

SPECIFICATION

Electric igniter

- 5 This invention relates to igniter assemblies for the firing of resistive electrically actuable ignition elements of the type used as electric fuseheads in blasting detonators and for the igniting of incendiary charges in pyrotechnic devices. Specifically, this
- 10 invention relates to an ignition assembly including such electrically actuable ignition elements, to methods for constructing and firing such assemblies and to methods for firing electrically actuable igniters.
- 15 Electrically actuable igniters generally include a resistive electric ignition element having two electrical connection terminals. A two conductor igniter leading wire is usually connected to these two electrical connection terminals so that just prior to
- 20 use, the two conductor igniter leading wires can be connected to a source of firing energy. The resistive electric ignition element is a conducting composition that is electrically heated to an ignition point or includes a bridge wire element having a predetermined
- 25 resistance for generating heat in thermal contact with an incendiary composition. The construction and use of electrically actuable igniters commonly used as the fuseheads of blasting detonators are described and illustrated in *Blasting Practice*
- 30 published by ICI-Nobel's Explosives Company Limited (Kynoch 1972), Chapters 2 and 3. In these igniters an ignition element is disposed within a tubular casing and electrically conductive leading wires extend from terminals of the element through
- 35 the seal in the mouth end of the casing to provide external leading wire lengths for connection to a source of electrical energy for igniting the element.
- In the igniter discussed, the resistive electric ignition element includes a bridge wire that is
- 40 metallurgically bonded across a pair of metal electrodes, to which ignition leading wires are also bonded. The electrodes are embedded in an incendiary composition. The igniter leading wires are 0.51-1.22 mm. in diameter copper or iron wires
- 45 insulated with a synthetic plastic material such as polyvinyl chloride.

Specifically, three groups of resistive electric ignition elements having different sensitivities have been developed for electric detonators:

- 50 Group 1 ignition elements have a characteristic resistance of 0.9-1.6 ohms and a firing sensitivity in the range of 3-5 millijoules/ohms;
- Group 2 ignition elements have a characteristic resistance of 0.15-0.18 ohms and a firing sensitivity
- 55 in the range of 80-140 millijoules/ohms; and
- Group 3 ignition elements have a characteristic resistance of 0.02-0.04 ohm and a firing sensitivity in the range of 1,000-2,500 millijoules/ohms.
- Commercial electric detonators are generally supplied with two separate leading wires which, to
- 60 facilitate later connection to a source of firing energy are bared to a length of about 1 cm. at their unconnected ends. In use, it is understood that the bared ends of the leading wires are connected by
- 65 twisting a bared end of a leading wire from one

ignition element with a bared wire end from another igniter to connect the igniters in series, parallel or series-parallel arrangement to the source of electrical firing energy. In many cases igniters arrive from a manufacturer with the two bared wire ends from each igniter twisted together and sheathed by the manufacturer as a safeguard against extraneous electrical sources. In these cases, the bared ends have to be separated by the user.

- 70 When the wires are unsheathed the detonator is subject to the risk of accidental ignition by extraneous electrical energy sources such as an electrostatic discharge from a person or from a substance in close proximity to the igniter such as pneumatically loaded ammonium nitrate fuel oil explosive (ANFO), a stray current from a battery or electric line, or a stray galvanic current. In addition to this serious safety problem, the use of these commercially available igniters is highly inconvenient. The actual
- 80 connection of the leading wires is tedious, difficult and time consuming, especially for parallel or series-parallel circuits. Connections must often be made in the poor light and confined space of an underground mine or tunnel. In such an environment, there is
- 85 always the possibility of a faulty connection or of bare wire connections coming into contact with water or other good earth leakage contact prior to the intended firing of the igniters.

- Various arrangements have been attempted to protect igniters from stray current and reduce the safety hazard. Igniters have been coupled to a firing circuit through a transformer core and, in some igniter assemblies designed for military use, the cores of the transformers have been separable into
- 100 two parts to allow the primary and secondary circuits to be kept separate until assembly was required for firing. Then, the assembly was armed for use by coupling the transformer core portions to one another. In these military igniter assemblies the transformer windings were separate from the leading wires of the igniter and also separate from the firing cable coupled to the power supply. If used with a commercial igniter the transformer windings would have to be connected to the firing cable and to
- 105 the igniter leading wires manually. Such a situation remains unsatisfactory.

Summary of the Invention

- It is therefore the primary object of the present invention to provide an electrically actuable igniter assembly that is safe to use, and to provide methods for the construction and use of such igniter assemblies. The present invention provides an igniter assembly wherein wire-to-wire connections are eliminated and wherein external leading wires are
- 120 insulated at all times.

- The insulated leading wires from a commercially available electrically actuable igniter of the leading wires from a source of electrical firing energy are
- 125 used to form a winding of a transformer electromagnetically coupling the electrically actuable igniter to the source of electrical firing energy. This arrangement eliminates the need for any wire-to-wire connections to transformer windings and eliminates the need for wire-to-wire connections be-
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between leading wires. It further provides protection of the igniter against the hazard of an inadvertent and unintended firing from extraneous sources of firing energy. Adequate coupling is readily achieved even with a single loop of leading wire loosely threaded through the core of a ring core transformer.

Specifically, according to the present invention an electrically actuable igniter assembly comprises:

10 a resistive electric ignition element disposed within a casing, said element having two electrical connection terminals; and electrically conductive leading wire electrically connected to said terminals to provide a continuous electrical circuit across said terminals, said leading wire extending outside said casing, the portion of leading wire external to said casing being completely covered with insulating material and providing at least one loop adapted for electromagnetic coupling to a transformer core as a secondary winding on said core.

20 In use in a preferred form of assembly the wire provides a winding of at least one turn on a magnetically permeable transformer core. Leading wires from a source of electrical energy (firing cable) and the ignition element respectively are coupled through the transformer, an insulated portion of the leading wires being looped through the transformer core to form at least part of the transformer winding. The insulation of the leading wires is continuous over the entire length of the wires in order to avoid accidental contact with extraneous electrical sources.

In one preferred form of the assembly (shown in Figure 1), the loops of the insulated leading wires from one or more ignition elements are electromagnetically coupled to a transformer core, preferably a ring core, as a winding of at least one turn thereon. Looping the leading wires and the electrical supply (firing cable) on a ring core is facilitated when the core is physically openable for example by means of a movable core segment which can be moved into or out of magnetic contact with the remainder of the core. This arrangement permits the use of continuous leading wires thereby avoiding the need for intermediate wire-to-wire connection.

45 Thus, the igniter leading wire is formed from a single continuous insulated wire whose ends are respectively electrically coupled to the two electrical connection terminals of an ignition element and having a loop intermediate its ends. This combination of an igniter electrically coupled to a continuous length of insulated wire forming an intermediate loop forms an ignition assembly. The intermediate loop of this igniter assembly is looped into an openable transformer core to which the electrical supply leading wires are also coupled.

Several ignition elements can be simultaneously and conveniently coupled to the same transformer core and ignited by a single signal from the electrical supply. Such a parallel arrangement of igniters is particularly advantageous in multi-shot blasting as it avoids the usual problem of detonator lag time variation, which can cause misfires with series connected igniters, and also avoids the problem of circuit balancing in parallel connected circuits.

65 In a second embodiment, shown in Figure 2, an

igniter assembly is formed by looping the continuous length of igniter leading wires through a toroidal transformer core. A plurality of such toroidal cores are then electromagnetically coupled to a further transformer core by a single loop of insulated wire passed as a primary winding through each toroidal core and as a secondary winding through the further transformer core.

70 Thus, there may be more than one transformer coupled in series between the electrical supply and the igniter and an extending link of insulated leading wire similar to the igniter leading wire may be used to couple the primary and secondary of two transformers to which the igniter and supply leading wires are respectively coupled. With such an arrangement one of the transformers coupled to the igniter, for example one with an inexpensive toroidal core, may be expendable and placed close to an igniter in a blasting charge.

85 In a third ignition system embodiment, shown in Figure 3, the firing cable from a source of electrical firing energy is a single, continuous, insulated wire whose ends are electrically coupled to the electrical supply terminals, an intermediate portion of this cable being looped as primary winding into one or more transformer cores, one or more igniter leading wires being coupled to each core.

The present invention also provides a method for constructing the igniter assembly of the invention comprising electrically connecting electrically conductive, insulated leading wire across the two terminals of a resistive electric ignition element to provide a continuous electric circuit across said terminals,

100 encasing said element in a casing with a completely insulated portion of said leading wire extending outside said casing, and forming in the external portion of leading wire at least one loop adapted for electromagnetic coupling as a secondary winding to a transformer core. The leading wire may advantageously be electromagnetically coupled to a transformer core for example a toroidal core.

For firing the ignition element the transformer core is in turn electromagnetically coupled to a source of electrical energy for firing.

The present invention further provides a method for firing the electrically actuable igniter assembly of the invention comprising electromagnetically coupling at least one loop provided in the external portion of the leading wire to a transformer core as a secondary winding thereon and electromagnetically coupling the transformer core to a source of electrical firing energy by means of a primary winding on the transformer core.

120 The igniter assembly and methods of the present invention provide a marked improvement in safety from the effects of extraneous electrical sources and leakage currents. The assembly may be readily designed to protect against accidental electrostatic discharge, direct current and low frequency alternating sources. It has been found, for example, that with a single loop coupling of igniter leading wires to the transformer, provided the leading wires are at least six meters in total length, the protection obtained against high voltage discharges from small capaci-

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tors (2000×10^{-12} Farad) is such that adequate safety against electrostatic discharge from persons and from ANFO explosive is ensured.

- The igniter assembly and construction and firing methods according to the present invention solve the long standing safety problem associated with the firing of conventional electrically actuatable igniters. There is no longer a need to unsheath the leading wire coupled to an electrically actuatable igniter exposing the user to risk of accidental ignition by an extraneous electrical source such as an electrostatic discharge from a person or from a neighboring substance. In addition the utilization of the arrangement disclosed minimizes the tedious connection of wires required by conventional arrangements. The firing method according to the present invention can be utilized in poor light conditions and in the confined space of an underground mine or tunnel. There is virtually no risk of inadvertent connection or coupling to environmental water or other sources of inadvertent firing energy. The use of a transformer core having a movable portion particularly simplifies the integration of all components into a total system suitable for firing a plurality of electrically actuatable igniters.

- Insulated leading wires from a commercially available igniter or from a firing unit are advantageously utilized as the windings of a transformer coupling the igniters to a source of electrical firing energy. This arrangement eliminates the requirements for any connection to transformer windings or between the leading wires and provides added protection by isolating the igniters from sources of stray firing energy. Adequate electromagnetic coupling is readily obtained even with a single loop of leading wire loosely threaded through a ring-core transformer.

The Brief Description of the Drawings

- Many of the attendant advantages of the present invention will be readily apparent as the invention becomes better understood by reference to the following detailed description with the appended claims, when considered in conjunction with the accompanying drawings, wherein:

- Figure 1* is a diagrammatic representation of a first embodiment of the igniter assembly according to the present invention.

- Figure 2* is a diagrammatic representation of a second embodiment of the igniter assembly according to the present invention.

- Figure 3* is a third embodiment of the igniter assembly according to the present invention.

Description of the Preferred Embodiments

- Referring now to the figures wherein like reference numerals designate like or corresponding parts throughout, and specifically referring to *Figure 1*, there is shown a first embodiment of the ignition system according to the present invention. A firing unit 11 provides a source of electrical firing energy for the actuation of a plurality of resistive electric ignition elements 16 (electrically actuatable igniters). Electrical energy from firing unit 11 is electrically coupled into a firing cable 12 which is in turn electrically coupled to the ends of a primary winding

13 wound about a transformer ring-core 14. Transformer ring core-14 has a rectangular shape and a movable portion 15 that is movable to permit the transformer ring core to be temporarily opened as shown by the solid and dotted lines in the *Figure 1*.

- The two electrical connection terminals of each resistive electric ignition element 16 are coupled to an ignition leading wire 17 which is a continuous length of insulated electrically conductive wire. Igniter leading wire 17, since it is a continuous wire, includes a loop end which is looped over transformer ring-core 14 through the opening created by the manipulation of movable portion 15 of the transformer ring-core. By looping the loop end of igniter leading wire 17 around transformer ring-core 14, a secondary transformer winding 18 is created which electromagnetically couples each igniter leading wire to the transformer ring-core. The ignition system is ready for firing when movable portion 15 of transformer ring-core 14 is closed into the position illustrated by the dotted lines in the *Figure 1*. The closing of movable portion 15 completes the magnetic circuit of transformer ring-core 14 so that primary winding 13 and looped secondary windings 18 are electromagnetically coupled to one another. Ignition elements 16 are fired simultaneously when a firing signal is generated within firing unit 11.

- The loop of igniter leading wire 17 is slipped over transformer ring-core 14 just prior to the desired firing of the igniter.

- By way of nonlimitative example, firing unit 11 includes a signal generator having an output frequency of 10 kHz. coupled to and driving a 25-watt power amplifier having an output stage suitable for working into a 16-ohm load impedance. The amplifier output is fed directly into a 100-meter long twin core firing cable 12 in which each core of the cable includes 7 strands of .4 mm. diameter copper wire and is insulated to 3.1 mm. diameter using polyvinyl chloride, the total resistance of the firing cable being 4 ohms. Transformer ring-core 14 is a high permeability ferrite material formed in the shape of a rectangle having outside dimension 6.3 cm. x 5.7 cm. and having cross-sectional dimensions of 13 mm. x 13 mm. Primary winding 13 of transformer ring-core 14 includes 12 turns of .61 mm. diameter copper wire insulated to an outside diameter of 1.14 mm. using polyvinyl chloride. Ignition elements 16 are fuseheads incorporated into detonators and are sensitive to a firing impulse of 3 to 5 millijoules/ohm and fitted with 5-meter long twin igniter leading wires 17. Igniter leading wires 17 utilized the same wire that is used to form primary winding 13 of transformer ring-core 14. Igniter leading wires 17 terminate in closed, fully insulated loops which form secondary transformer windings 18 of transformer ring-core 14. Thirty detonators were simultaneously fired by a single signal from firing unit 11.

- Referring now to *Figure 2* which is a diagrammatic representation of a second embodiment of the ignition system according to the present invention, again there is shown a plurality of resistive electric ignition elements 16 to be actuated by a signal from firing unit 11.

- Firing unit 11 is again coupled by firing cable 12 to

primary winding 13 of a transformer. In this embodiment, however, the transformer windings are wound about a transformer ring-core 19 having no movable portions. Transformer ring-core 19 is a continuous ring of ferromagnetic material. Again, the two electrical connection terminals of each of resistive electric ignition elements 16 are coupled to the two ends of igniter leading wire 17 that is a continuous length of electrically conductive wire. In this embodiment, instead of the loop end of igniter leading wire 17 being wrapped as a secondary transformer winding 18 around transformer ring-core 14 having a movable portion 15, the loop end of the igniter leading wire from each ignition element is electromagnetically coupled to a toroidal transformer core 20. This electromagnetic coupling is accomplished by winding several turns of the loop end of igniter leading wire 17 around toroidal transformer core 20. Toroidal transformer cores 20 are in turn electromagnetically coupled to transformer ring-core 19 by a single loop of insulated wire 21 passing through each toroid to be coupled and passing through the transformer ring-core. This electromagnetic coupling between toroidal transformer core 20 and transformer ring-core 19 can be accomplished just prior to firing of ignition elements 16 in the field.

In the arrangement represented in Figure 2, the following method of firing actuates resistive electric ignition elements 16: Firing unit 11 generates a source of electrical firing energy which is electromagnetically coupled to transformer ring-core 19 via firing cable 12 and primary winding 13. The changing magnetic flux induced within transformer ring-core 19 electromagnetically couples an electrical signal to loop 21 of insulated wire passing through toroidal transformer cores 20. By virtue of the electromagnetic coupling between loop 21 and toroidal transformer cores 20, a magnetic flux is induced within each of the toroids. The electromagnetic coupling between toroidal transformer cores 20 and igniter leading wires 17 induce an electrical signal within the igniter leading wires which in turn actuates resistive electric ignition elements 16.

The arrangement shown in Figure 2 allows for the construction of ignition assemblies each including a resistive electric ignition element 16, and igniter leading wire 17, and a toroidal transformer core 20. Igniter leading wire 17, being a continuous length of electrically conductive wire, is looped several times around a toroidal transformer core 20. Its two ends are electrically connected to the two electrical connection terminals of an ignition element 16. In this manner, an ignition assembly is constructed for easy and safe use in the field. In order to utilize the ignition assembly so constructed, the user need only pass a single loop of insulated wire 21 through each of the toroidal transformer cores 20 of such an ignition assembly to be fired. This loop 21 of insulated wire is then linked through transformer ring-core 19 and ignition elements 16 are ready for firing.

By means of specific nonlimitative example, one particular arrangement as shown in Figure 2 is constructed as follows: resistive electric ignition

elements 16 are arranged as shown. Firing unit 11 includes a signal generator having an output frequency of 10 kHz, driving a 25-watt power amplifier designed to work into a 16-ohm load. The amplifier output is coupled directly to a 100-meter long twin core firing cable 12 in which each core consists of 7 strands of .4 mm. diameter copper wire and is insulated to a total diameter of 3.1 mm. using polyvinyl chloride, the total resistance of the firing cable being 4 ohms. Transformer ring-core 19 is a continuous rectangle of high permeability ferrite material having outside dimension 6.3 cm x 5.7 cm. and cross-sectional dimension of 13 mm. x 13 mm. Primary winding 13 consists of 12 turns of .61 mm. diameter copper wire coated to an outside diameter of 1.14 mm. with polyvinyl chloride. Toroidal transformer cores 20 are high permeability ferrite material each having an outside diameter of 2.5 cm. and a cross-sectional area of 15 mm². Ignition leading wires 17 are constructed from the same wire utilized in primary winding 13 and are looped five times around toroidal transformer cores 20. Loop 21 is a one meter length of .61 mm. diameter copper wire insulated with polyvinyl chloride to an outside diameter of 1.14 mm. Ten ignition elements 16 were fired simultaneously from a single signal from power unit 11 using this configuration.

Referring now to Figure 3 which is a diagrammatic representation of a third embodiment of the ignition system according to the present invention, again, the object is to fire a plurality of resistive electric ignition elements 16 from a firing signal generated by firing unit 11. As in the embodiment shown in Figure 1, a plurality of ignition assemblies, each including an ignition element 16, and an igniter leading wire 17 are electromagnetically coupled to transformer ring-core 14 having a movable portion 15. The loop end of igniter leading wire 17 forms a secondary transformer winding 18 so that magnetic flux within transformer ring-core 14 induces an electrical signal within igniter leading wire 17. Also, in a similar fashion to the arrangement illustrated in Figure 1, firing unit 11, generates a firing signal coupled into firing cable 12. However, in this embodiment, firing cable 12 is coupled across both ends of a loop 21 of insulated wire passing through each of a plurality of transformer ring-cores 14. Each such transformer ring-core 14 includes a group of ignition assemblies electromagnetically coupled thereto as secondary windings. Loop 21 in essence, forms a primary winding having one turn only on each of transformer ring-cores 14.

The firing method of the arrangement shown in Figure 3 is as follows: firing unit 11 generates a firing signal coupled to loop 21 by firing cable 12. Loop 21, passing through each of a plurality of transformer cores 14, functions as primary winding of each of the transformer cores and induces a magnetic flux by virtue of its electromagnetic coupling with each such core. The changing magnetic flux within each of transformer cores 14 induces an electrical signal in each of igniter leading wires 17 coupled to a transformer core, the signal induced therein actuating the resistive electric ignition element 16 electrically connected thereto.

In the arrangement of Figure 3, ignition assemblies including ignition element 16 and igniter leading wires 17 are constructed as a single unit as in the first embodiment so that in field use, the loop end of igniter leading wire 17 need only be slipped over a transformer core 14 to make the assembly ready for use. The user can then loop as many transformer cores 14 as necessary together with a loop 21 of continuous insulated wire that is then coupled to firing cable 12.

By way of nonlimitative example, a specific arrangement is described: Nine resistive electric ignition elements 16 are arranged as shown in Figure 3, each group of three ignition elements 16 is coupled to a transformer core 14 having a movable portion 15. Loop 21 is a one meter length of .61 mm. diameter copper wire insulated with polyvinyl chloride to an outside diameter of 1.14 mm. Loop 21 is connected directly to firing cable 12 which in turn is coupled to firing unit 11. The specific characteristic of ignition element 16, cores 14, firing cable 12, and firing unit 11 are the same as stated in the specific example related to the embodiment shown in Figure 1. All nine detonators are simultaneously fired by a single signal from firing unit 11.

Therefore it is apparent that there has been provided an apparatus and an arrangement for firing resistive electric igniter elements of the type commonly used in detonators and other pyrotechnic or explosive devices. There has further been provided a safe method for coupling an electrically actuable igniter to a supply of electrical firing energy which does not involve making wire-to-wire connections and wherein external leading wires are insulated at all times to promote safety. There has further been provided a method of constructing igniter assemblies that are easy to utilize in conjunction with applicant's entire system at a field location such as igniter assemblies being, by virtue of their design, easy and safe to handle and use.

Obviously, other embodiments and modifications of the present invention will readily come to those of ordinary skill in the art having the benefit of the teachings presented in the foregoing description and the drawings. It is, therefore, to be understood that this invention is not to be limited thereto and that said modifications and embodiments are intended to be included within the scope of the appended claims.

For example, in a specific design, the transformer (or transformers) in the assembly can be used either as a step-up or step-down transformer by appropriate adjustment of the number of turns of the supply and igniter leading wires looped into the magnetic circuit. The transformer core can have any desired configuration and cross-sectional shape but conventional shapes such as toroidal, circular or rectangular configuration with rectangular cross-sections, are readily available. The core material should be a high permeability ferrite material.

The transformer characteristics can be chosen so that alternating currents at line power frequencies of 50-60 Hz. will not induce sufficient energy within the transformer to fire an igniter. The transformer is preferably chosen to transmit the required firing

energy when the primary current is provided at about 1-20 kHz. from a pulsed supply.

The igniter leading wires can be those used in conventional igniter devices, for example, 0.5 to 1.22 mm. diameter copper or iron wires insulated with a synthetic plastics material, such as polyvinyl chloride. The electrical supply leading wires from the firing cable may be similar to the igniter leading wires or could be a heavier gauge wire, or multi-strand wire.

The invention is applicable to all the commonly used igniters, and in particular those used in electric fuseheads of blasting detonators, the preferred bridgewire fusehed resistances being in the range of 0.5-1.6 ohms and having sensitivities in the range of 3-16 millijoules/ohms.

CLAIMS

1. An electrically actuable igniter assembly comprising: a resistive electric ignition element disposed within a casing, said element having two electrical connection terminals; and electrically conductive leading wire electrically connected to said terminals to provide a continuous electrical circuit across said terminals, said leading wire extending outside said casing, the portion of leading wire external to said casing being completely covered with insulating material and providing at least one loop adapted for electromagnetic coupling to a transformer core as a secondary winding on said core.

2. An assembly as claimed in Claim 1 further comprising a transformer core, said loop or loops being electromagnetically coupled to said core as a winding of at least one turn thereon.

3. An assembly as claimed in Claim 2 wherein the transformer core is a ring core.

4. An assembly as claimed in Claim 3 wherein the transformer core is physically openable to admit loops or windings of leading wire thereto.

5. An assembly as claimed in Claim 4 wherein the transformer core has at least one segment that is movable such that the magnetic circuit of said core can be made or broken by moving said movable segment into or out of magnetic contact with the remaining portion of said core.

6. An assembly as claimed in Claim 3 wherein the transformer core is a toroidal core.

7. An assembly as claimed in any one of Claims 2 to 6 inclusive comprising two or more of said resistive electric ignition elements and respectively connected leading wires electromagnetically coupled to said transformer core.

8. An assembly as claimed in any one of Claims 2 to 7 inclusive further comprising a primary winding linking said transformer core whereby said ignition element leading wire may be electromagnetically coupled to a source of electrical energy for actuating said ignition element.

9. An assembly as claimed in Claim 8 comprising two or more of said transformer cores each having at least one of said resistive electric ignition elements electromagnetically coupled thereto, all said transformer cores being simultaneously linked by said primary winding.



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In the arrangement of Figure 3, ignition assemblies including ignition element 16 and igniter leading wires 17 are constructed as a single unit as in the first embodiment so that in field use, the loop end of igniter leading wire 17 need only be slipped over a transformer core 14 to make the assembly ready for use. The user can then loop as many transformer cores 14 as necessary together with a loop 21 of continuous insulated wire that is then coupled to firing cable 12.

By way of nonlimitive example, a specific arrangement is described: Nine resistive electric ignition elements 16 are arranged as shown in Figure 3, each group of three ignition elements 16 is coupled to a transformer core 14 having a movable portion 15. Loop 21 is a one meter length of .61 mm. diameter copper wire insulated with polyvinyl chloride to an outside diameter of 1.14 mm. Loop 21 is connected directly to firing cable 12 which in turn is coupled to firing unit 11. The specific characteristic of ignition element 16, cores 14, firing cable 12, and firing unit 11 are the same as stated in the specific example related to the embodiment shown in Figure 1. All nine detonators are simultaneously fired by a single signal from firing unit 11.

Therefore it is apparent that there has been provided an apparatus and an arrangement for firing resistive electric igniter elements of the type commonly used in detonators and other pyrotechnic or explosive devices. There has further been provided a safe method for coupling an electrically actuable igniter to a supply of electrical firing energy which does not involve making wire-to-wire connections and wherein external leading wires are insulated at all times to promote safety. There has further been provided a method of constructing igniter assemblies that are easy to utilize in conjunction with applicant's entire system at a field location such as igniter assemblies being, by virtue of their design, easy and safe to handle and use.

Obviously, other embodiments and modifications of the present invention will readily come to those of ordinary skill in the art having the benefit of the teachings presented in the foregoing description and the drawings. It is, therefore, to be understood that this invention is not to be limited thereto and that said modifications and embodiments are intended to be included within the scope of the appended claims.

For example, in a specific design, the transformer (or transformers) in the assembly can be used either as a step-up or step-down transformer by appropriate adjustment of the number of turns of the supply and igniter leading wires looped into the magnetic circuit. The transformer core can have any desired configuration and cross-sectional shape but conventional shapes such as toroidal, circular or rectangular configuration with rectangular cross-sections, are readily available. The core material should be a high permeability ferrite material.

The transformer characteristics can be chosen so that alternating currents at line power frequencies of 50-60 Hz. will not induce sufficient energy within the transformer to fire an igniter. The transformer is preferably chosen to transmit the required firing

energy when the primary current is provided at about 1-20 kHz. from a pulsed supply.

The igniter leading wires can be those used in conventional igniter devices, for example, 0.5 to 1.22 mm. diameter copper or iron wires insulated with a synthetic plastics material, such as polyvinyl chloride. The electrical supply leading wires from the firing cable may be similar to the igniter leading wires or could be a heavier gauge wire, or multi-strand wire.

The invention is applicable to all the commonly used igniters, and in particular those used in electric fuseheads of blasting detonators, the preferred bridgewire fusehead resistances being in the range of 0.5-1.6 ohms and having sensitivities in the range of 3-16 millijoules/ohms.

CLAIMS

1. An electrically actuable igniter assembly comprising: a resistive electric ignition element disposed within a casing, said element having two electrical connection terminals; and electrically conductive leading wire electrically connected to said terminals to provide a continuous electrical circuit across said terminals, said leading wire extending outside said casing, the portion of leading wire external to said casing being completely covered with insulating material and providing at least one loop adapted for electromagnetic coupling to a transformer core as a secondary winding on said core.

2. An assembly as claimed in Claim 1 further comprising a transformer core, said loop or loops being electromagnetically coupled to said core as a winding of at least one turn thereon.

3. An assembly as claimed in Claim 2 wherein the transformer core is a ring core.

4. An assembly as claimed in Claim 3 wherein the transformer core is physically openable to admit loops or windings of leading wire thereto.

5. An assembly as claimed in Claim 4 wherein the transformer core has at least one segment that is movable such that the magnetic circuit of said core can be made or broken by moving said movable segment into or out of magnetic contact with the remaining portion of said core.

6. An assembly as claimed in Claim 3 wherein the transformer core is a toroidal core.

7. An assembly as claimed in any one of Claims 2 to 6 inclusive comprising two or more of said resistive electric ignition elements and respectively connected leading wires electromagnetically coupled to said transformer core.

8. An assembly as claimed in any one of Claims 2 to 7 inclusive further comprising a primary winding linking said transformer core whereby said ignition element leading wire may be electromagnetically coupled to a source of electrical energy for actuating said ignition element.

9. An assembly as claimed in Claim 8 comprising two or more of said transformer cores each having at least one of said resistive electric ignition elements electromagnetically coupled thereto, all said transformer cores being simultaneously linked by said primary winding.



10. An assembly as claimed in Claim 8 or Claim 9 wherein said primary winding consists of a single turn of wire electromagnetically coupled to the, or each, transformer core.

5 11. An assembly as claimed in any one of Claims 2 to 10 inclusive further comprising an additional transformer core having a primary winding linking therewith for connection to a source of electrical energy and means for electromagnetically coupling
10 said additional core with the, or each of the transformers to which a loop of said external portion of leading wire is electromagnetically coupled.

12. An assembly as claimed in Claim 11 wherein the means for electromagnetically coupling said
15 transformer cores is a single length of electrically conductive wire.

13. An assembly as claimed in any one of Claims 8 to 12 inclusive further comprising a power supply connected to said primary winding.

20 14. An assembly as claimed in any one of Claims 1 to 3 inclusive wherein said resistive electric ignition element is a fusehead having a bridgewire resistance in the range from 0.5 to 1.6 ohms and sensitivity in the range from 3 to 16 millijoules/ohm.

25 15. An assembly as claimed in any one of Claims 1 to 14 inclusive wherein the leading wire is 0.5 to 1.22 mm diameter wire insulated with a sheath of synthetic plastics material.

30 16. An assembly as claimed in Claim 15 wherein the leading wire is wire made from copper or iron or a composite thereof.

17. A method for constructing an electrically actuable igniter assembly as claimed in Claim 1 comprising the steps of:

35 electrically connecting electrically conductive insulated leading wire across the two terminals of a resistive electric ignition element to provide a continuous electric circuit across said terminals;
encasing said element in a casing with a complete-
40 ly insulated portion of said leading wire extending outside said casing;

and forming in the external portion of leading wire at least one loop adapted for electromagnetic coupling as a secondary winding to a transformer core.

45 18. A method in accordance with Claim 17 for constructing the electrically actuable ignition assembly of Claim 2 wherein the external portion of the insulated electrically conductive leading wire is electromagnetically coupled to a transformer ring
50 core.

19. A method for firing the electrically actuable igniter assembly of Claim 1, which comprises electromagnetically coupling at least one loop provided in the external portion of the leading wire to a
55 transformer core as a secondary winding thereon and electromagnetically coupling the transformer core to a source of electrical firing energy by means of a primary winding on the transformer core.

20. A method as claimed in Claim 19 wherein
60 loops from the external portions of leading wire from two or more of said ignition elements are electromagnetically coupled to the transformer core.

21. A method as claimed in Claim 19 or Claim 20 wherein two or more said transformer cores are
65 electromagnetically coupled to a source of electrical

firing energy by means of a primary winding simultaneously linking each core.

22. A method as claimed in Claim 21 wherein the transformer cores are single cores and the primary winding consists of a single loop of wire threaded through each core to provide a single turn of wire on each core.

23. A method as claimed in any one of Claims 19 to 22 inclusive wherein the transformer core is a ring core including at least one movable segment and the external portion of leading wire is electromagnetically coupled to the transformer core by moving said segment out of contact with the remainder of said core, slipping a loop of the external portion of
80 leading wire around the transformer core via the opening created by moving said segment, and returning said segment to its closed position.

24. A method as claimed in any one of Claims 19 to 23 inclusive wherein the, or each transformer core
85 is electromagnetically coupled to the source of electrical firing energy through at least one additional transformer core.

25. A method as claimed in Claim 24 wherein the transformer cores are electromagnetically coupled
90 by means of a single length of electrically conductive wire.

26. An electrically actuable ignition assembly in accordance with Claim 1 substantially as described herein and shown in the accompanying drawings.

95 27. A method for constructing an electrically actuable ignition assembly in accordance with Claim 17 substantially as described herein with reference to the accompanying drawings.

28. A method in accordance with Claim 19 for
100 firing a resistive electric ignition element substantially as described herein with reference to the accompanying drawings.