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Seismic Recording

This invention relates to a method of seismic recording using an explosive charge to generate the seismic
5 signal and in particular to an improved method of indicating the time-break on a seismic record. The invention also includes an apparatus assembly for indicating the time break on a seismic record.

In the prospecting of geological formations using
10 explosive charges, seismic waves are generated in the formations by an exploding charge and are reflected or refracted at rock layer interfaces. The reflected or refracted waves are detected at the earth's surface by geophones which convert the waves into electrical
15 energy and this is used to make a permanent record, on photographic paper or magnetic tape, of the waves received at each geophone location. The seismic record indicates the time of generation of the seismic waves, i.e. the explosion of the charge, and the time of detection of
20 each wave (seismic event) at the geophone. From a knowledge of the speed of the seismic wave through the earth, the depth of each subterranean rock interface can be calculated. For accurate calculation of the interface depths it is important that the exact instant of generation
25 of the seismic wave, or a time accurately related thereto, should be recorded accurately as a reference time. This reference time is generally termed the 'time-break' of the record.

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In the current method of seismic prospecting using an explosive charge as the seismic energy source the time-break indicated on the record is the time of application of electric current to the electric detonator used to ignite the explosive charge. However, even with special electric detonators designed for rapid bursting, there is a delay of about one millisecond between the application of the current and the bursting of the detonator, due mainly to the time required to heat the detonator heating wire element and fusehead priming composition to ignition temperature. This delay time is variable and consequently the time break indication is not a completely accurate reference point for the generation of the seismic wave.

It is an object of this invention to provide a method and apparatus for providing a more accurate indication of the time-break on a seismic record than the method currently used in seismic prospecting systems using explosives to generate seismic waves.

In accordance with this invention a method of seismic recording wherein seismic waves are generated by firing an explosive charge by means of a detonator having an electrical ignition element and are subsequently recorded after reflection or refraction at subterranean rock layer interfaces, comprises the steps of:-

feeding firing energy from an A.C. energy source to said electric ignition element through a transformer which has a primary circuit connected to said A.C. source and a secondary circuit connected to said electric ignition element, said primary circuit having a breakable portion adapted and disposed so as to be ruptured by the explosion of said explosive charge;

detecting the time when the said breakable circuit portion is broken; and, in response thereto,

making a mark on the seismic record to indicate a time-break on the record.

In this method current will flow in the primary circuit until the explosion even if the ignition element is previously fused.

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In a preferred manner of putting the invention into practice the break in the circuit is detected by the cessation of current or a rapid rise in voltage across the breakable circuit portion.

5 The time difference between the explosion of the charge and the marking of the time-break on the record will depend on the time taken for the circuit to break and the additional time required for the detecting means to operate a marking device on the record. Using a
10 circuit of insulated copper wire as used for standard electric blasting detonator leading wires with currently available electrical sensing devices the time break can be marked on the seismic record at about 100 microseconds after the explosion of the charge, i.e. in about one
15 tenth of the time difference between the time break recorded from the application of current to the electric detonator and the explosion of the charge in the method used hitherto.

20 Transformer coupled detonator arrangements suitable for the present invention are shown, for example, in our United Kingdom Patent Specification No. GB 2022222A and are marketed under the trade name 'Magnadet' (Registered Trade Mark). In such detonators the insulated leading wire from the detonator igniter element is looped as a
25 secondary winding around a ring-shaped transformer core, usually a toroid, to which a firing lead wire from the A.C. source is electromagnetically coupled as a primary winding, the primary winding usually being coupled to several detonator igniter elements. These detonators
30 give the advantages of protection against accidental firing by stray electric currents and static electricity because the secondary circuit through the detonator can be short and totally shielded, and, since the transformer core is frequency selective, it can be designed to prevent
35 firing of the detonator from high D.C. and low frequency A.C. currents (e.g. 50 Hz) and static discharge in the primary circuit. Moreover protection from electromagnetic radiation is also obtained because the aerial effect of

the short secondary detonator circuit is insignificant and that of the primary is less than that of the directly connected seismic detonator currently used by a factor of at least the number of turns in the secondary winding of the transformer.

Conveniently the ignition element is electromagnetically coupled to the A.C. source by threading leading wires from the ignition element and the A.C. source through a toroidal transformer core. The leading wires from the ignition element to the transformer are advantageously kept sufficiently short to ensure that a portion of the primary circuit is broken by the explosion.

The apparatus assembly of the invention for indicating a time-break on a record of a seismic signal generated by firing an explosive charge by means of a detonator having an electrical ignition element comprises:-

a transformer having a primary circuit for connection to an A.C. energy source and a secondary circuit for connection to said electric ignition element, said primary circuit having a breakable portion adapted to be ruptured by the explosion of said explosive charge;

and electrical sensing means adapted to generate a signal to mark a time-break on the said record in response to the rupture of said breakable circuit portion.

The transformer advantageously has a ring core through which the conductor wires from the A.C. source and the detonator ignition element are looped to provide primary and secondary transformer circuits.

The electrical sensing means may conveniently comprise a current responsive device connected in series with the breakable electrical circuit portion, which device, on cessation of the current generates a signal to mark the time-break on the seismic record. Alternatively the sensing means may comprise a voltage responsive device shunt connected across the breakable circuit portion, which device, in response to the increased voltage consequent on the circuit break, generates a signal to mark the time-break. Preferred electrical sensing means comprise a transformer

having a primary circuit connected to the breakable circuit portion and a pulse detector connected to a secondary circuit of the said transformer, said pulse detector being adapted to detect the presence and cessation of pulses induced in the said secondary circuit when energy is passed through the breakable circuit portion from an A.C. source during the explosion of the explosive charge. A preferred pulse detector for sensing high frequency pulses as used for firing electromagnetically coupled detonators comprises a resistor-capacitor circuit connected via a rectifier to the said secondary circuit whereby the capacitor is charged by induced pulses in the secondary circuit, a voltage comparator to compare the capacitor voltage with a reference voltage and means responsive to the voltage comparator output to mark the time-break on the seismic record when the capacitor voltage falls below the reference voltage. The values of the resistor and capacitor may be chosen so as to control the capacitor voltage decay rate so that the voltage of the charged capacitor will not fall below the reference voltage during one pulse cycle but will fall below the reference voltage in a time interval not greatly exceeding one pulse cycle.

The invention is further illustrated by the embodiments which are hereinafter particularly described by way of example with reference to the accompanying drawings wherein

Fig.1 shows diagrammatically a circuit diagram including an apparatus assembly of the invention in conjunction with an explosive charge for generating seismic waves; and

Fig.2 is a schematic diagram of a current sensing device for the circuit of Fig.1.

In Fig.1 an electric detonator casing 1 is located in a pocket 2 in a cylindrical explosive charge 3. The resistive bridgewire 4 is electrically connected at its terminals to the ends of a continuous leading wire 5 which is insulated with a coating of polyvinylchloride

and has an intermediate portion wound as a secondary winding around a toroidal transformer core 6. The bridgewire 4 is embedded in matchhead composition 7 as in a conventional electric fusehead assembly. The
5 detonator contains a primary charge 8 and base charge 9.

An electric generator 10 is connected in series with an electric sensing device 11 by a circuit of insulated conductor wire 12 which is looped into
10 transformer core 6 as a primary winding, the portion of the circuit forming the primary winding being sufficiently close to the explosive charge 3 to be broken when the charge explodes. The transformer core 6 is located in a hollow space formed in a protective plastics cap 13 on top of the explosive charge.

15 The sensing device 11 is connected to a seismic recorder 14 to mark the time-break on, for example, magnetic tape or photographic paper when the circuit through conductor wire 12 is broken.

In operation, a high frequency current (for example
20 15 KHz) is generated by generator 10 which is sufficiently strong and at the correct frequency determined by the transformer core characteristics to induce a current in the secondary winding on the core and ignite the matchhead composition 7, which in turn ignites the explosive charge 3
25 in the conventional manner.

The current continues to flow in the conductor wire 12 after the ignition of the composition 7 and breaking of the detonator circuit and only ceases when the circuit 12 is broken by the explosion of the charge 3. When the current
30 in the conductor wire 12 ceases a signal is passed from sensing device 11 to the recorder 14 and the time-break is marked on the record. The subsequent signals from geophones in response to the reflected or refracted seismic waves are subsequently recorded on the seismic record in the
35 usual manner.

The current sensing device 11 shown in Fig.2 is appropriate for sensing a high frequency current in the conductor wire 12. The device comprises a toroidal

transformer core 15 through which a single turn of the conductor wire 12 is looped as a primary winding. A secondary winding 16 on the toroidal core 15 is connected to a rectifier circuit comprising a rectifier diode 17, a current limiting resistor 18 and a voltage controlling zener diode 19. The rectifier circuit is connected to charge a capacitor 20, which has a discharge resistor 21 connected therewith to control the rate of decay of the capacitor discharge. The capacitor voltage is fed to a voltage comparator 22, suitably a high gain amplifying switching circuit, which is connected to a monostable multivibrator pulse generator 23. The output from the pulse generator 23 is connected to the recorder 14. A reference voltage is also fed to the comparator 22.

While current flows in conductor wire 12 capacitor 20 is recharged by each current cycle to a voltage exceeding the reference voltage. The capacitor 20 and resistor 21 are chosen to give a discharge time constant of the capacitor 20 ($R \times C$) such that the capacitor voltage does not fall below the comparator reference level during one current cycle time, but will fall below the level within a time interval not greatly exceeding the time of one cycle. Thus when the current in conductor wire 12 ceases the voltage of capacitor 20 quickly falls below the reference voltage in comparator 22. In this condition the comparator provides an output which triggers the pulse generator 23 and a pulse is fed to the seismic recorder 14 to mark the time-break on the seismic record.



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Claims:

1. A method of seismic recording wherein seismic waves are generated by firing an explosive charge by means of a detonator having an electrical ignition element and are subsequently recorded after reflection or refraction at subterrean rock layer interfaces, the said method comprising the steps of:-
 - feeding firing energy from an A.C. energy source to said electric ignition element through a transformer which has a primary circuit connected to said A.C. source and a secondary circuit connected to said electric ignition element, said primary circuit having a breakable portion adapted and disposed so as to be ruptured by the explosion of said explosive charge;
 - detecting the time when the said breakable circuit portion is broken; and, in response thereto, making a mark on the seismic record to indicate a time-break on the record.
2. A method as claimed in Claim 1 wherein the break in the breakable circuit portion is detected by the cessation of current or a rapid rise in voltage across the breakable circuit portion.
3. A method as claimed in Claim 2 wherein the said breakable electrical circuit portion is included in a primary circuit of a transformer which also has a secondary circuit, A.C. energy is fed through the said breakable electrical circuit portion during the explosion of the charge, and the break in said breakable circuit portion is detected by detecting the cessation of current in said secondary circuit.
4. A method as claimed in any one of Claims 1 to 3 inclusive wherein the said igniter element is electromagnetically coupled to the A.C. source by threading leading wires from the ignition element and the A.C. source through a toroidal transformer core.
5. A method of seismic recording substantially as described herein with reference to the accompanying drawings.

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6. An apparatus assembly for indicating a time-break on a record of a seismic signal generated by firing an explosive charge by means of a detonator having an electrical ignition element, said assembly comprising:-

5 a transformer having a primary circuit for connection to an A.C. energy source and a secondary circuit for connection to said electric ignition element, said primary circuit having a breakable portion adapted to be ruptured by the explosion of said explosive charge;
10 and electrical sensing means adapted to generate a signal to mark a time-break on the said record in response to the rupture of said breakable circuit portion.

7. An assembly as claimed in Claim 6 wherein the transformer has a ring core through which conductor wires
15 from an A.C. source and the ignition element are looped to provide primary and secondary transformer circuits.

8. An assembly as claimed in Claim 6 or Claim 7 wherein the electrical sensing means comprises a current responsive device connected in series with the breakable
20 electrical circuit portion, which device, on cessation of the current in the said breakable circuit portion generates a signal to mark a time-break on the seismic record.

9. An assembly as claimed in Claim 6 or Claim 7 wherein the electrical sensing means comprises a voltage responsive device shunt connected across the breakable
25 electrical circuit portion, which device in response to the increased voltage consequent on the circuit break generates a signal to mark the time-break.

10. An assembly as claimed in any one of Claims 6 to 8
30 inclusive wherein the electrical sensing means comprises a transformer having a primary circuit connected to the said breakable circuit portion and a pulse detector connected to a secondary circuit of said transformer, said pulse detector being adapted to detect the presence and cessation
35 of pulses induced in the secondary circuit when energy is passed through said breakable circuit portion from an A.C. source during the explosion of the explosive charge.



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11. An assembly as claimed in Claim 10 wherein the pulse detector comprises a resistor-capacitor circuit connected via a rectifier to the said secondary circuit whereby the capacitor is charged by induced pulses in the secondary circuit, a voltage comparator to compare the capacitor voltage with a reference voltage and means responsive to the voltage comparator output to mark the time-break on the seismic record when the capacitor voltage falls below the reference voltage.
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- 10 12. An apparatus assembly for indicating a time-break on a record of a seismic signal generated by an explosive charge substantially as described herein and shown in the accompanying drawings.
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