion received within said second side wall recess, and adapted to engage said rearward extension around said axial opening, electrically responsive igniting means in said container, a donor detonating explosive adjacent to said igniting means and in said closed container and within detonating proximity of said receptor explosive, and first conductor means connected to said igniting means and extending from said container base portion; means releasably securing said container to said rearward extension; second conductor means having an enlarged head portion fluidly sealed and secured within said first side wall recess and a reduced portion extending therefrom through said transverse passage and releasably connected to said first conductor means; and passage means for admitting such liquid into said space intermediate of said detonating explosives and into wetting engagement with said receptor explosive to disable said shaped charge means should liquid enter the interior of said carrier and contact said shaped charge means.

15. The perforating apparatus of claim 14 further comprising means for atenuating lateral explosive forces of said shaped charge means including a tubular outer case coaxially mounted around said shaped charge means and defining an annular space therebetween.

16. Perforating apparatus for perforating earth formations traversed by a well bore comprising: an elongated carrier having a plurality of longitudinally spaced separate chambers therein, each of said chambers having opposed side walls with a first transverse passage through one of said side walls and counterbored at each end thereof for providing a first recess in the exterior of said carrier and a second recess opening into the interior of said chamber and a second transverse passage through the other of said opposed side walls coincidentally aligned with said first transverse passage and recesses; closure means releasably secured in each of said second transverse passages for fluidly sealing said passages; shaped charge means disposed in each of said chambers, each of said shaped charge means including a body of explosive material having a hollowed forward end and adapted to develop a perforating jet along a perforating axis, a case around the rearward end of said body and having a rearward extension with an axial opening therethrough, and a receptor detonating explosive disposed in the forward portion of said axial opening, each of said shaped charge means being disposed in one of said chambers with its perforating axis coincidental with the axes of one related set of said transverse passages and recesses and its forward end facing the second transverse passage of said related set; means for detonating the receptor explosive in respective ones of said shaped charge means, each of said detonating means including a tubular container coincidentally aligned with said axis and having a reduced forward portion with a closed end extending into said axial opening of said case and spaced apart from said receptor explosive therein and an enlarged base portion received within said second side wall recess and adapted to engage said rearward extension around said axial opening, electrically responsive detonating means in said container, a donor detonating explosive adjacent to said igniting means and in said closed container end within detonating proximity of said receptor explosive, first conductor means connected to said igniting means and extending rearwardly from said container base portion, and means releasably securing said container relative to said rearward extension; means for attenuating lateral explosive forces of respective ones of said shaped charge means, each of said attenuating means including a tubular outer case coaxially mounted around said shaped charge means intermediate of said enlarged base portion of its detonator means and the forward end of its body and providing an annular space therebetween; means for securing said shaped charge means and detonator means within their respective chambers, each of said securing means including an annular member coaxially mounted around the forward end of said explosive body and abutted against the forward end of said outer case, the forward end of said annular member being adapted for engagement by the related one of said closure members for urging said outer case rearwardly against said enlarged base portion to maintain said base portion within said second recess; means adapted to disable respective ones of said shaped charge means should liquid enter their respective chambers, each of said disabling means including passage means for admitting such liquid into said space intermediate of said detonating explosives and into wetting engagement with said receptor explosive; and means for providing an electrical connection to respective ones of said detonator means, each of said connecting means including a second conductor means having an enlarged head portion fluidly sealed and secured within its related first recess and a reduced portion extending therefrom through said first transverse passage and releasably connected to its related first conductor.

17. Perforating apparatus for perforating earth formations traversed by a well bore comprising: a sealed, hollow carrier having opposed side walls with a transverse passage through one of said opposed side walls opening into the interior of said carrier; shaped charge means including a body of explosive material having a hollowed forward end and adapted to develop a perforating jet along a perforating axis, said shaped charge means being disposed in the interior of said carrier with its perforating axis coincidental with the axis of said transverse passage and its forward end facing the other of said opposed side walls, a case around the rearward end of said body and having a substantially axial opening therethrough, and a receptor detonating explosive disposed in said axial opening; means for detonating said receptor explosive including a tubular container having a closed forward end extending into said axial opening and a rearward end extending into said transverse passage, electrically responsive igniting means in said container, a donor detonating explosive in said closed container and adjacent to said igniting means and within detonating proximity of said receptor explosive, and conductor means connected to said igniting means and extending rearwardly therefrom through said container and transverse passage and fluidly sealed and secured relative to said one said wall; and passage means for admitting such liquid into said axial opening intermediate of said detonating explosives and into wetting engagement with said receptor explosive to disable said shaped

charge means should liquid enter the interior of said carrier and contact said shaped charge means.

18. Perforating apparatus for perforating earth formations traversed by a well bore comprising: a sealed, hollow carrier having opposed side walls with a transverse passage through one of said opposed side walls opening into the interior of said carrier; shaped charge means including a body of explosive material having a hollowed forward end and adapted to develop a perforating jet along a perforating axis, said shaped charge means being disposed in the interior of said carrier with its perforating axis coincidental with the axis of said transverse passage and its forward end facing the other of said opposed side walls, a case around the rearward end of said body and having a substantially axial opening therethrough, and a receptor detonating explosive disposed in said axial opening; means for detonating said receptor explosive including a tubular container having a reduced portion with a closed forward end extending through said transverse passage and into said axial opening and an enlarged head portion engaged with the exterior of said carrier, electrically responsive igniting means in said container, a donor detonating explosive in said closed container and adjacent to said igniting means and within detonating proximity of said receptor explosive, and conductor means connected to said igniting means and extending rearwardly therefrom through said enlarged head of said container and fluidly sealed and secured therein; sealing means fluidly sealing said container relative to said carrier; and passage means for admitting liquid into said axial opening intermediate of said detonatng explosives and into wetting engagement with said receptor explosive to disable said shaped charge means should liquid enter the interior of said carrier and contact said shaped charge means.

19. The perforating apparatus of claim 18 further comprising means for attenuating rearwardly directed explosive forces of said shaped charge means wherein said case has a rearward extension therefrom through which said axial opening extends to provide a thick wall about said reduced portion of said detonator container.

20. Perforating apparatus for perforating earth formations traversed by a well bore comprising: a sealed, hollow carrier having opposed side walls with a transverse passage through one of said opposed side walls and counterbored for providing a recess opening into the interior of said carrier; shaped charge means including a body of explosive material having a hollowed forward end and adapted to develop a perforating jet along a perforating axis, said shaped charge means being disposed in the interior of said carrier with its perforating axis coincidental with the axis of said transverse passage and its forward end facing the other of said opposed side walls, a case around the rearward end of said body and having a substantially axial opening therethrough, and a receptor detonating explosive disposed in said axial opening; means for detonating said receptor explosive including a tubular container having a reduced forward portion with a closed end extending into said axial opening and an enlarged intermediate portion received within said side wall recess and a reduced rearward portion extending into said transverse passage, electrically responsive igniting means in said container, a donor detonating explosive in said closed container end adjacent to said igniting means and within detonating proximity of said receptor explosive, and conductor means connected to said igniting means and extending rearwardly therefrom through said container and fluidly sealed and secured therein; sealing means fluidly sealing said container relative to said carrier; and passage means for admitting liquid into said axial opening intermediate of said detonating explosives and into wetting engagement with said receptor explosive to disable said shaped charge means should liquid enter the interior of said carrier and contact said shaped charge means.

21. Shaped charge means arranged for mounting within a sealed, hollow carrier and comprising: a body of explosive material having a hollowed forward end, a case around the rearward end of said body and having an axial opening therethrough, and a receptor detonating explosive disposed in said opening: means for detonating said receptor explosive including a tubular container having a recessed forward end abutting said case over said opening to define a space therebetween, electrically responsive igniting means in said container and a donor detonating explosive sealingly enclosed in said container adjacent to said igniting means and within detonating proximity of said receptor explosive; means for attenuating lateral explosive forces including an annular body receiving said forward container end and at least a portion of said case; and passage means for admitting liquid into said space and into wetting engagement with said receptor explosive to disable said shaped charge means should liquid contact said shaped charge means.

22. Perforating apparatus for perforating earth formations traversed by a well bore comprising: a sealed, hollow carrier having opposed side walls with a transverse passage through one of said opposed side walls providing a recess opening into the interior of said carrier; shaped charge means including a body of explosive material having a hollowed forward end and adapted to develop a perforating jet along a perforating axis, said shaped charge means being disposed in the interior of said carrier with its perforating axis coincidental with the axis of said transverse passage and its forward end facing the other of said opposed side walls, a case around the rearward end of said body and having a substantially axial opening therethrough, and a receptor detonating explosive disposed in said axial opening; means for detonating said receptor explosive including a tubular container having a recessed forward end abutting said case around said opening to define a space therebetween and extending rearwardly into said transverse passage and fluidly sealed therein, electrically responsive igniting means in said container, a donor detonating explosive adjacent to said igniting means and in said forward container end within detonating proximity of said receptor explosive, and conductor means connected at one end to said igniting means and fluidly sealed and secured within said container and extending rearwardly therefrom through said transverse passage in said one side wall; means for absorbing lateral explosive forces including an annular body received within said side wall recess and extending around said forward container end and at least a portion of said case; and passage means for admitting liquid into said space intermediate of said detonating explosives and into wetting engagement with said receptor explosives to disable said shaped charge means should liquid enter the interior of said carrier and contact said shaped charge means.

23. Perforating apparatus for perforating earth formations traversed by a well bore comprising: a sealed, hollow carrier having opposed side walls with a transverse passage through one of said opposed side walls providing a recess opening into the interior of said carrier; shaped charge means including a body of explosive material having a hollowed forward end and adapted to develop a perforating jet along a perforating axis, said shaped charge means being disposed in the interior of said carrier with its perforating axis coincidental with the axis of said transverse passage and its forward end facing the other of said opposed side walls, a case around the rearward end of said body and having a substantially axial opening therethrough, and a receptor detonating explosive disposed in said axial opening; means for detonating said receptor explosive including a tubular container having a forwardly diverging frusto-conical forward portion abutting said case around said opening and a rearward portion extending into said transverse passage and fluidly sealed therein, electrically responsive igniting

means in said container, a donor detonating explosive adjacent to said igniting means and having a hollowed forward end received in said container forward portion within detonating proximity of said receptor explosive, a hollow liner received within said hollowed forward end of said donor explosive to define a generally conical space between said detonating explosives, and conductor means connected to said igniting means and fluidly sealed and secured within said container and extending rearwardly therefrom through said transverse passage in said one side wall; means for absorbing lateral explosive forces including an annular body received within said side wall recess and extending around said forward container end and at least a portion of said case; and passage means for admitting liquid into said space intermediate of said detonating explosives and into wetting engagement with said receptor explosive to disable said shaped charge means should liquid enter the interior of said carrier and contact said shaped charge means.

References Cited

UNITED STATES PATENTS

2,043,340	6/1936	Tilbury et al.	175—4.6 X
2,062,975	12/1936	Lane	175—4.57
2,649,736	8/1953	Phillips	175—4.59 X
2,833,213	5/1958	Udry	175—4.6
2,946,283	7/1960	Udry	175—4.6 X
3,169,578	2/1965	Voetter	175—4.6 X
3,282,354	11/1966	Hakala et al.	175—4.6

CHARLES E. O'CONNELL, *Primary Examiner.*

DAVID H. BROWN, *Assistant Examiner.*

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,329,218 July 4, 1967

William T. Bell

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

In the heading to the printed specification, lines 4 and 5, "assignor to Schlumberger Well Surveying Corporation," should read -- assignor to Schlumberger Technology Corporation, --. Column 5, line 66, "This" should read -- Thus --. Column 6, line 42, "34" should read -- 35 --; line 56, cancel "the", second occurrence. Column 7, line 6, "more" should read -- more small --. Column 9, line 3, "diamater" should read -- diameter --; line 22, "on" should read -- or --. Column 10, line 29, "cup cup" should read -- cup --. Column 11, line 60, "lighting" should read -- igniting --. Column 13, line 1, "aid" should read -- said --. Column 14, line 55, "threthrough" should read -- therethrough --. Column 15, line 48, "atenuating" should read -- attenuating --. Column 17, line 32, "detonatng" should read -- detonating --.

Signed and sealed this 28th day of October 1969.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents