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(54) **INITIATION DEVICE, BLASTING SYSTEM AND METHOD OF BLASTING**

ZÜNDVORRICHTUNG, SPRENGSYSTEM UND SPRENGVERFAHREN

INITIATEUR, SYSTÈME D'ABATTAGE À L'EXPLOSIF ET PROCÉDÉ D'ABATTAGE À L'EXPLOSIF

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Description

[0001] The present invention relates to a device for initiation of an explosives charge, to a blasting system including the device and to a method of blasting using the device. The invention is believed to have particular utility in commercial blasting operations, such as in mining and in oil and gas wells.

Background to invention

[0002] In commercial blasting operations a bulk or packaged explosive is generally required to be initiated according to a predetermined blast design that specifies the time and sequence of initiation as between individual charges in a blast. In this context the bulk or packaged explosive is responsible for fracturing rock etc - it is the "working" or main explosives charge. This explosives charge is itself typically initiated by firing of a smaller explosives charge that is invariably provided under heavy confinement in the form of a cartridged detonator. The detonator is in signal communication with blast control equipment that is responsible for its firing. There is a continuing need to enhance the performance of commercial blasts by the development of blasting methodologies and componentry used. The present invention seeks to contribute in this regard.

[0003] U.S Patent No. 4,862,802 discloses a pyrotechnic ignition method in which semiconductor laser bar(s) containing a number of independent laser array sources deliver optical power in a specified sequence through optical fibres to a set of pyrotechnic elements in order to initiate a sequence of pyrotechnic events.

[0004] U.S. Patent No. 3,362,329 relates to an electro-explosive device and describes a detonating cap wherein the electrical energy that is used to initiate the explosion is coupled to the material used as the primer explosive via a laser beam, whereby the laser output radiation is transmitted via fibre optics.

[0005] U.S. Patent No. 6,460,460 describes a laser-activated grenade which includes a controllable laser source that is activated to generate radiation pulses. A fibre optic cable transmits the radiation pulses (light) to an energetic material (explosive) within the grenade to ignite the energetic material.

[0006] U.S. Patent No. 6,499,404 discloses an ignition element having a laser light source for igniting the explosive in a detonation body, wherein the laser light source is a laser diode and the explosive to be ignited is arranged directly on the portion of the housing of the laser diode that is permeable to the laser light.

Summary of the invention

[0007] Accordingly, in one embodiment the present invention provides an initiation device for initiation of an explosives charge, which comprises:

a transceiver for receipt of wireless command signals;

a control circuit for processing of wireless command signals received by the transceiver; and

a light source that is suitable for initiation of the explosives charge and that is activated by the control circuit;

wherein the control circuit comprises a timing mechanism to allow precise control of activation of the light source when a fire command is received by the transceiver, and wherein the light source discharges through a focusing lens directly into or onto the explosives charge, and

wherein the explosives charge is a secondary explosives material dosed with a heat transfer medium.

[0008] In use, this initiation device will be operatively associated with an explosives charge that is capable of being initiated by the light source. Thus, in another embodiment there is provided an explosive device comprising an initiation device in accordance with the invention and an associated explosives charge, the explosives charge being provided and being adapted to be initiated by the light source.

[0009] The invention also provides a method of blasting using the initiation device of the invention, and a blasting system comprising the initiation device and associated blast control equipment.

[0010] As will be explained, the present invention combines wireless communication capability with light initiation of an explosives charge. This combination is believed to provide significant improvements over known blasting methodologies and componentry.

Detailed discussion of the invention

[0011] The initiation device underlying the present invention includes a transceiver and the function of this is to receive wireless communication signals sent from blast control equipment. The device can therefore be controlled remotely without the need for physical connections (e.g. wires) to convey command signals required in a blasting operation. Preferably, the transceiver has the capability for two-way communication so that such things as diagnostic and status checks can be conducted prior to a blast being initiated. The use of wireless communication in blasting operations is known in the art and transceivers useful in the present invention are known and available, or they may be made by the adaptation of known componentry. In an embodiment of the initiation device of the present invention, the transceiver has the capability for receipt only of wireless command signals.

[0012] The initiation device also includes a control circuit. The basic function of this is to process wireless command signals received by the transceiver and, subject to receipt of a suitable command signal, to activate the associated light source. In practice the control circuit is likely to have additional functional capability and will be responsive to a variety of wireless command signals received by the transceiver.

[0013] The control circuit includes some form of timing mechanism to allow precise control of activation of the light source when a FIRE command is received by the transceiver. The control circuit will invariably be an integrated circuit. Such circuits are well known in the art. They are used for example in electronic detonators in order to control detonator functionality and timed initiation. One skilled in the art would therefore be familiar with the design of and componentry required in such circuits.

[0014] The initiation device also includes a light source and the function of this is to cause initiation of a secondary explosives charge into or onto which light from the light source is discharged through a focusing lens. The light source used in a particular device will be selected based on the type of explosives charge to be initiated - appropriate pairing of the light source and explosives charge is important to implementation of the present invention. Typically, the explosives charge will have been sensitised in some way to render it susceptible to initiation by a given light source. As noted herein above, the light source discharges directly into/onto the explosives charge with a focussing lens.

[0015] An important characteristic of the present invention is that each initiation device has its own light source and, in use, this will typically be located in a borehole (or well hole or the like). The light source is controlled by the control circuit of the device. The device is under the (wireless) control of blast control equipment but, otherwise, the device is self-governing. This means, for example, that a single firing command can be sent to an array of initiation devices with the devices then being able to implement firing independently in accordance with the time delay programmed into the firing circuit. This allows increased control and reliability. This arrangement also allows a burning front to be achieved in a blast field in which a particular initiation device or devices has/have been (light) initiated whilst other initiation devices are in the process of timing down to (light) initiation.

[0016] This arrangement should be contrasted with a system in which a single (centralised) light source is used to deliver light through individual fibre optics to multiple points of intended initiation. This arrangement offers only crude control since a single light source is used to initiate multiple initiation events and this light source can only be either on or off. Optical switches would be required to control the transmission of light over individual fibre optics and this adds to operating complexity and cost. There may also be reliability issues with this type of system since there exists the possibility that a fibre optic may be damaged by detonation of charges in proximity before or during light transmission by the fibre optic. The approach used in the present invention does not suffer these drawbacks.

[0017] In an embodiment of the invention the initiation device includes a single transceiver and a plurality of associated control circuits and light sources. In this embodiment the transceiver has the capability of directing multiple independent control circuits and light sources associated with those control circuits. This allows a number of control units (and light sources) to be loaded in the same blast-hole with all control circuits being in communication with a single transceiver. This enables each control circuit/light source to initiate an associated explosive charge at independent delay times whilst maintaining a burning front. In other words, this embodiment allows multi-decking of a blast-hole using the same transceiver, noting here that the down-hole componentry (control circuits and light sources) are independently powered. In this embodiment the transceiver may be provided at the surface at ground level although it is possible depending upon the nature of the wireless commands to the transceiver that it is positioned below ground in the blast-hole.

[0018] In accordance with the invention, wireless command signals are sent from blast control equipment to the transceiver of an initiation device. One or more mechanisms may be relied upon to ensure suitable transmission and receipt of the command signals.

[0019] In one embodiment, the transceiver may need to be physically positioned so that wireless command signals can be received directly. For example, in this case, the transceiver may need to be provided at the top of a blast-hole. In this case, communication may take place using standard radio frequency transmission systems and protocols.

[0020] In another embodiment, the transceiver may be positioned below ground level with wireless command signals being transmitted through the ground via low frequency signals. Low frequency communication is common through the mining industry and a number of systems to control blasting already exist.

[0021] A further possibility might involve the use of an aerial system extending from the transceiver to a point at which the wireless command signals can be received. For example, if the initiation device is positioned down a borehole, an aerial may extend from the transceiver along the length of the borehole to the surface.

[0022] In yet another embodiment of the present invention, direct communication between blast control equipment and one or more initiation devices is not necessary for successful implementation. This embodiment involves indirect communication between these components by the formation of a low powered network in which one or more initiation devices act to relay a wireless command signal to a particular initiation device even if that device is out of range or otherwise unable to receive the wireless command signal directly. In this embodiment, one or more initiation devices that is/are not intended to act on a wireless command signal relay the signal to one or more initiation devices that is/are intended to act on the command signal. It will be appreciated that in this embodiment the initiation devices will also have the ability to transmit wireless command signals. Formation of a cross-communicating network in this way can extend the range over which a wireless command signal may be effective. This approach is disclosed in International Patent Publication No. WO 2006/076777 entitled "Wireless detonator assemblies, and corresponding networks".

[0023] A clear advantage of using a network of initiation devices to ensure communication of command signals over a blast field is that if a communication "connection" to a particular device is lost, it may be possible to re-route the communication pathway around the lost connection thereby maintaining operability. The system may also be configured to diagnose communication problems thereby allowing corrective action to be taken. This should be contrasted with conventional direct communication systems where loss of a single communication pathway will usually bring down the whole system.

[0024] Another advantage of employing a low powered network to facilitate communication of wireless command signals is that the network has the potential to allow two-way communication. In this case, a transceiver having two-way communication capability is used. This allows, for example, an initiation device to send information to blast control equipment on the current status of a network of the devices and for the blast control equipment to communicate to individual initiation devices timing protocols and firing commands. Thus, the control, timing and firing of a blast can be carried out using a remote (wireless) system with two-way communication allowing a blast operator to assess the status and performance of the blasting system before committing to a fire command. This adds an extra level of safety to a blasting operation. A further advantage is that the network is low powered and, as such, it should not interfere with other communications systems in operation at a blast site. Further, being a low powered network, no special operating licence is likely to be required.

[0025] In the initiation device, the transceiver is required to be in signal communication with the control circuit. The two components may be provided together, for example in a single housing, or they may be separate but suitably connected for signal communication for example, by wire, wireless or optical communication means. Likewise, the control circuit is required to be in signal communication with the light source in order to activate the light source as necessary. The control circuit and light source can be provided together, for example within the same housing, or they may be separate but suitably connected. The initiation device will also require a power supply to power the transceiver, control circuit and light source. The power supply may be physically associated with the device, or a component thereof, but this is not essential. In this regard, safety requirements and regulations concerning the provision of a power supply on a downhole unit may need to be respected.

[0026] The power supply may be conventional in design, such as a low voltage battery (possibly located with the light source component) or a supercapacitor charged from a battery. In the latter case, the supercapacitor may be charged using a battery provided at the surface with the supercapacitor provided as part of the downhole componentry.

[0027] In another embodiment, one or more components of the device may be powered by less conventional means. For example, it may be possible to use environmental means, such as solar power. Other possibilities may exist depending upon how the present invention is implemented in practice. It may be desirable, however, for the device of the invention to function without the need to use a conventional power source such as a battery.

[0028] It will be appreciated from the preceding paragraphs that the transceiver functionality and the light source may be physically separated from each other (the control circuit can be associated with either). Thus, the transceiver could be located at or above ground level and the light source (the firing functionality of the device) provided adjacent or on top of an explosives train (of working explosives) in a borehole. This offers a number of advantages as follows:

- Simplified design for receipt of wireless command signals.
- The transceiver can be used to transmit blast performance data during and possibly after a blast. For example, if the transmitter and control unit are connected via wires, the wire could be used to measure VOD in the hole via a change in resistance and this information transmitted back to the control centre.
- The size of the down-hole componentry may be reduced and this will be beneficial for small bore applications. In this regard, current solid state lasers may be of very compact design.
- As noted, it may be possible for a single transceiver, for example located at the surface, to control the activation of a number of down-hole firing units by having multiple output points which allow connection of a number of units. This would be beneficial for holes in which there are multiple detonators, for example, multi decked holes.

[0029] The explosives charge that is light initiated in accordance with the present invention may be used to initiate an associated "working" or main explosives charge. In this case, the light initiated explosives charge is relatively small but selected to, nevertheless, be effective in detonating the main explosives charge. In this case, the light initiated explosive charges may be provided under heavy confinement as per a conventional cartridge detonator. Light can be delivered into the cartridge direct.

[0030] In another embodiment, the light initiated explosives charge is used to detonate an associated main explosives charge but the arrangement is detonator free. In this case, the light initiated explosives charge is provided in direct contact with at least part of the main charge or the two may be separated by a membrane that does not influence detonation of the main explosives charge. This approach is described in International Patent Publication No. WO 2008/113108 entitled "Initiation of explosives materials". The latter stipulates use of an optic fibre to convey light but this is not essential in accordance with the present invention.

[0031] Accordingly, in this embodiment the present invention provides a detonator free blasting system which comprises:

a working explosive charge;
a confined explosives charge; and
an initiation device in accordance with the present invention, wherein the initiation device is provided to deliver light directly into or onto the confined explosives charge and the confined explosives charge is adapted to be initiated by that light and wherein initiation of the confined explosives charge causes initiation of the working explosive.

[0032] In accordance with this embodiment, the working explosives charge is initiated by detonation of the confined explosives charge. In turn, initiation of the confined charge is caused by irradiation of the confined explosive by a suitable light source. Thus, the working explosive is initiated without using a conventional detonator device.

[0033] In accordance with this embodiment, initiation is achieved by irradiating the confined charge until ignition of it occurs. The confined charge is confined such that this initial ignition propagates to full detonation. The confined charge and working charge are provided relative to one another such that detonation of the confined charge causes initiation of the working charge. In an embodiment of the invention, a portion of the confined charge and a portion of the working charge may be in direct contact. However, in other embodiments this may not be essential, provided that the intended operative relationship between the charges is retained. For example, in certain embodiments, the charges may be separated by a membrane, or the like. In this case the membrane, or the like, may be included for ease of manufacture; the membrane (or like) does not influence detonation of the working charge.

[0034] The working explosives charge that is used is generally a secondary explosive too. The blasting system of the invention may therefore be free of primary explosives. The working explosives charge may be the same as or different from the light initiated explosives charge. When the charges are of the same explosives material, the invention may be implemented by suitable confinement of a portion of the bulk explosive.

[0035] An important aspect of this embodiment is the way in which the confined explosives charge is confined since it has been found that the geometry of the confinement is critical to the successful detonation of the working explosive. Thus, the confined explosive charge should be confined in such a manner to contain initial ignition of the confined charge and to allow subsequent propagation to full detonation. A variety of confinement means (geometry and material) may be employed in implementation of the embodiment of the present invention.

[0036] In one embodiment, the confined explosive charge may be confined in an elongate tubular member. Usually, this will be of circular cross-section, although this is not mandatory. When an elongate tubular member is used, the internal diameter of the tubular member should be greater than the critical diameter for the explosive being confined. When the confined explosive charge is strongly confined, for example, when the confinement means is made of a metal, the internal diameter of the tubular member may be up to 3 times larger than the critical diameter for the explosive being confined.

[0037] A typical tubular member of circular cross-section useful in the present invention generally has an internal diameter of about 2 to about 5mm, for example about 3mm, and a length of up to about 110mm, for example from 20 to 110mm. The length of the tubular member required for transition of the confined explosives charge will vary as between different types of explosive. For example, for PETN, the minimum length of the tubular member will be about 30mm, whereas for pentolite, the minimum length will be about 90mm (for an internal diameter of about 3mm).

[0038] The confinement means may take on other geometries. Thus, spherical or conical confinement means may be used. Examples of suitable materials for the confinement means include metals and metal alloys, for example aluminium and steel, and high strength polymeric materials.

[0039] For the purposes of illustration, in the following, the invention will be described in connection with a tubular elongate member of circular cross-section as confinement means.

[0040] Typically, the working explosives charge is provided in (direct) contact with a portion of the confined explosives charge.

[0041] In accordance with the present invention, a fibre optic is not used to communicate light from the light source to the confined explosives charge but rather, the light source discharges through a focusing lens directly into or onto the explosives charge. This simplifies design and manufacture, and is more economical. For example, it may be possible to replace the "window" portion of a laser diode with a (sapphire) lens that focuses light emitted from the diode onto the explosive. This approach enhances efficiency.

[0042] The working explosives charge that it is desired to detonate is generally provided in (direct) contact with at least a portion of the confined explosives charge. Depending upon the form in which the explosives charge is provided, the explosives charge may also surround the tubular member in which the confined explosive is confined. In other words, the tubular member may be embedded in the explosives charge.

[0043] In a related embodiment, the explosives charge that is to be light initiated takes the form of a booster, for example a pentolite booster. In this case, the confined explosives charge, preferably PETN or pentolite, is provided in an elongate tubular member that is embedded in the booster. The booster may be designed accordingly to accommodate the tubular member. Thus, the tubular member may be provided and secured in the booster in a suitable well, as is the case for detonator initiated boosters. Otherwise, conventional boosters may be used to implement this embodiment.

[0044] Alternatively, in another related embodiment of the invention, the pentolite booster may be cast around and with a suitable tubular member. In this case, it may be possible to implement the invention using a one-piece booster comprising a shell/casing and an integrally formed tubular member extending into a cavity defined by the shell/casing. Suitable explosives material(s) may then be cast into the shell/casing and tubular member.

[0045] These embodiments of the present invention relating to the booster may have practical application in seismic exploration where (pentolite) boosters are used to generate signals (shock waves) for analysis to determine geological characteristics in the search for oil and gas deposits. The present invention thus extends to use of this embodiment of the invention in seismic exploration.

[0046] It is also possible for the working explosives charge to take the form of a length of detonating cord. In this case, the end of the detonating cord is typically provided in direct contact with at least a portion of the confined explosives charge. Any suitable retainer or connector may be used to ensure that this direct contact is maintained prior to use. Initiation of the detonating cord aside, the detonating cord may be used in conventional manner. Instantaneous detonation of detonating cord across multiple blastholes could prove advantageous in pre-split and tunnel perimeter blasting operations. In another embodiment, the detonating cord may itself be used to initiate a booster, for example a booster comprising an emulsion explosive. In this case, one end of the detonating cord will be embedded in the booster explosive with the other end of the cord being available for light initiation in accordance with the present invention.

[0047] In another embodiment, the confined and working explosives charges may be an emulsion explosive material. Conventional emulsion explosive material may be used in this regard. In this embodiment, a portion of the emulsion explosives material may be confined in a suitable elongate tubular member and immersed/embedded in the working charge emulsion. In this embodiment (and for all others), the nature and dimensions of the means used for confinement may be manipulated in order to optimise implementation of the invention.

[0048] In another embodiment, the light initiated explosives charge may itself be adequate to achieve the desired blast outcome. For example, the explosives charge deployed in a suitable device configuration may be adequate to perforate a well casing in oil or gas exploration.

[0049] The explosives charge to be initiated by light and the light source are selected based on the required outcome and the two must be paired accordingly. Examples of light sources that may be used include solid state lasers, laser diodes, LEDs and other electronic light sources. Compact design and low power consumption are desirable characteristics for the light source. By way of example, a 1-10 W power laser may be suitable for use in the invention. The laser wavelength may be within the near infra-red region and, indeed, this is preferred, although other wavelengths may be used. A lens channels and focuses the laser output into or onto the explosives charge.

[0050] As noted herein above, the light initiated explosive is a secondary explosives material, such as PETN, tetryl, RDX, HMX, and pentolite. The use of PETN or pentolite tends to be preferred. It is possible, however, that the explosives charge is a conventional emulsion explosive, such as a water-in-oil emulsion explosive, or a water-gel explosives material.

[0051] The explosives charge is dosed with a heat transfer medium to enhance coupling of the light energy irradiated from the light source and the explosive charge. Typically, the heat transfer medium is a light absorbing material that has an absorption band in the wavelength of the light being used. Examples of heat transfer media include carbon black, carbon nanotubes, nanodiamonds and laser dyes. Such materials are known in the art and are commercially available.

[0052] In an embodiment of the invention it may be possible to use a conventional camera flash to initiate an explosives charge. It is known, for example, that unpurified single wall carbon nanotubes (SWCNT) can be caused to ignite when light is applied to them from a standard camera flash. This is believed to be due to oxidation of iron nanoparticle catalysts that are present at the ends or on the surface of the nanotubes.

[0053] The flash initiation reaction is not particularly violent since only small regions of the nanotubes seem to show reaction. However, if nano-magnesium and/or nano-iron is mixed with nano-iron particles a more intense and violent reaction can result with significant amounts of heat being given off. Typically, the particle size for the iron and magnesium particles will be 2 to 4000 μm but, preferably, in the order of 6 to 100 μm. The reaction may be a thermite reaction with the formed oxide. The additional heat associated with that reaction may enable initiation of an explosives charge dosed with the nanotubes, or a blend of nano-iron and nano-magnesium particles. It is possible that the same effect may be achieved using a high intensity LED or laser, rather than a camera flash.

[0054] In the same way, other additives that serve as a thermal source and that actively take part in detonation reactions may be included in the confined explosive. Such materials include nitrated nanomaterials, silicon nanowires and other optically sensitive fuels. The amount of such materials may be up to 10% by weight of the confined explosives charge. The use of one or more heat transfer media and optically sensitive materials may allow detonation to be achieved with irradiation energies orders of magnitude lower than when such media and materials are not used.

[0055] The invention also relates to a method of blasting using an initiation device in accordance with the invention. In this case, the light source of the device is provided in operative association with an explosives charge that is adapted to be light initiated by the light source used in the device. The method comprises the transmission of a suitable wireless command signal to the device, the command signal being received by the transceiver and processed by the control circuit. The control circuit activates the light source and this causes the explosives charge to be initiated. The explosives charge is typically associated with and causes initiation of an associated working explosives charge.

[0056] The invention further provides a blasting system comprising an initiation device in accordance with the invention and blast control equipment that is adapted to transmit wireless command signals to the device.

[0057] The present invention may have particular use in the Oil & Gas (O&G) industry. Possible applications within this industry include use in the completion of O&G wells, specifically the initiation of explosives within perforation guns. Perforation guns are used in the final stage (completion) of an O&G well to break through the concrete (and/or other materials) casing laid down during the well making process. A further purpose of the perforation gun is to fracture the formation holding the oil in order to stimulate oil and/or gas flow. This may happen whether the well casing is intact or not. Perforation of O&G wells is generally carried out by specialized personnel through dedicated service companies, although other arrangements are possible.

[0058] The presence of primary explosives (amongst other things) in the perforation gun firing train means that once the explosive train is established on (or near) an O&G well working platform a range of activities must cease, resulting in a significant loss of productivity from the well. Removing primary explosives from this environment thus provides a tangible economic benefit in addition to the substantial safety advantage inherent in secondary (vs. primary) explosives. The present invention enables direct photo-initiation of secondary explosives and this will remove this hazard and allow a significantly wider range of activities to continue.

[0059] A further application in the O&G industry is the use in exploration for O&G through seismic surveys. Explosives are important sources of seismic energy used to uncover underground geologic features able to retain O&G. Seismic surveys entail burying of one or more explosives charges to pre-determined depths (e.g. shotholes) in arrays of particular design. Geophone (or other measuring devices) arrays of are also established to detect reflected (as well in some cases direct) seismic energy. The explosives are then initiated, measurements of resultant (including background) seismic energy are recorded and analysis is performed to visualize relevant geologic features.

[0060] Explosive arrays are generally relatively large, consisting of 10's, 100's or even 1000's of individual charges. These charges are generally deployed by relatively small teams of people and a significant time can elapse between loading the first and last charges giving rise to long periods where live explosives are left in shotholes. Further delays can arise due to technical activities surrounding a survey including, but not limited to, establishing the firing train, measurement array or other related activities. Even further delays may be caused by non-specific issues including scheduling of staff/equipment, weather or other seasonal issues. Taken together, these delays (and others not specified) result in potentially long explosive sleep-times, i.e. explosives deployed before initiation. Seismic survey applications can result in longer sleep times than most other explosive applications making the removal of primary explosives particularly preferable in that context.

[0061] As noted, the present invention allows the use of primary explosives materials to be avoided. One of the safety benefits of this in seismic exploration is that the overall sensitivity to detonation by non-specific means is significantly reduced. This is advantageous during the survey as it reduces the possibility of an unintended detonation. It is also important following completion of the survey as it is accepted that a certain proportion of charges deployed will fail to detonate. This proportion can be up to 10% depending on local conditions but is generally considerably lower. Due to the hazards involved in recovering misfired charges, many are left in place and are abandoned. The presence of highly sensitive primary explosives in these deployed charges means that shock, or another event, can lead to unintended detonation by non-specific stimulus. The chances of this are significantly reduced if the present invention is employed in order to avoid the use of primary explosives.

[0062] Notwithstanding the reduced sensitivity of secondary explosives to a wide range of stimuli, the photo-initiation system will fire only in response to a specific stimulus. Proven, secure systems to generate this stimulus exist and include, but are not limited to electronic systems, able to generate a fire, no fire or disarm signals. It is highly unlikely that the fire signal will be generated in the environment of an abandoned charge by chance.

[0063] A further advantage of removal of primary explosives is environmental, in that many widely used primary explosives include highly toxic and environmentally stable compounds. One example of this is the wide use of lead azide in detonators - the azide component is a highly toxic poison and lead is a recognized environmental pollutant that cannot be broken down by any natural process. Whilst many secondary explosives are classed as recalcitrant pollutants, natural mechanisms do exist in nature for their efficient degradation with biodegradation reported for all secondary explosives in wide use.

[0064] Many modifications will be apparent to those skilled in the art without departing from the scope of the present invention defined by the appended claims.

[0065] Throughout this specification and the claims which follow, unless the context requires otherwise, the word "comprise", and variations such as "comprises" and "comprising", will be understood to imply the inclusion of a stated integer or step or group of integers or steps but not the exclusion of any other integer or step or group of integers or steps.

[0066] The reference in this specification to any prior publication (or information derived from it), or to any matter which is known, is not, and should not be taken as an acknowledgment or admission or any form of suggestion that that prior publication (or information derived from it) or known matter forms part of the common general knowledge in the field of endeavour to which this specification relates.

Claims

1. An initiation device for initiation of an explosives charge, which comprises:

   a transceiver for receipt of wireless command signals;
   a control circuit for processing of wireless command signals received by the transceiver; and
   a light source that is suitable for initiation of the explosives charge and that is activated by the control circuit,
   characterised in that the control circuit comprises a timing mechanism to allow precise control of activation of the light source when a fire command is received by the transceiver,
   the light source discharges through a focusing lens directly into or onto the explosives charge, and
   the explosives charge is a secondary explosives material dosed with a heat transfer medium.

2. The initiation device of claim 1, wherein the transceiver has the capability for receipt only of wireless command signals.

3. The initiation device of claim 1, wherein the transceiver has the capability for two-way communication.

4. The initiation device of claim 1, wherein the control circuit has additional functional capability and is responsive to a variety of wireless command signals received by the transceiver.

5. The initiation device of claim 1, comprising a single transceiver and a plurality of associated control circuits and light sources.

6. The initiation device of claim 1, wherein the secondary explosives material is selected from PETN, tetryl, RDX, HMX and pentolite.

7. The initiation device of claim 1, wherein the heat transfer medium is selected from carbon black, carbon nanotubes, nanodiamonds and laser dyes.

8. A detonator free blasting system which comprises:

   a working explosive charge;
   a confined explosives charge; and
   an initiation device as claimed in any one of claims 1 to 7, wherein the initiation device is provided to deliver light directly into or onto the confined explosives charge and the confined explosives charge is adapted to be initiated by that light and wherein initiation of the confined explosives charge causes initiation of the working explosive.

9. A blasting system comprising an initiation device as claimed in any one of claims 1 to 7 and blast control equipment that is adapted to transmit wireless command signals to the device.

10. A method of blasting using an initiation device as claimed in any one of claims 1 to 7, which method comprises transmission of a wireless command FIRE signal to the device, receipt of the command signal by the transceiver and processing of the command signal by the control circuit, and activation of the light source by the control circuit thereby causing initiation of the explosives charge.

11. The method of claim 10, wherein a single wireless command FIRE signal is sent to an array of initiation devices with the devices then implementing firing independently in accordance with the time delay programmed into the control circuit of respective devices.

12. The method of claim 10, wherein a single transceiver receives the wireless command signal and a plurality of associated control circuits process the command signal and activate a plurality of associated light sources.

13. The method of claim 10, wherein the transceiver is physically positioned so that wireless command signals can be received directly using standard radio frequency transmission systems and protocols.

14. The method of claim 10, wherein the transceiver is positioned below ground level with wireless command signals being transmitted through the ground via low frequency signals.

15. The method of claim 10, wherein an aerial system extends from the transceiver to a point at which the

wireless command signals can be received.

16. The method of claim 10, wherein a low powered network is formed in which one or more initiation devices act to relay a wireless command signal to a particular initiation device even if that device is out of range or otherwise unable to receive the wireless command signal directly.

Patentansprüche

1. Zündvorrichtung zur Zündung eines Sprengsatzes, welche umfasst:

einen Sendeempfänger zum Empfang drahtloser Befehlssignale;
eine Kontrollschaltung zum Verarbeiten drahtloser Befehlssignale, empfangen von dem Sendeempfänger; und
eine Lichtquelle, die geeignet ist zur Zündung des Sprengsatzes und die von der Kontrollschaltung aktiviert wird,
dadurch gekennzeichnet, dass
die Kontrollschaltung einen Zeitmesser umfasst, um eine präzise Kontrolle der Aktivierung der Lichtquelle zu ermöglichen, wenn ein Feuerbefehl von dem Sendeempfänger empfangen ist,
die Lichtquelle sich durch eine Fokusierlinse direkt in oder auf den Sprengsatz entläd, und
der Sprengsatz ein sekundäres Explosionsmaterial, dosiert mit einem Wärmetransfermedium, ist.

2. Zündvorrichtung nach Anspruch 1, wobei der Sendeempfänger die Fähigkeit zum Empfang von nur drahtlosen Befehlssignalen hat.

3. Zündvorrichtung nach Anspruch 1, wobei der Sendeempfänger die Fähigkeit zur Zwei-Wege-Kommunikation hat.

4. Zündvorrichtung nach Anspruch 1, wobei die Kontrollschaltung zusätzliche funktionelle Fähigkeit hat und auf eine Vielfalt drahtloser Befehlssignale, empfangen vom Sendeempfänger, reagiert.

5. Zündvorrichtung nach Anspruch 1, umfassend einen einzelnen Sendeempfänger und eine Vielzahl von assoziierten Kontrollschaltungen und Lichtquellen.

6. Zündvorrichtung nach Anspruch 1, wobei das sekundäre Explosionsmaterial ausgewählt ist aus PETN, Tetryl, RDX, HMX und Pentolit.

7. Zündvorrichtung nach Anspruch 1, wobei das Wärmetransfermedium ausgewählt ist aus Ruß, Kohlenstoff-Nanoröhrchen, Nanodiamanten und Laserfarbstoffen.

8. Zünder-freies Sprengsystem, welches umfasst:

einen Arbeitssprengsatz;
einen begrenzten Sprengsatz; und
eine Zündvorrichtung wie beansprucht in einem der der Ansprüche 1 bis 7, wobei die Zündvorrichtung bereitgestellt ist, um Licht direkt in oder auf den begrenzen Sprengsatz zu liefern und der begrenzte Sprengsatz angepasst ist, um durch das Licht gezündet zu werden und wobei Zündung des begrenzten Sprengsatzes Zündung des Arbeitssprengsatzes verursacht.

9. Sprengsystem, umfassend eine Zündvorrichtung, wie beansprucht in einem der Ansprüche 1 bis 7 und Spreng-Kontroll-Ausrüstung, die angepasst ist, um drahtlose Befehlssignale an die Vorrichtung zu übertragen.

10. Verfahren zum Sprengen, unter Verwendung einer Sprengvorrichtung wie beansprucht in einem der Ansprüche 1 bis 7, welches Verfahren Übermittelung eines drahtlosen FEUER Befehlssignals an die Vorrichtung, Empfang des Befehlssignals durch den Sendeempfänger und Verarbeiten des Befehlssignals durch die Kontrollschaltung, und Aktivierung der Lichtquelle durch die Kontrollschaltung umfasst wodurch Zündung des Sprengsatzes, verursacht wird.

11. Verfahren nach Anspruch 10, wobei ein einzelnes drahtloses FEUER Befehlssignal an eine Reihe an Zündvorrichtungen gesendet wird, mit den Vorrichtungen dann Implementieren des unabhängigen Feuerns in Übereinstimmung mit der Zeitverzögerung, programmiert in der Kontrollschaltung der entsprechenden Vorrichtungen.

12. Verfahren nach Anspruch 10, wobei ein einzelner Sendeempfänger das drahtlose Befehlssignal empfängt und eine Vielzahl assoziierter Kontrollschaltungen das Befehlssignal verarbeiten und eine Vielzahl von assoziierten Lichtquellen aktivieren.

13. Verfahren nach Anspruch 10, wobei der Sendeempfänger physisch so positioniert ist, dass drahtlose Befehlssignale unter Verwendung von Standard-Radiofrequenz Übermittlungsystemen und Protokollen direkt empfangen werden können.

14. Verfahren nach Anspruch 10, wobei der Sendeempfänger unter der Erde positioniert ist, mit drahtlosen Befehlssignalen, die durch die Erde mittels Niedrig-Frequenz-Signalen übermittelt werden.

15. Verfahren nach Anspruch 10, wobei sich ein Antennensystem von dem Sendeempfänger zu einem Punkt, an dem die drahtlosen Befehlssignale empfangen werden können, erstreckt.

16. Verfahren nach Anspruch 10, wobei ein Niedrigspannungsnetzwerk gebildet wird, in welchem ein oder mehrere Sprengvorrichtungen agieren, um ein drahtloses Befehlssignal an eine bestimmte Sprengvorrichtung weiterzugeben, auch wenn diese Vorrichtung außer Reichweite ist oder anderweitig unfähig ist, das drahtlose Befehlssignal direkt zu empfangen.

Revendications

1. Dispositif d'amorçage pour l'amorçage d'une charge explosive, qui comprend :

un émetteur-récepteur pour la réception de signaux de commande sans fil ;
un circuit de commande pour le traitement de signaux de commande sans fil reçus par l'émetteur-récepteur ; et
une source de lumière qui est adaptée pour l'amorçage de la charge explosive et qui est activée par le circuit de commande,
caractérisé en ce que
le circuit de commande comprend un mécanisme de minutage pour permettre une commande précise d'activation de la source de lumière lorsqu'une commande de mise à feu est reçue par l'émetteur-récepteur,
la source de lumière se décharge par l'intermédiaire d'une lentille de focalisation directement dans ou sur la charge explosive, et
la charge explosive est un matériau explosif secondaire dosé avec un milieu caloporteur.

2. Dispositif d'amorçage selon la revendication 1, dans lequel l'émetteur-récepteur a la capacité de réception de signaux de commande sans fil uniquement.

3. Dispositif d'amorçage selon la revendication 1, dans lequel l'émetteur-récepteur a la capacité de communication bidirectionnelle.

4. Dispositif d'amorçage selon la revendication 1, dans lequel le circuit de commande a une capacité fonctionnelle supplémentaire et est sensible à une variété de signaux de commande sans fil reçus par l'émetteur-récepteur.

5. Dispositif d'amorçage selon la revendication 1, comprenant un émetteur-récepteur unique et une pluralité de circuits de commande et de sources de lumière associés.

6. Dispositif d'amorçage selon la revendication 1, dans lequel le matériau explosif secondaire est choisi parmi les PETN, tétryle, RDX, HMX et pentolite.

7. Dispositif d'amorçage selon la revendication 1, dans lequel le milieu caloporteur est choisi parmi le noir de carbone, des nanotubes de carbone, des nanodiamants et des colorants laser.

8. Système d'explosion sans détonateur qui comprend :

une charge explosive de travail ;
une charge explosive confinée ; et
un dispositif d'amorçage selon l'une quelconque des revendications 1 à 7, dans lequel le dispositif d'amorçage est fourni pour délivrer de la lumière directement dans ou sur la charge explosive confinée et la charge explosive confinée est adaptée pour être amorcée par cette lumière et dans lequel l'amorçage de la charge explosive confinée cause l'amorçage de l'explosif de travail.

9. Système d'explosion comprenant un dispositif d'amorçage selon l'une quelconque des revendications 1 à 7 et un équipement de commande d'explosion qui est adapté pour transmettre des signaux de commande sans fil au dispositif.

10. Procédé d'explosion utilisant un dispositif d'amorçage selon l'une quelconque des revendications 1 à 7, ledit procédé comprenant la transmission d'un signal de commande sans fil de mise à feu au dispositif, la réception du signal de commande par l'émetteur-récepteur et le traitement du signal de commande par le circuit de commande, et l'activation de la source de lumière par le circuit de commande de façon à causer l'amorçage de la charge explosive.

11. Procédé selon la revendication 10, dans lequel un signal de commande sans fil de mise à feu est envoyé à un réseau de dispositifs d'amorçage avec les dispositifs mettant en oeuvre ensuite une mise à feu indépendamment, conformément au temps de retard programmé dans le circuit de commande de dispositifs respectifs.

12. Procédé selon la revendication 10, dans lequel un émetteur-récepteur unique reçoit le signal de commande sans fil et une pluralité de circuits de commande associés traite le signal de commande et active une pluralité de sources de lumière associées.

13. Procédé selon la revendication 10, dans lequel l'émetteur-récepteur est physiquement positionné de sorte que des signaux de commande sans fil puissent être reçus directement en utilisant des systèmes et des protocoles de transmission de radiofréquence standard.

14. Procédé selon la revendication 10, dans lequel l'émetteur-récepteur est positionné au-dessous du niveau du sol avec des signaux de commande sans fil étant transmis à travers le sol par l'intermédiaire de signaux à basse fréquence.

15. Procédé selon la revendication 10, dans lequel un système aérien s'étend de l'émetteur-récepteur à un point auquel les signaux de commande sans fil peuvent être reçus.

16. Procédé selon la revendication 10, dans lequel un réseau à basse puissance est formé dans lequel un ou plusieurs dispositifs d'amorçage agissent pour relayer un signal de commande sans fil vers un dispositif d'amorçage particulier, même si ce dispositif est hors plage ou autrement incapable de recevoir le signal de commande sans fil directement.

REFERENCES CITED IN THE DESCRIPTION

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