PROCESS OF IMPROVING A GUN ARMING EFFICIENCY

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention generally relates to perforating apparatus, and, more particularly, to a process for improving the efficiency with which a perforating gun is armed.

Description of the Prior Art

[0002] For purposes of enhancing production from a subterranean formation, a perforating gun typically is lowered down into a wellbore that extends through the formation. A perforating gun may, for example, comprise a plurality of radially-oriented shaped charges which are detonated to form perforations in the formation proximate the wellbore. The shaped charges may, for example, be placed at points along a helical spiral that extends around a longitudinal axis of the perforating gun.

[0003] Current gun systems use separate components for the pressure bulkhead, detonator, charge holder, detonation cord and wiring to the guns below. When a gun is built, all the pieces are assembled together except the detonator and shipped to the location where the perforating operation is to be conducted. At that location, the gun is opened and the detonator is installed. The detonator may, for example, be an RF-safe detonator provided by the assignee of the present application, and this detonator may include an addressable switch, a fireset and an initiator. Accordingly, the installation of the detonator assembly at the site where perforating is to take place involves the connection of a number of wires in a very small space. The installation of the detonator also involves the utilization of a safety tube in which the detonator is placed before connection of the detonator to the wiring in the loading tube.

[0004] It would be advantageous to be able to arm a perforating gun by utilizing a port in the gun assembly thereby avoiding the disassembly of the gun components. These novel and useful results have been realized by the method and apparatus of the present invention.

SUMMARY OF THE INVENTION

[0005] In accordance with the present invention, a process is provided for assembling a perforating gun. A process in accordance with the present invention comprises installing into a gun tube at a first location (e.g. a workshop, manufacturing site, testing facility or non-field location that is not the site at which perforating operations will be conducted) a plurality of shaped charges having primer ends, a ballistics train including a detonating cord connected to the primer ends of the shaped charges, a detonator receptor that holds a booster and cord in place near a port, and wiring operatively connected between the ends of the gun tube and to the detonator receptor. One end of the detonating cord is also operatively connected to the detonator receptor. An embodiment of the detonator receptor includes an addressable switch and a fireset and a receptacle for receiving either an exploding foil initiator or an exploding bridge wire detonator. In other embodiments, the detonator receptor includes a receptacle for receiving either an exploding foil initiator or an exploding bridge wire, but does not include an addressable switch. An addressable switch comprises a circuit facilitating selection (e.g., from a surface location) of a particular perforating gun in a string of perforating guns. While the detonator receptor includes a receptacle for receiving either an exploding foil initiator or an exploding bridge wire detonator, it is significant that the exploding foil initiator or exploding bridge wire is not installed into the receptacle at the first location. The gun tube thus assembled may easily be packaged and electrically tested at the first location.

[0006] A gun tube thus assembled at the first location is then transported to a second location, where the second location is the site at which the perforating operation will be conducted (e.g. a field location or other deployment site). At the second location, a process in accordance with the present invention comprises the step of installing an initiating device into the gun tube through a port in the carrier. The initiating device may, for example, be electrically connected to the fireset of the detonator receptor by a pair of wires through the port while in a safety tube and may then be operatively connected to the detonation cord by installing it into the detonator receptor . In one embodiment, the initiating device comprises an exploding foil initiator, while in another embodiment the initiating device is an exploding bridge wire detonator.

[0007] In accordance with the present invention, a method of operating a perforating system is provided which comprises assembling a plurality of gun assemblies as described above and installing the assemblies into a carrier. Each adjacent pair of gun assemblies is separated by a pressure bulkhead. After many gun assemblies and pressure bulkhead as are needed in the perforating operation are assembled into the perforating string, the perforating string may then be lowered into the wellbore and the shaped charges may be detonated.

[0008] In accordance with the present invention, a gun tube is provided which is made in accordance with the process of installing shaped charges, a detonating cord, a detonator receptor and wiring into the gun tube at a first location which is not the site at which the perforating operation will be conducted. Apparatus in accordance with the present invention includes a gun tube into which an RF-safe or similar detonator is installed at the location where the perforating operations are to be conducted.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] In the accompanying drawings:

[0010] FIGS. 1-3 are pictorial diagrams in partial cross-section which illustrates an installation of a detonator into a perforating gun according to the prior art.

[0011] FIGS. 4-6 are pictorial diagrams in partial cross-section which illustrate a process in accordance with the present invention.

DESCRIPTION OF THE SPECIFIC EMBODIMENTS

[0012] It will be appreciated that the present invention may take many forms and embodiments. In the following description, some embodiments of the invention are described and numerous details are set forth to provide an understanding of the present invention. Those skilled in the art will appreciate, however, that the present invention may be practiced without those details and that numerous variations and modifications from the described embodiments may be possible. The following description is thus intended to illustrate and not to limit the present invention.

[0013] In the specification and appended claims: the terms "connect", "connection", "connected", "in connection with", and "connecting" are used to mean "in direct

connection with" or "in connection with via another element"; and the term "set" is used to mean "one element" or "more than one element". As used herein, the terms "up" and "down", "upper" and "lower", "upwardly" and downwardly", "upstream" and "downstream"; "above" and "below"; and other like terms indicating relative positions above or below a given point or element are used in this description to more clearly described some embodiments of the invention. However, when applied to equipment and methods for use in wells that are deviated or horizontal, such terms may refer to a left to right, right to left, or other relationship as appropriate.

[0014] In general, the present invention regards improved perforating gun apparatuses and processes of manufacture, assembly, and use for RF-safe gun systems. As used herein, the term "RF-safe" means that the initiator of the gun system is designed to be substantially immune to typical levels of electrostatic discharge, RF radiation, and/or accidental or unintended applications of power. Moreover, various embodiments of the perforating gun apparatus and processes of manufacture and use are described with respect to selective fire (e.g., wherein the RF-safe initiator includes an addressable switch). It is intended, however, that other embodiments of the present invention include improved perforating gun apparatuses and processes of manufacture, assembly, and use for non-selective fire gun systems (e.g., wherein the RF-safe initiator does not include an addressable switch). In the specification, the term "RF-safe initiating device" is used to mean an exploding foil initiator, an exploding bridge wire detonator, or other component to initiate the gun system in an RF-safe manner. In the specification and appended claims, the terms "detonator" and "initiator" may be used interchangeably.

[0015] With reference to FIGS. 1-3, there is illustrated a process according to the prior art for installing a detonator 10 in a gun tube 12 at a location where perforating operations are to be conducted. The size of detonator 10 necessitates the removal of end-to-end connections 22 of adjacent gun assemblies 12 and 20 to install detonator 10 in gun tube 12. After end-to-end connections 22 have been removed detonator 10 is placed in safety tube 18 and the wires 14 are then connected to the leads of the detonator 14. Once wired, detonator 10 may be removed from safety tube 18 and installed in the ballistics train by connecting detonating cord 16 to detonator 10. The end-to-end connections 22

of the gun assemblies 12 and 20 may then be re-established. This prior art method of assembling a perforating gun for deployment in the field is inefficient due to the disassembly required.

[0016] With reference now to FIGS. 4-6, an embodiment of a gun tube 40 in accordance with the present invention comprises a detonator receptor 48 which could include an addressable switch, a fireset, or simply a receptacle 49 for receiving an RF-safe initiating device, but does not include an initiating device. In other embodiments, the detonator receptor 48 does not include an addressable switch. The detonator receptor 48, along with shaped charges (not shown), wiring 41, and detonating cord 52 are installed in gun tube tube 40 at a first location which is not the site where perforating operations are to be conducted. The wiring 20 interconnects the ends of the gun tube 44, 40 and is connected to the detonator receptor 48. The detonating cord 52 is connected to the primer ends of the shaped charges, and one end of detonating cord 52 is operatively connected to detonator receptor 48. All of the components of the detonating apparatus (absent the RF-safe initiating device) are thus installed at the first location.

[0017] Gun tube 40 further comprises a port 42 covered by a removable plug 43. In various embodiments, the plug 43 may be an insertable, threaded, or sliding cover, or any other device to removably obstruct communication into the inner bore of the gun tube. At a second location which is the site at which perforating operations are to be conducted, port 42 is opened and RF-safe initiating device 56 is connected to wires 50 such that the RF-safe initiating device is operatively connected to the fireset in the detonator receptor 48. Once wired, RF-safe initiating device 56 may be installed via port 42 into receptacle 49 of detonator receptor 48. The installation of RF-safe initiator 56 into detonator receptor 48 is such that RF-safe initiating device 56 is operatively connected to the detonating cord 52. After installation of the RF-safe initiating device 56, port 42 is closed again communication into the gun tube 40 is interrupted by plug 43.

[0018] In some embodiments, the gun tube may comprise a loading tube, or any other tubular gun housing assembly. Also, in some embodiments, the detonator receptor may comprise an electronic board.

[0019] Embodiments of the perforating gun of the present invention -- as described above -- include apparatuses, processes, and methods wherein a perforating gun is assembled at a first location that is not the site of perforating operations. The "first location" can actually comprise one location that is not the actual perforating site (i.e., at the well), or alternatively a combination of locations each of which are not the actual perforating site. For example, the initiator (without the final RF-safe initiating device) may be manufactured and installed into the gun tube at a shop in China, and then the gun tube may be transported to a shop in the United States where the detonating cord and shaped charges are installed and the gun tube is transported to the well site. At the wellsite, the RF-safe initiating device may be installed via a port in the gun tube. One or more of the guns may be connected together to form an assembled and armed perforating gun string. Finally, the perforating gun string may be deployed in the well for detonation downhole.

WHAT IS CLAIMED IS:

1. A process for assembling a gun tube with first and second ends for use in a perforating gun, comprising:

installing shaped charges and detonating cord in the gun tube at a first location which is not where the perforating operation will be conducted, the detonating cord being operatively connected to the primer ends of the shaped charges;

forming a port in the gun tube to permit access to the interior of the gun tube;

installing a fireset and detonator receptor adapted to receive an initiating device into the gun tube proximate said port; and

installing wiring into said gun tube at the first location where the wiring is operatively connected between the ends of the gun tube and to the detonator receptor.

2. The process of claim 1, further comprising steps to be performed at a second location where perforating operations are to be conducted, the steps comprising:

connecting an initiating device to the fireset of detonator receptor via the port and installing the initiating device via the port into the gun tube so that the initiating device is in operative connection with one end of the detonating cord; and

closing the port.

3. The process of claim 2, wherein the initiating device is an RF-safe exploding foil initiator.

4. The process of claim 2, wherein the initiating device is an RF-safe exploding bridge wire detonator.

5. A gun tube for a perforating gun which is assembled in accordance with the process of claim 1.

6. A method of assembling a perforating system, comprising:

(a) installing a detonator receptor comprising an addressable switch and a fireset into a gun tube at a first location which is not the site of the perforating operation;

(b) installing wiring into said gun tube at said first location;

(c) installing shaped charges and a detonating cord into the gun tube at said first location;

(d) repeating steps (a)-(c) for as many gun tubes as are required in the perforating system;

(e) transporting the gun tubes assembled in steps (a)-(c) to a second location which is the site where perforating operations will be conducted; and

(f) installing an RF-safe initiating device into each gun tube at said second location through a port in the gun tube, said RF-safe initiating device, when installed, being operatively connected to said fireset and to said detonating cord.

7. The method of claim 6, wherein the RF-safe initiating device comprises an exploding bridge wire detonator.

8. The method of claim 6, wherein the RF-safe initiating device comprises an exploding foil initiator.

9. Apparatus for use in a perforating gun comprising:

a gun tube with first and second ends with connectors at said ends for receiving shaped charges, a detonating cord and wiring;

a detonator receptor comprising a fireset installed in said gun tube at a first location which is not the site at which perforating operations are to be conducted;

wiring which is installed at said first location and which is operatively connected between the connectors and to the detonator receptor;

a detonating cord and shaped charges which are installed into the gun tube at a said first location, the detonating cord being operatively connected to the primer ends of the shaped charges and to the detonator receptor.

10. The apparatus in claim 9, further comprising an RF-safe initiating device which is installed in the gun tube via a port in the gun tube at a second location which is the site of perforating operations.

11. The gun tube apparatus of claim 10, wherein the RF-safe initiating device is selected from a group consisting of an exploding bridge wire detonator and an exploding foil initiator.

12. The gun tube apparatus of claim 9, wherein the detonator receptor further comprises an addressable switch.

13. A perforating apparatus for assembly at a first location and for use in a perforating system at a second location, where the first location is not the site where perforating operations will be conducted, comprising:

a gun tube having an inner bore formed therein and first and second ends and connectors at each first and second end, the inner bore adapted for receiving shaped charges, a detonating cord, wiring, and a detonator receptor, the gun tube further comprising a port formed therein adapted to establish communication between the inner bore and external of the gun tube, the detonator receptor comprising an addressable switch and a fireset for operative connection to the detonating cord, the detonator receptor further comprising a receptacle for receiving a RF-safe initiating device;

a plug adapted to close the port in the gun tube;

a plurality of shaped charges having primer ends;

a detonating cord for connection to the primer ends of the shaped charges; and

wiring for connection between the connectors and to the detonator receptor.

14. The perforating apparatus of claim 13, wherein the RF-safe initiating device is an exploding foil initiator.

15. The perforating apparatus of claim 13, wherein the RF-safe initiating device is an exploding bridge wire.