United States Patent

Morris

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[54] **SEISMIC IMPULSE GENERATION TECHNIQUE**

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[52] **U.S. Cl.**.....**181/.5 XC,** 340/15.5 TI
[51] **Int. Cl.**.....**G01v 1/08,** G01v 1/12
[58] **Field of Search**.....181/.5 XC, .5 EC, .5 R; 340/15.5 BI, 15.5 TI, 17

[56] **References Cited**

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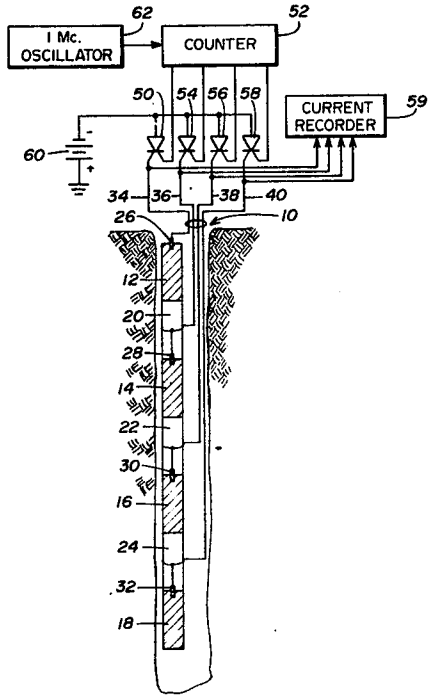
[57] **ABSTRACT**

The specification discloses a technique for generating seismic impulses which includes suspending a plurality of discrete explosive charges one above the other. Detonation wires lead to detonation caps attached to each of the explosive charges. Circuitry generates a plurality of firing pulses which are applied to the detonation wires to sequentially explode the charges from top to bottom. All of the charges are detonated within a time interval less than the time required for the blast from the top charge to destroy the detonation wire leading to the bottom charge. The charges are sequentially detonated at time intervals substantially corresponding to the time of travel of an acoustic pulse through the formations between the adjacent charges.

6 Claims, 3 Drawing Figures



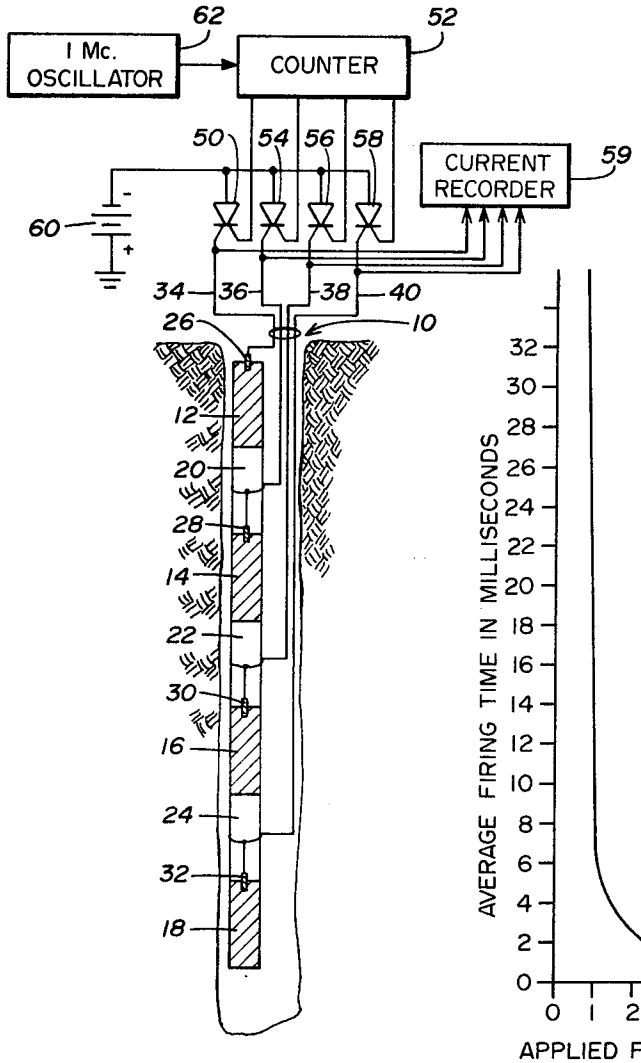


FIG. 1

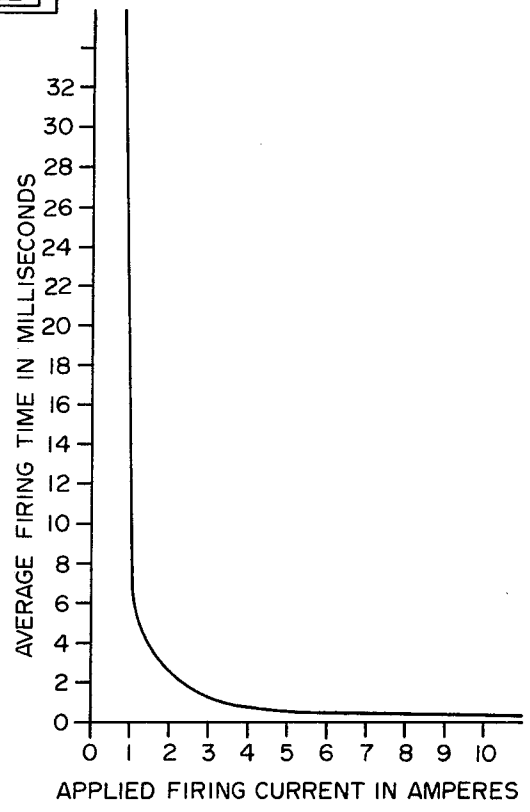


FIG. 2

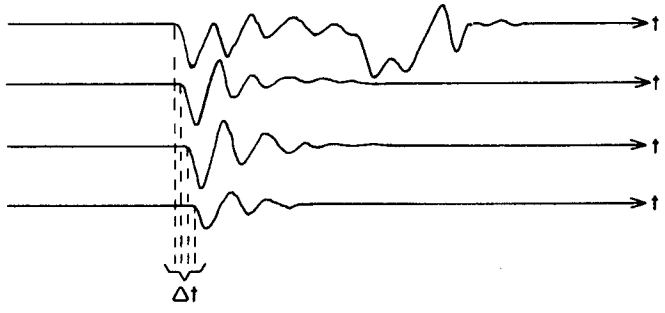


FIG. 3

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SEISMIC IMPULSE GENERATION TECHNIQUE

FIELD OF THE INVENTION

This invention relates to seismic exploration and more particularly to a method and apparatus for generating seismic impulses for use in seismic exploration.

THE PRIOR ART

It has long been known to detonate vertically oriented explosive charges disposed within a borehole or in a body of water in order o generate seismic impulses for use in seismic exploration. A variety of techniques have been utilized for detonation of such explosive charges, such as the use of phase blasters and other devices which serially detonate the charges in response to an initial detonation. Such systems have not been completely satisfactory in providing the desired depth penetration for the generated acoustic waves, and the prior systems have often been relatively expensive due to the cost of the phase blasters and other triggering devices. Heretofore, it has generally not been considered practical to provide separate detonation wires for each explosive charge in a vertical blast, as the blast from the upper charge ruptures the detonation lines running to the lower charges.

SUMMARY OF THE INVENTION

In accordance with he present invention, a seismic impulse detonating technique is provided which enables separate detonation wires to be connected to each of a plurality of vertically spaced discrete explosive charges, thereby eliminating expensive and complex detonation devices such as phase blasters and the like.

In accordance with a more specific aspect of the invention, a plurality of discrete explosive charges are spaced one above the other. The charges are sequentially detonated from the top to bottom within a time interval less than the time for the blast form the top charge to destroy the detonation line leading to the bottom charge, with the charges sequentially fired at time intervals substantially corresponding to he time of travel of an acoustic pulse through the formations between adjacent charges.

In accordance with yet another aspect of the invention, a plurality of discrete explosive charges are suspended one above the other within a borehole or the like. A plurality of electrical pulses are applied to detonation wires leading to detonation caps attached to each of the charges. The electrical pulses are spaced within a time interval less than the time required for the resulting explosion from the upper charge to destroy the detonation wire leading to the lower charge.

THE DRAWINGS

For a more complete understanding of the present invention and for further objects and advantages thereof, reference is now made to the following description taken in conjunction with the accompanying drawings, in which:

FIG. **1** is a somewhat diagrammatic illustration of the preferred embodiment of the present invention;

FIG. **2** is a graph illustrating the firing time versus firing current for typical explosive charges utilized with the present invention; and

FIG. **3** illustrates currents passed through the detonation wires shown in FIG. **1**.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. **1**, a borehole **10** is diagrammatically illustrated. A plurality of explosive charges **12**, **14**, **16** and **18** are suspended one above the other within the borehole **10**. Spacer members **20**, **22** and **24** are disposed between adjacent charges to maintain the charges in a close predetermined spaced apart relationship. In practice suitable explosive charges for use with the invention may comprise cylindrical metal cans containing a suitable explosive and having diameters of 2 inches and lengths of 6 inches. Such explosive cans are presently manufactured and sold by a number of companies on the open market. Empty ones of the explosive cans may be attached between adjacent explosive charges to serve as the spacers **20**, **22** and **24**. Such explosive charge cans contain threaded connections at the ends thereof to enable the assembly of a generally rigid explosive unit which may be suspended within the borehole **10**. The charges **12**, **14**, **16** and **18** are thus spaced apart by a matter of inches, a much closer spaced configuration than prior art charges used for seismic exploration.

Detonation caps **26**, **28**, **30** and **32** are connected to each of the explosive charges in a conventional manner. A detonation wire **34** extends from the surface down the borehole for connection with the detonation cap **26**. While only one detonation wire is shown connected to each of the explosive charges for ease of illustration, it will be understood that in actual use of the invention a pair of insulated wires will be utilized for each explosive charge in the conventional manner. A detonation wire **36** extends from the surface down the borehole, wherein it is looped around the spacer **20** and then connected to the detonation cap **28** in the conventional manner. A detonation wire **38** extends form the surface down the borehole, wherein it is wrapped around the spacer **22** and is connected to the detonation cap **30**. Likewise, a detonation wire **40** extends form the surface down the borehole, where it is wrapped around spacer **24** and is connected to detonation cap **32**.

The cathode of a silicon controlled rectifier **50** is connected to the detonation wire **34**, with the gate electrode of the rectifier **50** being connected to the output of a digital counter **52**. The cathode of a silicon controlled rectifier **54** is connected to the detonation wire **36**, while the gate electrode of rectifier **54** is connected to a second output of the counter **52**. The cathode of a silicon controlled rectifier **56** is connected to the detonation wire **38**, with the gate electrode thereof being connected to a third output of the counter **52**. The cathode of a silicon controlled rectifier **58** is connected to the detonation wire **40**, with the gate electrode being coupled to an output of the counter **52**. A battery **60** or other suitable source of voltage potential is directly connected to the anodes of each of the silicon control rectifiers **50**, **54**, **56** and **58**. A 1 megacycle oscillator **62** supplies timing pulses to the counter **52**. A recorder **59**, which may comprise for instance a galvanometer, is coupled to each of the detonation wires **34–40** in order to record variations in the current

passing therethrough. While recorder **59**, is shown as being directly connected to the detonation wires, in practice each input of the recorder will be inductively coupled across a very small resistance in series with each detonation wire.

An extremely important aspect of the present invention is that all of the detonation current pulses applied to the detonation caps are essentially equal in magnitude. Thus, each detonation wire leading to a detonation cap is required to have essentially the same resistance as the remaining wires.

In operation of the embodiments shown in FIG. **1**, when it is desired to initiate seismic impulses, the oscillator **62** is energized to feed a **1** megacycle pulse train to the counter **52**. Counter **52** is of conventional design, and sequentially generates a series of electrical signals, each of which is applied to the gate electrode of one of the rectifiers **50**, **54**, **56** and **58**. Rectifier **50** receives the first trigger pulse form counter **52**, and is thus fired to direct a relatively high level of current through he detonation wire **34** to the detonation cap **26** to thereby detonate the explosive charge **12**. Subsequently, an electrical signal is applied to the gate of the rectifier **54**, firing the rectifier and causing a relatively high current to be applied to the detonation cap **28** to explode the explosive charge **14**. Likewise, the counter **52** subsequently fires rectifiers **56** and **58** to sequentially explode explosive charges **16** and **18**. The resulting explosions from the charges creates acoustic waves which travel through the formation adjacent the charges to provide useful seismic energy for seismic exploration.

Upon explosion of the upper charge **12**, each of the detonation wires **34**, **36**, **38** and **40** will be broken by the resulting explosion. An important aspect of the invention is the fact that the electrical signals generated by the counter **52** are spaced apart within a time interval less than required for the explosion from the upper charge **12** to destroy the detonation wire **40** leading to the lower charge **18**.

Additionally, another important aspect of the invention is that the time intervals between each of the individual trigger pulses generated by the counter **52**, and thus the time intervals between the successive detonation of each of the explosive charges, substantially correspond to the time of travel of an acoustic pulse through the borehole formations between adjacent explosive charges. Thus, the time interval between the detonation of explosive charge **12** and explosive charge **14** will substantially correspond to the time of travel of an acoustic pulse through the formation adjacent the charges **12** and **14**. Firing of the charges in this manner tends to reinforce the generated seismic waves, thereby providing enhance seismic exploration results. As an example, for a formation velocity of 4,000 feet per second, the time interval between the detonation of explosive charges **12** and **14** according to the invention will be about 250 microseconds. Similarly, for a formation velocity of 10,000 feet per second, the time interval between detonation of explosive charges **12** and **14** will be set at about 100 microseconds. It is to be understood that the counter **52** is of conventional design and includes circuitry to enable accurate setting and calibration of the time intervals between the pulses which are applied to the silicon controlled rectifiers **50**, **54**, **56** and **58**.

Extremely fast sequential firing of the explosive charges of the invention is possible because of use with a seismic exploration system responsive to relatively high frequency seismic waves. For example, the present seismic wave generation technique is particularly useful with the high frequency responsive system disclosed in applicant's U.S. Pat. No. 3,489,997, issued Jan. 13, 1970.

Another important aspect of the present invention is that relatively high firing current should be applied to the explosive charges of the invention in order to obtain the extremely fast detonation of the charges required. FIG. **2** illustrates a graph of the average firing time of a typical seismic explosive used with the invention, versus the applied firing current in amperes. With the use of the invention, it is important to apply at least in the range of about five amperes firing current in order to obtain the fast firing times necessitated by the invention. It should be understood that a plurality of conventional seismic explosive primers, caps and boosters may be used according to the present invention.

FIGS. *3a–d* illustrates a typical recording made by recorder **59** of the currents appearing on the detonation wires **34**, **36**, **38** and **40** during the detonation of the system shown in FIG. **1**. Each record trace shown in FIG. **3** represents the current applied to a respective detonation wire, with the upper trace shown in FIG. **3** representing the current applied to wire **34**. The peak of the initial negative excursion of each trace represents the instant of detonation of the respective detonation cap. The initiation of each of the current pulses shown in FIG. **3** are spaced apart by a total time interval Δt which is less than the time required for the blast from the upper charge to destroy any of the detonation wires **34–40**. Similarly, the time interval between the generation of adjacent current pulses is essentially equal to the time of travel of an acoustic pulse through the particular formation between the adjacent charges. This causes the resulting generated acoustic pulses to provide excellent formation depth penetration. The record provided by recorder **59** provides an indication that the system is working properly, as well as useful time break information.

While the present invention has been particularly described with respect to use in land based seismic exploration, it will be understood that the present invention has also utility for marine seismic exploration. Additionally, it will be understood that various shapes and sizes of explosive charges may be utilized with the present technique in addition to the specifically described charges.

Whereas the present invention has been described with respect to specific embodiments thereof, it will be suggested to one skilled in the art, and it is intended to encompass such changes and modifications as fall within the scope of the appended claims.

What is claimed is:

1. The method of generating seismic impulses which comprises spacing a plurality of discrete explosive charges one above the other, and sequentially applying electrical pulses to detonation lines leading to said charges to detonate said charges from top to bottom within a time interval less than the time required for the blast from the top charge to destroy the detonation lines leading to the lower charges and at time intervals

substantially corresponding to the time of travel of an acoustic pulse through the formations between adjacent charges.

2. The method of generating seismic impulses comprising:

suspending a plurality of discrete explosive charges one above the other in a close relationship,

generating a plurality of electrical pulses upon detonation wires leading to detonation caps attached to each of said charges, said electrical pulses being spaced within a time interval less than the time required for the resulting explosion from the upper charge to destroy the detonation wire leading to the lower charges.

3. The method of claim 2 wherein the time intervals between said electrical pulses substantially corresponds to the time of travel of an acoustic wave through the formations between adjacent charges.

4. A system for generating seismic impulses comprising:

a plurality of discrete explosive charges suspended one above the other,

detonation wires leading to detonation caps attached to each of said charges,

circuit means for generating a plurality of firing pulses and for sequentially applying said pulses to ones of said detonation wires to sequentially explode said charges beginning with the upper charge, and

said firing pulses being spaced within a time interval less than the time required for the explosion from the upper charge to destroy the detonation wire leading to the lower charges and said firing pulses being spaced apart by time intervals substantially corresponding to the time of travel of acoustic waves through the formations between adjacent charges.

5. The system of claim 4 wherein said circuit means comprises:

counter means for sequentially generating electrical pulses, and

silicon controlled rectifiers operable in response to said electrical pulses for applying relatively high current pulses to said detonation wires.

6. The system of claim 4 wherein said firing pulses are of the same amplitude.

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