(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number : **0 601 880 A2**

(12) **EUROPEAN PATENT APPLICATION**

(21) Application number : **93309990.5**

(51) Int. Cl.^{5} : **E21B 43/1185**

(22) Date of filing : **10.12.93**

(30) Priority : **10.12.92 US 988528**

(43) Date of publication of application :
15.06.94 Bulletin 94/24

(84) Designated Contracting States :
AT BE CH DE DK ES FR GB GR IE IT LI LU MC NL PT SE

(71) Applicant : **HALLIBURTON COMPANY**
P.O. Drawer 1431
Duncan Oklahoma 73536 (US)

(72) Inventor : **Barker, James M.**
22415 Indian Ridge
Katy, Texas 77450 (US)
Inventor : **Grigar, Larry Lee**
Route 2,
Box 75C
East Bernard, Texas 77435 (US)

(74) Representative : **Wain, Christopher Paul et al**
A.A. THORNTON & CO.
Northumberland House
303-306 High Holborn
London WC1V 7LE (GB)

(54) **Perforating gun detonator package incorporating exploding foil.**

(57) A perforating gun assembly incorporates an elongate body (20,30) which supports a capacitive discharge firing unit (25) having the form of an elongate cylinder terminating at the lower end with a feedthrough. The feedthrough, protected by a resilient boot (37), connects with a very short coaxial cable (40) stored in a chamber (32). At the bottom of the chamber (32), the coaxial cable connects with a detonator head (55) of an elongate cylindrical structure. It encloses and protectively houses the end of a detonating cord (52). On the interior, it supports an electric pulse initiated flying disk detonator mechanism. The structure is constructed to suppress inductance in the firing circuit from the capacitive firing unit so that appropriate firing pulse rise time and current magnitude can be achieved.

FIG.1A

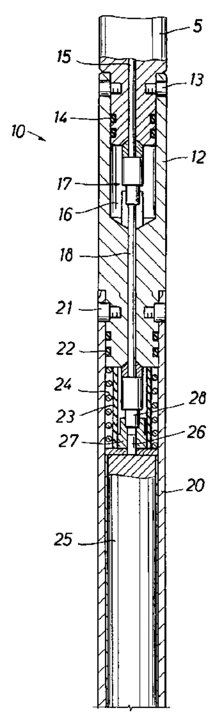
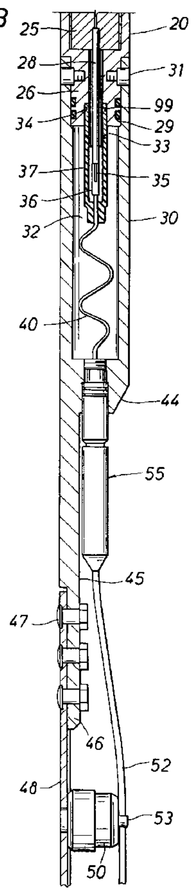


FIG.1B



EP 0 601 880 A2

BACKGROUND OF THE DISCLOSURE

The present disclosure is directed to an exploding foil detonator for use in a perforating gun assembly which is typically installed in a cased well borehole for forming perforations through the casing, through the cement on the exterior of the casings and into the adjacent formations. As will be understood, the perforations are formed by shaped charges which are cone shaped explosive components in appropriate shells. While a perforating gun can support only one at a minimum, it typically is assembled supporting a large number of shaped charges so that a large number of perforations can be formed in a defined region. It is necessary to assemble the perforating gun and the numerous shaped charges at the surface and the entire perforating gun assembly is then lowered into the well borehole. As it is lowered in the borehole, there is always the risk of premature detonation which may form the perforations at the wrong depth. This can be very damaging to the well, and can even force premature abandonment of the well should the perforations be formed at a shallow depth. Even worse than that, if the shaped charges are detonated at the surface, it is possible to kill, injure, or maim personnel operating the equipment at the well head site.

Premature detonation must be prevented. One way to accomplish this is to utilize explosives which are not very sensitive. The relative sensitivity of explosives is defined by designating the explosives as primary or secondary explosives. As a generalization, the secondary explosives used in detonators are relatively insensitive. That makes premature or unintended detonation difficult. This virtue enhances the safety of the perforating gun assembly. However, and in opposite fashion, it also makes it very difficult to detonate when intended.

A safety device which has found acceptance is an exploding foil detonator, sometimes called a slapper detonator. The slapper type detonator is difficult to initiate. This again is a safety feature because, in order to function, the rate of energy delivery is perhaps a million more times than a conventional hot wire detonator. This helps assure safety because it reduces sensitivity to stimuli which might otherwise cause unintended detonation such as exposure to RF fields, perhaps detonation as a result of static electricity in the region, friction, heat, or impact during usage.

The lack of sensitivity and the requirement of more than one million times the power (or rate of energy delivered) of a conventional hot wire detonator mandates that a very substantial electric current be applied to a detonator to initiate the charge in the detonator. In order to achieve the necessary heating to burst the heated foil of the detonator, a very substantial current must flow through the detonator foil.

In addition, the current must be delivered in a very short time. Typical values of the current pulse are 2000-3000 amperes delivered in less than 1/2 microsecond. It is this unique combination of high current and short delivery time that make exploding foil initiators so safe. This type of firing pulse is simply a firing stimuli which is not found in nature. Because of the unique characteristics of this signal (rise time and current peak), it is necessary to employ a capacitive discharge firing unit to create it. The capacitive discharge unit allows electrical energy to be stored, up to a predetermined value, and dumped at once to the detonator foil. The discharged energy causes a very high current to flow through the foil, heating it to the plasma state. The violently expanding plasma causes a disk of plastic (which was in contact with the foil) to be propelled across a gap until it impacts the secondary explosive charge. It is the impact of this disk which causes prompt (and safe) initiation of the secondary explosive pellet within the detonator.

In a downhole environment, it is necessary to place the capacitive discharge firing unit in close proximity to the detonator. Spacing must be close, normally less than 36 inches, and closer is desirable. While it would be beneficial to move the detonator closer to the firing unit from an initiation standpoint, it is usually prudent to leave some distance between the firing unit and detonator in order to minimize damage to the firing unit. A typical compromise might be 12-18 inches. Because of this, a firing cable is now necessary in order to transmit the current pulse from the capacitive discharge firing unit to the detonator. It is critically important that this firing cable not impede the firing signal as it is delivered, otherwise the foil bridge will not receive sufficient energy in the short duration needed to cause proper functioning of the exploding foil device. Because of this requirement of high current delivered in a short time period, it is paramount that the firing cable have as low inductance as possible. Otherwise, current rise time will suffer. One way to reduce the inductance of the firing cable extending to the detonator mechanism is to utilize flat conductors. An example of this is given in patent 4,602,565. A flat cable does provide reduced inductance but it is somewhat difficult to interconnect with the housing that supports the detonator. As a very broad but meaningful generalization, a cylindrical structure is much more desirable and much more easily interconnected. A cylindrical structure permits readily available seal mechanisms to be installed to provide isolation. In other words, the detonator mechanism requires packaging in a number of structural components which are cylindrical.

In an effort to make cylindrical structures for the detonators and especially that aspect where the detonator interconnects with the cable, some have provided a pin and socket construction which mates with the connector firing line These typically include hermetic feedthrough. An example of this found in U.S. patent 4,762,067. One particular disadvantage results from such a construction. High quality hermetic feedthrough are relatively expensive, and one is consumed in every shot. This is an expensive replacement procedure.

One important feature of the present apparatus is the availability of cylindrical components which are fitted together, thereby defining a cylindrical construction for the entire set of apparatus. Also. a hermetic feedthrough is not consumed in every shot. Cylindrical geometry enables the components to be more readily manufactured and assembled. This also enables easy assembly into a set of equipment which has reduced inductance. This reduces the voltage required for firing purposes. More specifically, this enables provision of a detonator assembly which responds with the intended explosion when a current is applied to it so that the circuit inductance does not prevent proper and reliable firing of the detonator.

The present apparatus is able to cooperate with a cylindrical, coaxial feedthrough in conjunction with a coaxial cable. The equipment is therefore quite easy to assemble and provides a reliable structure. Moreover, it is constructed in such a way as to reduce the inductive and resistive losses through the connection. The risk of arcing is reduced, and the feedthrough is not destroyed with each shot.

According to one aspect of the present invention, there is provided a perforating gun assembly for use in detonating one or more shaped charges supported by the perforating gun assembly, which assembly comprises:

(a) an elongate supportive body;

(b) a capacitive discharge firing unit within said body, said firing unit being connectable to the surface by an elongate cable for providing an electrical current flow thereto to provide an electrical charge to said firing unit;

(c) a detonating cord extending to one or more shaped charges for providing detonation thereto;

(d) a firing head connected to an upper end of the detonating cord, said firing head incorporating an exploding foil initiator means for initiating said detonating cord;

(e) coaxial cable means connected from said firing unit to transfer an electrical charge therefrom to said exploding foil initiator;

and wherein said exploding foil initiator includes a conductive metal bridge adjacent to a disk for forming a flying disk when an electrical current from said firing unit flows through said bridge; and intermediate explosive materials spaced from said flying disk; and wherein said explosive materials are responsive to initiation near the end of said detonating cord for detonation of said detonating cord.

According to a further aspect, there is provided an apparatus for use in an exploding foil detonator assembly for a perforating gun supporting one or more shape charges, the apparatus comprising:

(a) an elongate body adapted to be supported on a cable to be lowered in a well borehole;

(b) a capacitive discharge firing unit supported in said body wherein said capacitive discharge firing unit accumulates and stores an electrical charge;

(c) an elongate hermetically sealed, centralized feedthrough connected with said firing unit and extending along said body and terminating at a resilient boot around the end thereof to exclude the intrusion of borehole fluids;

(d) an elongate coaxial cable of fixed length extending from said feedthrough and having a remote end for delivery of electric current through said cable to the remote end thereof;

(e) an exploding foil means connected to the remote end of said coaxial cable forming a flyer disk; and

(f) an exploding foil initiator connected with said coaxial cable also having a resilient boot thereon to enable connection with the proximate end of a detonating cord to enable firing of one or more shaped charges.

In order that the invention may be more fully understood, reference is made to the accompanying drawings.

It is to be noted, however, that the appended drawings illustrate only typical embodiments of this invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

Fig 1 (formed by Figs. 1A and 1B jointly) is an elongate sectional view taken through the firing assembly and detonator of the present disclosure showing details of construction extending from the upper end firing assembly to a detonator and further providing means for detonation of a detonating cord connected with many shaped charges wherein the number of shaped charges increases with length and the detonating cord provides for detonation of them;

Fig. 2 is an enlarged sectional view of a portion of the apparatus shown in Fig. 1 illustrating additional details of construction of the detonator so that the appropriate current flow for detonation is provided;

Fig. 3 shows an exploding foil in sectional view;

Fig. 4 shows a perforating gun assembly; and

Fig. 5 shows a firing circuit schematic.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Attention is directed to Fig. 4 which shows a typical embodiment of the perforating gun tool string. The tool string 1 is comprised (from the top) of a cable head 2 which permits the assembly to be suspended from a wireline logging cable 3. The lower end of the cable head is connected to a device for depth correlation 4; this device 4 can either be a casing collar locator or logging tool that measures gamma-ray activity from the downhole formations. Attached below the correlation device 4 is a decentralizer 5 which is used to obtain proper azimuthal orientation of the tool string inside the casing. A capacitive discharge firing unit 6 is below the decentralizer 5. This is the device that internally stores electrical energy until it is ready to be discharged in order to fire the exploding foil initiator. Positioned below the capacitive discharge firing unit 6 is a firing head 7. This houses the firing cable and detonator as depicted in Fig. 1B. Attached to the firing head are the perforating components, detonating cord 52 and shaped charges 50, exposed to the wellbore environment. This type perforating gun is typically called a "capsule", or "semi-expendable" gun.

Attention is now directed to Fig. 1A which shows the upper end of the firing assembly. The description will begin with the upper end and proceed to the lower end which is shown in Fig. 1B, the two views being connected serially. After that, details will be given regarding the assembly shown in Fig. 2. Beginning therefore at the very top of the structure shown in Fig. 1A, the firing assembly 10 includes the aforementioned decentralizer 5 at the upper end which connects with a sub 12. The decentralizer 5 joins to the sub 12 and is held in place by means of cap screws 13. The interior volume is sealed by suitable seal rings 14.

A sealed chamber 16 is defined on the interior and encloses a connector formed with a plug and socket indicated generally at 17. This is assembled in the chamber 16. It connects serially with a short rod 18 which extends through the sub 12. The sub 12 is equipped with a surrounding outer shoulder which receives a surrounding housing 20 which is positioned on the exterior. The housing is fastened to the sub 12 by means of cap screws 21, there being two or more screws incorporated for this purpose. This interconnection is made fluid tight by the provision of circular seals 22. The seals define an internally located seal mechanism defining a fluid tight chamber on the interior.

By means of a sleeve 23 and cooperative spring 24, registration is accomplished for a cylindrically shaped capacitive discharge firing assembly 25. The assembly 25 has safety and arming circuits 90, a power supply 91, capacitors 92, bleeder resistors 93, and a spark gap 94. Fig. 5 is a block diagram that shows this circuit arrangement. The firing assembly 25 is connected with the input by means of a conductor 26 which is joined to a fitting 27. The conductor 26 connects with the conductor 18 previously mentioned wherein the two join at a mating plug and socket 28. This enables the telescoped construction to be joined. This enables electric current to be provided to the firing assembly 25 which is enclosed in the housing 20.

Continuing with the drawings, the housing 20 extends the full length of the cylindrical assembly 25. The housing terminates at a central plug 29 which has a reduced external diameter and which is formed integral with the housing 20. The plug 29 is incorporated to provide a transition for the next portion of the equipment, The plug 29 therefore has a reduced diameter. It is axially drilled to support a coaxial hermetic feedthrough 28. The feedthrough 28 connects to the assembly 25. The plug has several grooves in the exterior to receive seal rings. This enables a leak proof connection to be made.

The next portion of the apparatus, the firing head 7, is formed of an elongate cylindrical chamber 30. It is constructed with one end fitting around the plug 26 and is fastened by means of two or more cap screws 31. This defines a smooth exterior. Moreover, the chamber 30 is constructed with a hollow region 32 on the interior. That chamber region is sealed. It is sealed at the left hand end by the plug 29. The firing assembly 25 connects with the coaxial feedthrough 28 previously mentioned. There is an elastomeric sealing boot 37 which fits around the exterior of the feedthrough 28. In addition to that, the plug 29 is provided with an enlarged hole 34 drilled into it. This permits the sealing rings 99 on the feedthrough 28 to prevent fluid intrusion into the firing assembly 25 after detonation. The hollow region 32 is dry before firing; it is flooded afterward. Moreover, the end of the feedthrough terminates with a protruding metal coaxial conductor 35 which is electrically connected by a metal coaxial cap 36 fitted over it. The cap 36 is on the interior of the protective resilient rubber boot 37. The boot 37 surrounds the tip of the feedthrough and assures structural security so that the connection which is accomplished from the metal coaxial conductor 35 to the coaxial cap 36 is secure from impact or damage from wellbore fluids surrounding it after firing. More specifically, the coaxial cap 36 connects with a coaxial cable 40. The cable 40 is provided with extra length in the form of several loops in the chamber 32. The coaxial cable extends to the far end of the chamber and passes through an opening in a detonator which is positioned at the remote end of the chamber 32. Greater details will be observed on review of Fig. 2 of the drawings which is an enlarged view of this detonator.

Skipping therefore over the details of Fig. 2 for the moment, additional description will be continued with the primary focus on the structure shown in Fig. 1. Going again to the very top end of the apparatus which is shown at Fig. 1A, recall that it is the support mechanism which holds a string of shaped charges. While the apparatus will certainly function with only one shaped charge, normally several are included. Assuming that a large number of shaped charges are supported by the equipment shown in Fig. 1, that equipment has to be sufficiently rugged to support the weight of the shaped charges attached to the lower end of the equipment. This is taken into account in the thickness of the components shown in Fig. 1. To this end, the housing 20 has a specified wall thickness so that it can support the weight of the equipment suspended below. Moreover, the screws 13, 21 and 31 are sized and provided in sufficient quantity so that the equipment can readily support the weight which is suspended below.

At this juncture, it is perhaps best to focus on the cylindrical shape at the top end of Fig. 1B, the chamber 30 in particular being cylindrical and to note that it terminates at a truncated face 44. This defines a flat face 45 which extends downwardly below, thereby providing a protruding finger 46 which receives and supports several bolts 47. These bolts serve as fasteners for securing a strip 48. The strip 48 serves as an anchor or support for one or more shaped charges 50. The shaped charges are aligned by the strip 48 to a common azimuth. One strip 48 is shown in this view.

Continuing however with the description, it is necessary to provide an explosive initiation connection to each of the shaped charges. The shape charges are all connected to a common detonating cord 52. The detonating cord 52 connects at multiple explosive cord connectors 53 for the several shaped charges 50. This permits the explosive connection to be made through the detonating cord to all the shaped charges. As will be understood, they are detonated from the top end. It is desirable that the detonating cord be initiated by the equipment shown in this disclosure which then extends the detonation to the several shaped charges hanging below the equipment. The detonating cord 52 terminates at the detonator mechanism which is shown in Fig. 2 of the drawings. The detonating cord 52 is therefore initiated in operation by the detonator assembly shown in Fig. 2 generally identified by the reference numeral 55, As a generalization, it is a separate assembly which is more aptly described in some detail in U.S. patent 4,759,291. In general terms, this detonator assembly shown at Fig. 2 incorporates a plug 56 which is provided with a set of threads for attachment in a mating hole at the end of the chamber 30 mentioned above. It incorporates a surrounding external sleeve 58 which is provided with one or more grooves for sealing O-rings 57. This prevents leakage along the exterior of the body. The sleeve 58 threads to the plug 56. There is an internal spacer sleeve 59 which encloses the firing cable 40 termination. The sleeve 59 may be filled with an insulative potting compound around the conductors. The coaxial cable is formed with an outer mesh which is in the form of a woven wire mesh cylinder surrounding an internal insulator. A pig tail is formed by trimming back and grouping the wires that make up the electrically conductive screen. In particular, this permits appropriate connection by soldering the described pig tail into the shaped pin 61. In like fashion, the coaxial cable includes an inner woven conductor which enables a pin 62 to be supported and connected thereby defining two spaced pins.. Two pins 61 and 62 are supported by appropriate spacers so that they make an electrical connection to the sacrificial foil shown in Fig. 3. As more fully detailed in the referenced patent 4,762,067, the device incorporates an electrical circuit which is completed through the structure shown in Fig. 3. This is formed of a sandwich type material. This composite or layered material utilizes an insulating material 63 shown in Fig. 3. The preferred construction utilizes a thin piece of dielectric material, one brand being known under the trademark Kapton. A thin film of copper is laminated on it, and this laminated blank material is sold under the trademark Microclad. It finds common application in making printed circuit boards. Thus, the copper layer is shaped into the narrow neck 64 and the insulative material remains over it. Generally the copper layer has the shape of an hour glass. It is mounted so that the insulative material (Kapton in the preferred version) faces an explosive initiating pellet 66. The pellet 66 in turn immediately abuts another explosive pellet 67. These two pellets are adjacent to the Kapton material and are separated by a narrow space. A thimble 68 having a central hole 70 is placed over the sacrificial foil construction described with regard to Fig. 3. Briefly, the thimble 68 has a surrounding skirt which enables it to be placed over that sacrificial foil. The central hole 70 serves as an alignment passage. It is able to direct a flying disk against the first explosive pellet 66. It should be noted that the skin on the thimble is not necessary provided other means are employed to maintain alignment of the central hole over the narrow neck.

Going back over some of the details just for the moment, an electric current is directed through the copper conductor having an hour glass shape. Recall that it is on the remote face of the insulative layer shown in Fig. 3. Current must flow through that narrow copper neck where the resistance is greater. Because the cross sectional area for conducting the current flow is so small, substantial quantities of heat are liberated at this region. In fact, the heat liberated from the current flow is so great that the heat practically vaporizes the copper with such speed that it creates a large cloud of gases or plasma which explode the foil. In turn, the laminated insulator material shown in Fig. 3 is likewise forced to move. It is however constrained by the covering of the thimble just mentioned. The thimble 68 is provided with a central hole 70 thereby forming a circular disk from the insulator which is fired by gas pressure through the circular hole 70. While Fig. 2 shows the hole to be quite short, it is nevertheless able to cut a flying disk from the insulator so that the flying disk is shot, so to speak, against the explosive pellet 66. The pellet 66 and 67 are selected for safety. They are secondary explosives which are difficult to initiate or detonate, but which are sufficiently sensitive to be responsive to the flying disk which is fired against the pellet 66. The explosion is initiated in the pellet 66 and in turn that is coupled to the explosive pellet 67. The pellet 67 is covered over with a thin metal plate 71. The plate 71 is severed to form a metal flyer which strikes against an explosive" pellet 72. On impact, that flyer impingement causes the pellet 72 to detonate and couples the explosive force to the detonating cord 52. This detonates the detonating cord at the end. Once started, the explosive reaction is carried by the detonating cord to the many shaped charges.

Structurally, the sleeve 58 encloses the assembled pellets 66 and 67 and provides spacing so that the metal flyer plate 71 has a specified distance of travel. Moreover, this spaced arrangement is assured so that the detonating cord does not pull free. The explosive pellet 72 is held against the end of the detonating cord by a pellet cap 74 which in turn is held in position by a sleeve 76 fastening over the end of the detonating cord. The sleeve 76 operates in conjunction with the end of the pellet cap 74 which rolls over to pinch and thereby staple the end of the detonating cord 52 at a fixed location. This keeps the detonating cord from pulling free.

The sleeve 58 threads at the far right hand end. It has sufficient length that it extends over the end of the detonating cord 52. It has sufficient length that it provides alignment, support and certain fastening for the end of the detonating cord. Moreover, the end of the sleeve 58 is sealed by a large resilient boot 80 which is positioned over the top end of the detonating cord to prevent leakage along the detonating cord into the boot. Finally, the entire assembly 55 shown in Fig. 2 of the drawings is anchored to the coaxial cable 40 previously mentioned and is threaded in place. At the time of assembly, the chamber 30 is made open and exposed for easy assembly. At the time of fabrication of the equipment, the detonating cord 52 is connected through the boot 80 shown in Fig. 2 of the drawings and is brought to the proper termination.

Advantages of the present apparatus should be especially noted. One of the advantages, and indeed a very important advantage, is the reduction of the inductance that is inherent in the coaxial system shown in the drawings. The coaxial cable 40 is required to be a large current conductor and more particularly a conductor in which the inductance must be kept low. The exploding foil operates under the ideal that the current is substantially a step function. When switched on, it is fully on so that the rise time of the current is substantially instantaneous. Distributed inductance along the route is detrimental. This type construction reduces the inductance. Should the inductance be excessive, it will retard the rise time. If that occurs, the velocity of the disk which is fired at the explosive pellets to begin detonation is reduced. Because of the controlled sensitivity of the explosive materials that are used, it is highly desirable to have as much impact as possible on the flying disk which strikes the first explosive pellet 66. That explosive material is made as insensitive as can be tolerated and yet sufficiently sensitive to respond to the flying disk which strikes it. After all, the entire assembly is lowered into a well borehole where it is subjected to shock impact during movement. Static electricity may occur. Background RF radiation likewise may occur and could also provide premature detonation. The various risks involved in loading the detonator in the field militates that an insensitive explosive material be used for the pellet 66. As that becomes more insensitive, the requirements for flying disk velocity are increased. In turn, that requires a more rapid rise time in the electric current. In turn, rise time is reduced if stray inductance is present. The present mechanism provides a means of reducing danger in handling the detonator 55 along with the increased rise time requirements for the current flow. Considering the fact that the detonator may be used at depths of 10,000 feet or greater in a well borehole, it becomes critical that the detonator provide as much safety as possible and that is accomplished by the presently disclosed apparatus.

The apparatus of this disclosure provides additional enhancement. The expensive part of the equipment is the firing assembly 25 and the coaxial feedthrough 28 which connects with it. These are structural components which can be used time and again. They are sufficiently spaced from the detonator 55 that they can be retrieved and reused. Moreover, the detonator 55 is constructed so that its use directs the explosive damages that result from proper operation downwardly. This accompanies the detonation of the detonating cord 52. This forms the necessary shock wave for the detonating cord initiation. Specifically, and after use, the equipment that is normally destroyed includes the detonating cord 52, and all the shaped charges 50 which are supported on the mounting strip. Generally, it is desirable that the remaining equipment be retrieved to the surface rather than left in the hole. This clears the hole of junk collection. The equipment retrieved, typically after proper operation, includes the cylinder 30 which is reused by positioning a new detonator 55 in it. While the detonator 55 is consumed, it can be replaced more readily because it is only a small portion of the structure. However, most of the detonator assembly 55 shown in Fig. 2 of the drawings is substantially destroyed. At the time of subsequent reuse, all the components shown in that view must be collected and assembled as new.

While the foregoing is directed to the preferred embodiment, the scope thereof is determined by the claims which follow:

Claims

1. A perforating gun assembly for use in detonating one or more shaped charges supported by the perforating gun assembly, which assembly comprises:
   (a) an elongate supportive body;
   (b) a capacitive discharge firing unit within said body, said firing unit being connectable to the surface by an elongate cable for providing an electrical current flow thereto to provide an electrical charge to said firing unit;
   (c) a detonating cord extending to one or more shaped charges for providing detonation thereto;
   (d) a firing head connected to an upper end of the detonating cord, said firing head incorporating an exploding foil initiator means for initiating said detonating cord;
   (e) coaxial cable means connected from said firing unit to transfer an electrical charge therefrom to said exploding foil initiator;

   and wherein said exploding foil initiator includes a conductive metal bridge adjacent to a disk for forming a flying disk when an electrical current from said firing unit flows through said bridge; and intermediate explosive materials spaced from said flying disk: and wherein said explosive materials are responsive to initiation near the end of said detonating cord for detonation of said detonating cord.

2. An assembly according to claim 1, wherein said elongate body includes a closed and hermetically sealed chamber, said chamber enclosing at one end thereof an elongate electrical current feedthrough connected with said coaxial cable, and said coaxial cable is located in said chamber and extends through said chamber to the opposite end thereof, and further wherein the opposite end of said chamber has an opening therein to support the exploding foil initiation means installed in said firing head.

3. An assembly according to claim 1 or 2, wherein said exploding foil initiation is constructed and arranged in an elongate cylindrical housing means sized to fit over the end of said detonating cord and said housing means for supporting the end of said coaxial cable operatively connected to said metal bridge.

4. An assembly according to claim 1,2 or 3, wherein said firing head includes an elongate, resilient, insulative boot for excluding well borehole fluids from entry along said detonating cord.

5. An assembly according to claim 1,2,3 or 4, wherein said firing head includes spaced secondary explosive pellets serially initiated by said flying disk, and further wherein said spaced pellets are initiated during firing so that the end of said detonating cord is initiated.

6. An assembly according to any of claims 1 to 5, wherein said firing head connects to said coaxial cable and said connection is formed by a pressure isolation seal cooperative with an electrical feedthrough and said feedthrough is supported by said body at the end of said capacitive discharge firing unit; and wherein an elongate resilient protective boot prevents leakage into said firing unit.

7. An assembly according to claim 2, wherein said hermetically sealed chamber is formed in said supportive body, and said firing unit is received within an adjacent chamber within said supportive body, and further including an electrical feedthrough connected into said chamber from said firing unit wherein said feedthrough has an exposed end which is covered by an elongate, resilient, insulative boot surrounding the end of said feedthrough and connecting with said coaxial cable means.

8. An assembly according to claim 7, further including retaining means for mounting said exploding foil initiator at the lower portions of said supportive body spaced downwardly from said capacitive discharge firing unit and wherein said exploding foil initiator incorporates a resilient boot for surrounding the end of said detonating cord.

9. An assembly according to claim 8, wherein said exploding foil initiator is a separate assembly which attached to and is positioned adjacent to said chamber and closes said chamber at the lower end thereof.

10. An apparatus for use in an exploding foil detonator assembly for a perforating gun supporting one or more shape charges, the apparatus comprising:
    (a) an elongate body adapted to be supported on a cable to be lowered in a well borehole;
    (b) a capacitive discharge firing unit supported in said body wherein said capacitive discharge firing unit accumulates and stores an electrical charge;
    (c) an elongate hermetically sealed, centralized feedthrough connected with said firing

unit and extending along said body and terminating at a resilient boot around the end thereof to exclude the intrusion of borehole fluids;

(d) an elongate coaxial cable of fixed length extending from said feedthrough and having a remote end for delivery of electric current through said cable to the remote end thereof;

(e) an exploding foil means connected to the remote end of said coaxial cable forming a flyer disk; and

(f) an exploding foil initiator connected with said coaxial cable also having a resilient boot thereon to enable connection with the proximate end of a detonating cord to enable firing of one or more shaped charges.

FIG.1A

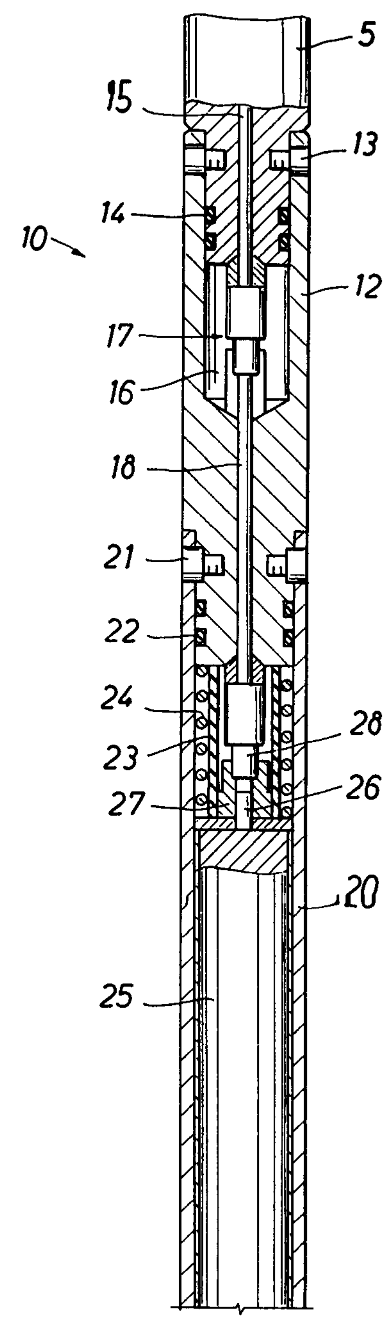

5
15
13
14
10
12
17
16
18
21
22
24
23
28
26
27
20
25

FIG.1B

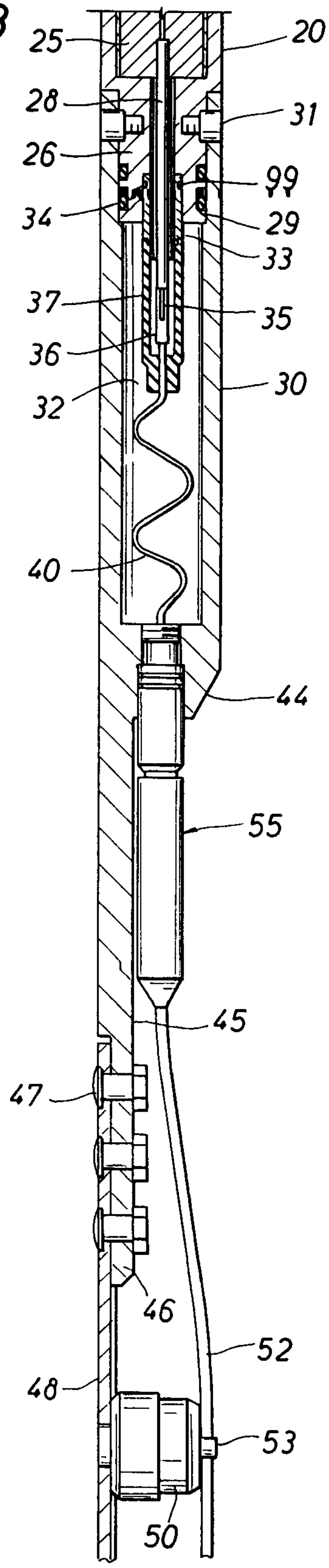

25
20
28
31
26
99
34
29
33
37
35
36
32
30
40
44
55
45
47
46
52
48
53
50

FIG. 2

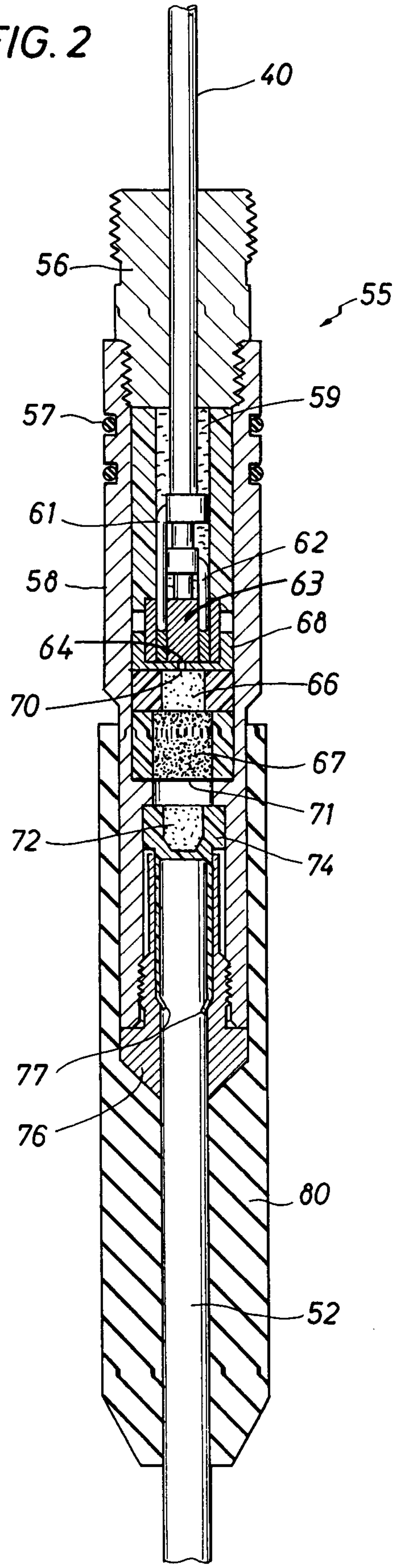
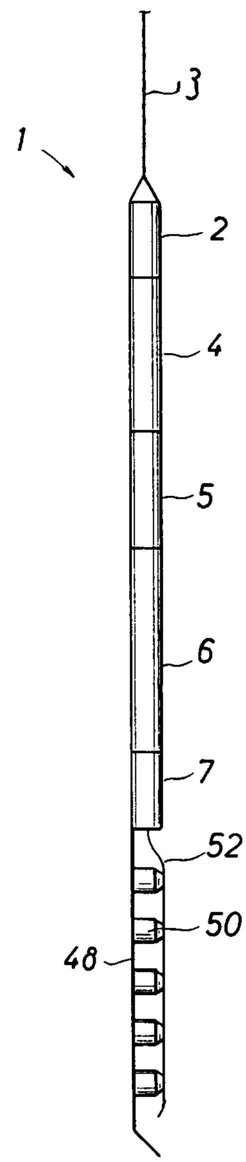

40
56
55
57
59
61
62
58
63
64
68
70
66
67
71
72
74
77
76
80
52

FIG. 4


3
1
2
4
5
6
7
52
50
48

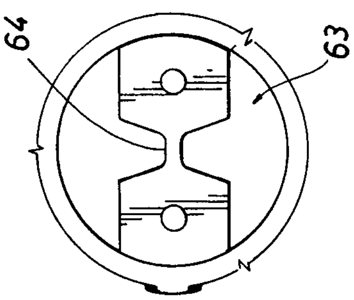

64
63

FIG. 3

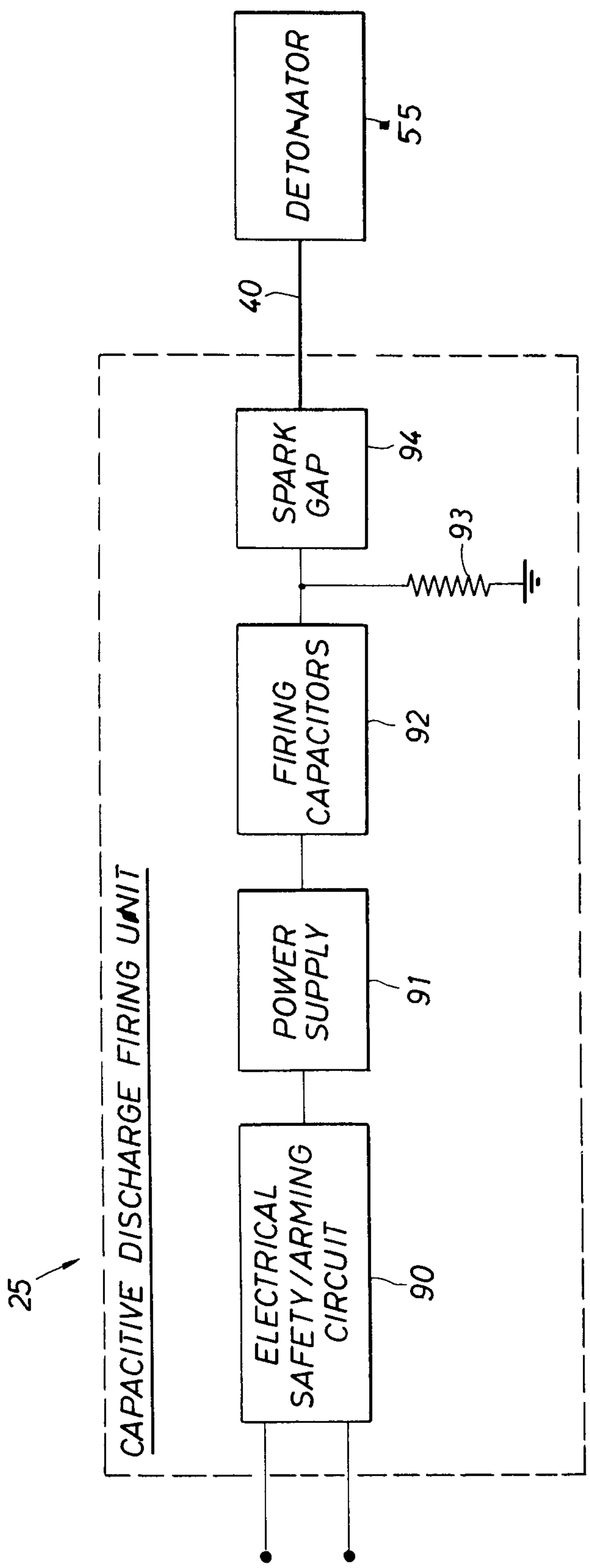

25
CAPACITIVE DISCHARGE FIRING UNIT
ELECTRICAL SAFETY/ARMING CIRCUIT
90
POWER SUPPLY
91
FIRING CAPACITORS
92
93
SPARK GAP
94
40
DETONATOR
55

FIG.5