

July 29, 1969

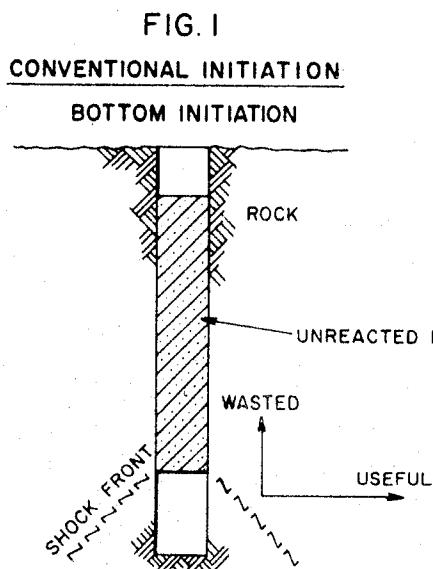
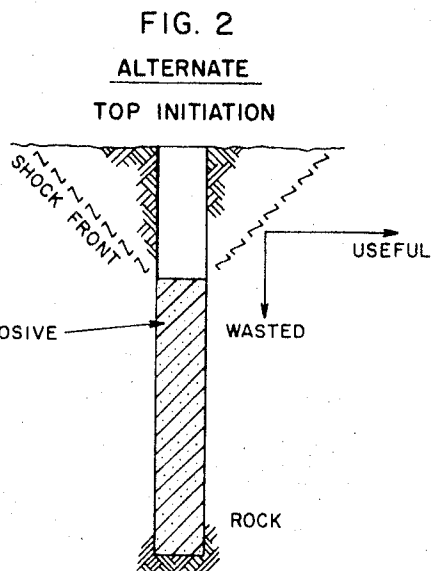
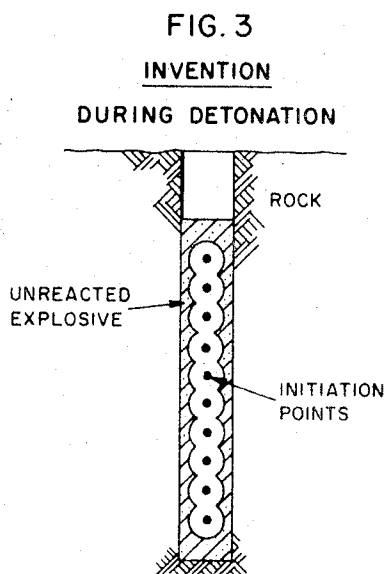
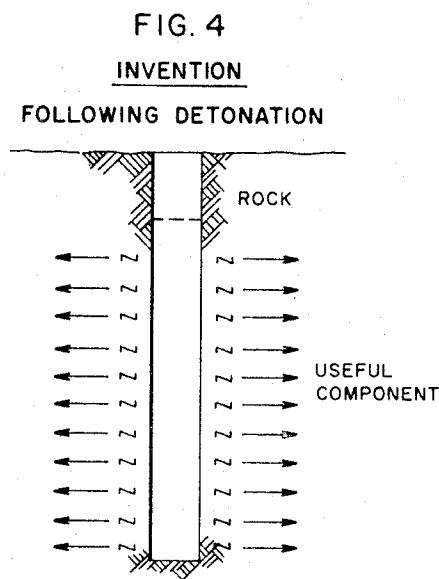
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3,457,859

METHOD AND SYSTEM FOR INITIATING EXPLOSIVE COMPOSITION

Filed Nov. 24, 1967

3 Sheets-Sheet 1



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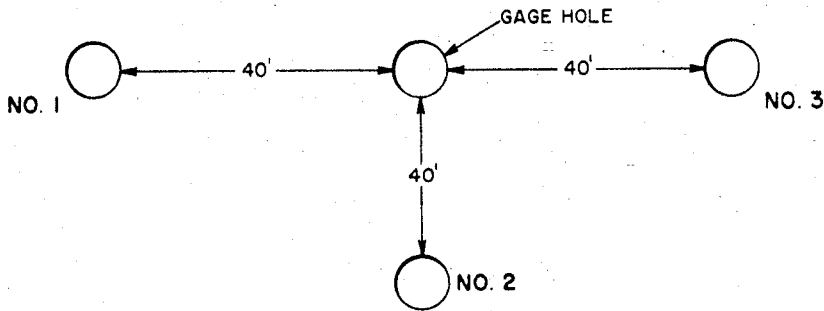
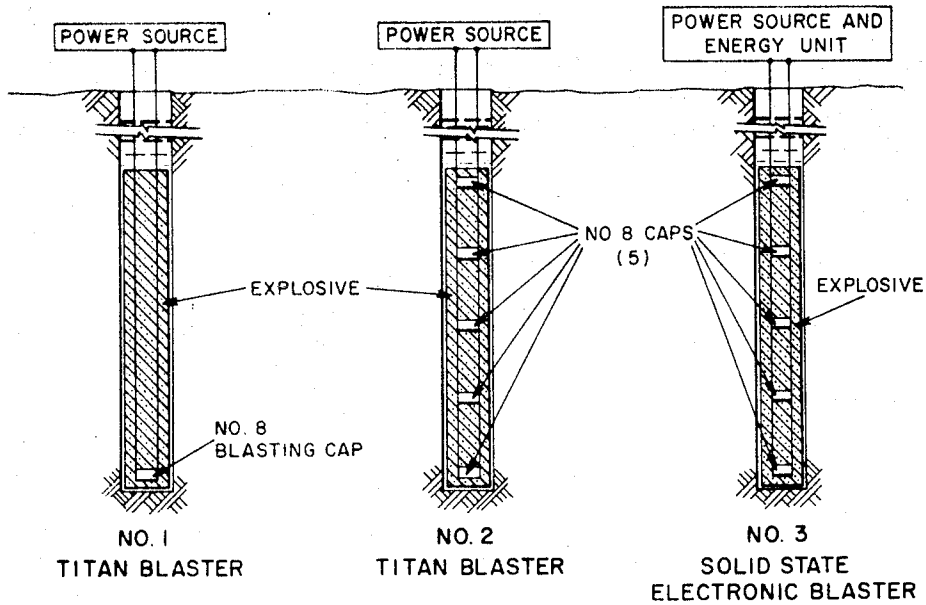
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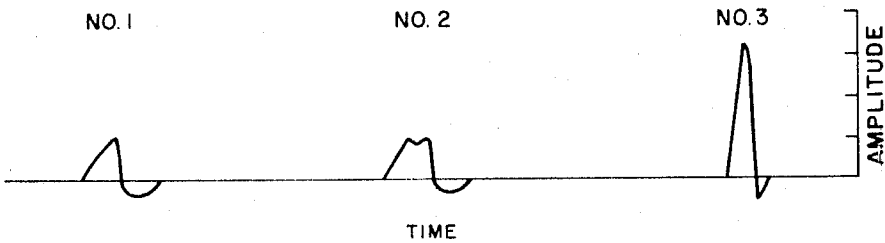
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FIG. 5



RESULTS



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METHOD AND SYSTEM FOR INITIATING EXPLOSIVE COMPOSITION

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3 Sheets-Sheet 3

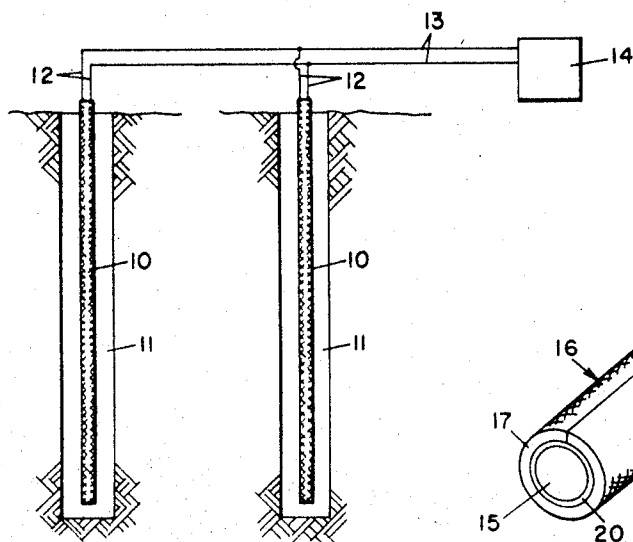


FIG. 6

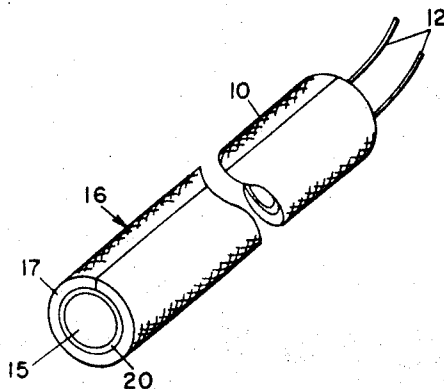


FIG. 7

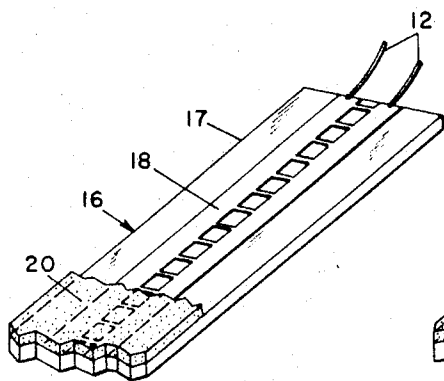


FIG. 8

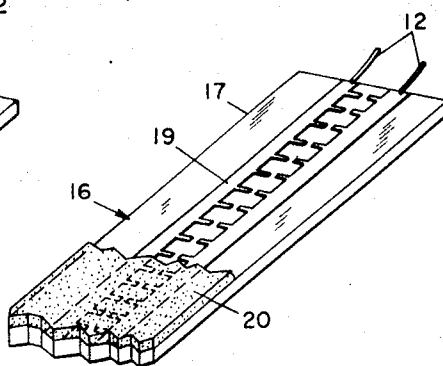


FIG. 9

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3,457,859

METHOD AND SYSTEM FOR INITIATING
EXPLOSIVE COMPOSITION

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ABSTRACT OF THE DISCLOSURE

A method and system for detonating an explosive composition to enhance its explosive characteristics in a borehole by detonating the explosive composition at more than one point along its length within a time interval sufficient to produce more than two co-existing detonation fronts. The detonation fronts co-exist for a substantial portion of the time period during which the explosive is being consumed.

This invention relates to a method and system for initiating and for controlling the detonation process of an explosive charge to enhance its explosive characteristics in a borehole.

Explosives used to fracture or fragment other materials are conventionally placed adjacent to the material that is to be fragmented. In the case of commercial blasting, such as mining, quarrying, and excavation, the customary procedure is to drill holes into the rock mass, fill each hole with an explosive charge and initiate the explosive by means of a detonator which usually is placed at the bottom of the explosive charge. When the explosive is so initiated, it is self-consumed by a detonation front that travels up the borehole at a rate commonly referred to as the detonation rate. It is recognized in the art that more rock is broken, and/or is broken into finer pieces, when the impedance of the explosive matches or approaches that of the rock mass. Impedance of the explosive is defined as the density of the explosive multiplied by its detonation velocity, and the impedance of the rock is defined as the density of the rock multiplied by its sonic velocity. Table I, which follows, lists typical values for these characteristics. It will be noted that the impedance values of many explosives are well below those of the rock types that need to be broken. Nor is the impedance value of the rock necessarily an upper limit for the impedance of the explosive. Heretofore, the art has been limited to explosives whose impedance is far below, or at best, about equal to that of the rock.

TABLE I
TYPICAL VALUES OF CHARACTERISTIC IMPEDANCE

Rock type	Velocity of compressional waves, ft./sec.	Density, lb./ft. ³	Characteristic impedance, lb./in. ² sec./in. ³
Rock:			
Granite.....	18,200	165	54
Sandstone.....	10,600	136	26
Chalk.....	9,100	135	22
Explosive:			
High velocity gelatin			
60% wt. strength.....	20,200	89	32.3
TNT.....	15,000	62	16.7
Permissible dynamite.....	9,200	44	7.3

It has been discovered in accordance with the present invention, that the scope of the accepted impedance equation is too narrow; that it is better written as density of

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the explosive multiplied by the reciprocal of the detonation time, or:

$$\text{Effective Impedance} = d \times \frac{1}{T} \times C$$

where

d=density of the explosive

C=constant specific to a given borehole configuration

T=time required for column of explosive to be consumed.

Thus, for any level of explosive density, the effective impedance increases as a direct function of the rate at which the explosive is consumed. This invention contemplates multiple and substantially instantaneous detonation means for consuming the explosive in a time period far less than that conventionally and heretofore achieved. And thus, effective impedance of an explosive in accordance with the present invention is raised by a factor in the order of two-fold, ten-fold, even one hundred-fold over the values heretofore obtained in conventional blasting.

This invention comprises a method and system for the initiation of an explosive column at several points along the major axis or length of the column and within a sufficiently short time span that several detonation fronts are co-existent. The initiation elements may be conventional blasting caps connected to a common source of electrical energy of a type to be described later. When a substantial number of initiating points are required, it is preferable to use a cord-like material comprising a core of explosive and a protective sheath on which has been printed a pattern of electrical conductors and a pattern of resistive or capacitive elements. Specifically, the present invention is directed to a method and system for detonating an explosive composition to enhance its explosive characteristics in a borehole which comprises, detonating the explosive composition at more than one point along its length within a time interval sufficient to produce more than two co-existing detonation fronts, said fronts being co-existent for a substantial portion of the time period during which the explosive is being consumed.

Simultaneity of activation of the initiation points, to a degree necessary to assure that the several detonation fronts co-exist, is achieved by the rapid discharge of high voltage through the initiation system, or by discharging through the initiation system a very high current flux by method and equipment hereinafter described.

This invention also contemplates near-simultaneous initiation of adjacent blast holes so that shock waves emanating from each hole will meet at or close to the midpoint between the two holes. This is accomplished by using two or more electric initiators in each blast hole, firing them as described previously so that more than two detonation fronts co-exist, and by wiring into the above type firing circuit two or more replicate blast holes and their initiators so that the time span over which all the initiators in all of the holes are activated is not more than about 100 microseconds.

Objects and features of the invention not apparent from the above discussion will become evident upon consideration of FIGS. 1-4, inclusive in respect to the foregoing and FIGS. 5-9 inclusive in respect to detailed additional description taken in connection with the accompanying drawings, wherein:

FIG. 1 is a diagrammatic illustration showing that in conventional bottom initiation of an explosive column a wasteful vertical component of energy is generated, and that the time T required for the explosive column to be consumed is relatively long, and is directly dependent on the length L of the column and the detonation velocity V, the explosive, or $T=L/V$.

FIG. 2 is a diagrammatic illustration showing that in

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alternate top initiation of an explosive column, a wasteful vertical component, likewise, of energy is generated; and that the time T required for the explosive column to be consumed is relatively long, and is directly dependent on the length L of the column and the detonation velocity V , the explosive, or $T=L/V$.

FIG. 3 is a diagrammatic illustration showing that in accordance with the invention and during detonation, the wasteful component of energy is not generated; and that the time T required for the explosive column to be consumed is very short and is directly dependent on the radius r , of the explosive column and the detonation velocity V , the explosive, or $T=r/V$.

FIG. 4 is a diagrammatic illustration showing that in accordance with the invention and following detonation, the wasteful component of energy is not generated;

FIG. 5 is a diagrammatic illustration showing an example of the invention as compared with conventional blasting technique;

FIG. 6 is a schematic illustration of a multiple point initiating cord and electrical circuitry arranged in accordance with the principles of the present invention for providing initiation points, especially when numerous points are desired;

FIG. 7 is an enlarged isometric view of the multiple point initiating cord depicted in FIG. 6.

FIG. 8 is a fragmentary isometric view of a resistive type printed circuit coated with sensitive explosive used in manufacture of the multiple point initiating cord of FIG. 7; and

FIG. 9 is similar to FIG. 8 except that it shows an alternate embodiment of providing a capacitive type printed circuit in lieu of the resistive type.

Example 1

Referring now particularly to FIG. 5, the following example demonstrates the advantages of multiple point initiation as embodied in this invention. Three identical charges of Gelamite No. 1 (semigelatin 60% strength) explosive, 2½ inches in diameter and 16 inches long, were placed at the bottom of 3 inches diameter, 20 feet deep blast holes drilled in rock. Water was poured into each hole to fill all void spaces between the charge and the rock and thereby insure complete coupling. No other stemming was used. At a distance of 40 feet from each of the above holes a 3 inch diameter, 20 feet deep hole was drilled. At the bottom of this hole was placed a piezo-electric gage. The gage was covered with water to insure coupling. Of the three explosive charges, charge No. 1 had been primed with one No. 8 electric blasting cap located at the bottom of the charge. Charge No. 2 was primed with five No. 8 electric blasting caps, located 4 inches apart. Thus, one cap was at the bottom of the charge, one at the top, and 3 spaced equally apart, all on the axis of the charge. Both charges No. 1 and No. 2 were to be initiated by a Titan Blaster, as a power source, which is a high-capacity, commercial blasting machine. Charge No. 3 was primed identical to charge No. 2, but it was to be initiated by a specially-designed, solid-state, electronic blasting machine. This machine operates at the same voltage level as the Titan Blaster, but is designed having a special energy unit so as to discharge the energy in its capacitor in a time period approximately ¼₁₀₀ of that of the commercial blasting machine.

More specifically, the special energy unit comprised a timing circuit, an energy storage capacitor and a switching circuit. This unit has a conventional power supply. Voltage is applied to the storage capacitor until fully charged. The firing command switch causes a silicon controlled rectifier (SCR), which is the heart of the switching circuit, to become conductive, thereby applying the stored energy of the unit across a 500-ohm load and any external devices such as caps placed across the output terminals. The rise time of energy applied to any external load is 0.5 microsecond or less, thereby, reducing the resistance change in the device due to heating.

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This rapid rise time causes a conventional bridge wire to act as an exploding bridge wire and to detonate substantially instantaneously.

The three explosive charges were then initiated as previously described, and the results of the shock wave curve created by each was recorded and depicted as curves in FIG. 5. Charge No. 1 generated the expectable curve. Charge No. 2 generated a low amplitude curve, suggesting that more than one cap managed to detonate within the allowable time period, but in doing so, generated interference waves that negated the value of firing more than one cap by a conventional blasting machine. Charge No. 3 created in the rock, 40 feet distant, a shock wave whose rise time was shortened by a factor of four, and whose amplitude was approximately three times the size, compared to charges No. 1 and No. 2. It is apparent, therefore, that the effective impedance of the explosive was substantially increased by causing it to be consumed more rapidly than heretofore. Since the total energy in the recorded shock wave from charge No. 3 was greater than that from charge No. 1 or No. 2, it follows that the wasted components depicted in FIG. 1 have been minimized.

Example 2

In another example, three holes, each 3 inches in diameter by 40 feet deep were drilled in granite, on a straight line, and on 7 feet spacings. The powder charge in each hole consisted of 7 sticks, each 2 inches in diameter by 16 inches long of 40% extra dynamite, on top of which was added sufficient AN/FO (ammonium nitrate/fuel oil) to fill the hole to within 5 feet of the collar. Five standard No. 8 electric blasting caps were spaced equidistant along the vertical axis of the explosive column. The five caps in a hole were connected in parallel to a special blasting machine. This machine comprised a capacitance and an electronic blasting switch as previously described. A mechanical switching arrangement triggered the discharge to the five caps in hole No. 1 of the high current flux required to assure that they would detonate within a time span of 20 microseconds. The mechanical switch, after a time delay of 10 milliseconds, similarly discharged electronic blasting switches that fired simultaneously the five caps in hole No. 2 and the five caps in hole No. 3. All ten caps fired within a time interval of 20 microseconds. The resultant co-existent detonation fronts in each borehole increased the effective impedance five-fold over conventional blasting and minimized or substantially eliminated the wasteful vertical components of the shock wave emanating from each hole. Also, the simultaneity of detonation of hole No. 2 and No. 3 insured that the shock and pressure waves emanating from these two holes would meet and interact halfway between holes No. 2 and No. 3. The effects noted were that: (1) ground shock to observers was significantly less than for identically loaded holes initiated by conventional methods, and (2) average size of the rock fragments was 8 inches in diameter compared to 10 to 12 inches in diameter from conventional shots in the same rock.

Example 3

In still another example, conditions were identical to the test described above, except that the scheduled delay between hole No. 1 and holes No. 2 and No. 3 was 30 milliseconds. The blast sound and the degree of fragmentation, was identical to that of the previous example. This is understandable, since the delay of 10 milliseconds and 30 milliseconds were each so long as to be completely outside the area of this invention, yet these delays of 10 to 30 milliseconds are typical of current practice. Holes No. 2 and No. 3, however, were fired within 20 microseconds of one another, and this technique yielded the improved and similar effects noted for Example 2.

Example 4

In still another example, twenty-two holes, each 3 inches in diameter by 42 to 45 feet deep, were spaced 7 feet apart. The pattern of holes was a conventional diamond shape, with 6 holes in Row No. 1, 5 holes in Row No. 2, 6 in Row No. 3, and 5 in Row No. 4. Each was loaded with explosives and primed with electric blasting caps plus one quarter pound of high explosive boosters and initiated as described in Example 2. The mechanical timing device was adjusted to discharge a certain number of holes substantially simultaneously (within 20 microseconds), and to delay 10 milliseconds before firing another group of holes within a time span of 20 microseconds. The results, shock level and rock fragmentation, was essentially the same as for the previous two examples.

With reference to the examples, it is evident that there are several factors which will influence conditions for the most satisfactory operation of the invention. For example, this invention comprises a system whereby a column of explosive is caused to detonate in such a manner that (a) wasteful energy components normal to the major axis of the explosive charge are substantially eliminated, and (b) the effective impedance value of the explosive is increased several-fold. These improvements are accomplished by placing within or along side the explosive column two or more initiators which all detonate within a sufficiently short time span so that more than two detonation fronts co-exist.

The time required to detonate an explosive column is exceedingly brief. In quarrying and mining, explosive columns seldom exceed 50 feet in length. Detonation rates of commercial explosives range from 10,000 to 20,000 feet/second, with very few less than 10,000 feet/second. Thus, 50 feet columns are consumed in from 5 to 2½ milliseconds. Some quarries, however, use explosive columns 100 feet long, and these are consumed within 10 to 15 milliseconds.

Features of the present invention singly and in combination which distinguish over prior art practices, therefore, reside in the following: (1) the use of several initiation points throughout the length of the explosive column; (2) the use of a suitable means, such as an electronic switch, to insure that all initiation points within the explosive column are actuated within an exceedingly short time interval of about 20 microseconds and not more than about 40 microseconds to insure that more than two detonation fronts co-exist; and (3) the combination of the first two elements when a series of holes are fired, to insure that the shock and pressure waves from one hole intersect those from an adjacent hole approximately equidistant between the two holes. It will be appreciated that in a multiplicity of blast holes, a delay period between groups of holes is desirable both to reduce vibrations to surrounding structures and to permit some acceleration of the rock mass broken by the first group of holes prior to initiation of the second group of holes.

An important requirement for carrying the concept of this invention into effect lies not only in spacing the initiation points at the spacing required to yield the required Effective Impedance, hence the required rock breakage and degree of fragmentation, but also in obtaining, as near as possible, simultaneity of explosive output from the initiation points. Means to assure this, when desired or required, are set forth as follows.

By way of understanding the contributions of the following means, some discussion is required as to why commercial blasting caps do not all function simultaneously. The cap has two principal elements: a bridge wire that is heated to incandescence by an electrical current, and a train of explosive ingredients that first ignite, then detonate, when the bridge wire is heated. The bridge wire is a high-grade, commercial wire which varies slightly,

but relative to the concept of this invention, varies quite significantly, in composition and in cross-section. During assembly of the cap, practical considerations again cause the length of wire bridge to vary slightly but significantly. Thus, when a constant voltage is applied to caps, even in parallel, each bridge wire heats up at a slightly different rate. In like manner, the composition, density, and quantity of explosives within the cap vary from cap to cap, so the time from bridge wire heating to explosion of the cap varies from cap to cap. These random characteristics are well known in the art and their control at best still poses problems to the art. This will be readily realized with reference to Table II which follows.

TABLE II.—TYPICAL FUNCTIONING TIME OF CONVENTIONAL NO. 8 E.B. CAPS

Recommended current level, amps.....	2	1 10
Average delay, milliseconds.....	2.42	0.36
Standard deviation, milliseconds.....	0.28	0.09
3-sigma limits, milliseconds.....	1.58-3.26	0.09-0.63
3-sigma spread in functioning time, microseconds.....	1,680	540
1-sigma spread, microseconds.....	560	180

¹ Maximum.

One means to reduce these random variations is to impress on the circuitry of several parallel initiation points, such as the above-described caps, a voltage-current surge of such magnitude as to cause the bridge wires to heat at a spectacular rate and, literally, to explode. Exploding bridge wires are well developed for military devices, and it has been demonstrated that the exploding wire emits a substantial shock wave capable of initiating secondary explosives. Charge No. 3 of Example 1 utilized this technique. In utilizing this technique, it will be appreciated that the voltage level, current level, and therefore the energy discharged to the caps was not substantially different in either instance; however, the time period was far shorter. Hence, the energy density was vastly increased, and the caps fired, for the reasons cited above, within a time span of 20 microseconds as compared to a typical time of 180 microseconds to as much as 540 microseconds when the standard blasting machine was used, even when the maximum recommended current was applied.

Another means to reduce these variations is by using a printed circuit so that all "bridge wires" would be essentially identical, and printing on this circuit for more initiation points than are needed. It is recognized that no improvement in Effective Impedance results when initiation points are closer together than the diameter of the blast hole. Since blast holes smaller than 1½ inches in diameter are not of significant interest as far as this invention is concerned, a printed circuit having "bridge wires" ¼ inch apart would provide six initiation points for every one point actually needed, so the probability of one of the six exploding when required would be increased 6400%. This system could then be initiated by a conventional blasting machine with improved results or by the use of a capacitive type blaster having an electronic switch as described above.

Whereas substantial improvement of the performance of explosives has been demonstrated as described in the examples by means of using a multiplicity of blasting caps, other means are contemplated within the purview of this invention by using instead the printed circuit referred to above and hereinafter described with specific reference to FIGS. 6, 7, 8 and 9.

A multiple point initiating cord 10, is disposed in each of a plurality of boreholes 11. The cord 10 has leg wires 12 extending therefrom which in turn are connected to electrical lines 13 which in turn are connected to a blasting machine 14. The boreholes 11 are filled to a suitable height with explosive (not shown). The cord 10 has a central core 15 of secondary explosive such as PETN overlaid by a multiple point initiating layer 16. The layer 16 comprises a dielectric film 17 such as ethyl cellulose

having printed thereon a resistive circuit 18 or alternatively, a capacitive circuit 19. These circuits are printed with conductive ink such as silver ink. A deposition of priming composition 20 such as lead beta resorcinate or diazo is placed over the printed circuit 18 or 19 whichever type circuitry is desired. The layer 16 may be applied over the PETN as a strip, a butt overlay, as depicted, convolute or spiral winding. Similarly, a protective covering (not shown) which may be of metal for shielding or other non-metallic material may be applied, using butt, convolute or spiral windings. The cross section of the assembly may be any configuration, but preferably is circular and preferably not more than about one half inch in diameter. Thus, there is provided a flexible initiating cord which, when inserted along the axis of an explosive column, and connected electrically to a suitable electric blasting machine, provides a simple, rugged means for initiating the explosive column at many points along its axis.

With reference to the foregoing, it will be appreciated that the present invention is not limited to a particular type of blasting machine and detonator, but is directed to the concept of initiating an entire charge or column of explosive simultaneously or at many points in a charge or column of explosive which approaches simultaneity. In a single point or end initiated charge, the explosive is consumed in a time period equal to L/V , where L =length, of charge and V =velocity of detonation of the explosive. By the unique method of this invention of initiating the column simultaneously at several points, the explosive can be consumed in successively shorter time periods as more initiating points are used; the limiting time being that arrangement where spacing between initiating points is one charge diameter. Under these conditions the explosive is consumed in a time period equal to r/V , where r is the radius of the explosive charge and V is the velocity of detonation of the explosive. Since r is accepted as $1/40$ to $1/200$ of L , this indicates the explosive in an infinite point initiated charge is consumed in $1/40$ to $1/200$ of the time required for an end or single point initiated charge.

If the validity of the impedance equation $V_{EDR}=V_R d_R$ is accepted where E =explosives and R =rock, then increasing the apparent or effective detonation velocity by any factor up to about 40 to 200 times the maximum values previously attainable provides firm basis for obtaining greater blasting efficiencies. It is the advantages of this concept of initiation which the foregoing specification has demonstrated.

While it has been stated and demonstrated according to this invention that simultaneous initiation of an explosive charge along its principal axis decreases or substantially eliminates wasteful vertical components of energy and simultaneously increases the effective impedance of the explosive, it is not restrictive to this invention that the initiation points be located centrally in the explosive column. The initiating points may be located along one side of the charge with desired beneficial effects. For example, the asymmetrical release of energy is useful for such applications as pre-splitting where predetermined directional thrust is desired. Moreover, the invention may be practiced in conjunction with any of the conventional compositions used in blasting, such as, dynamites, NCN blasting agents, aqueous slurry type blasting agents and explosives and may be practiced using delay techniques for reducing ground shock as heretofore set forth. In the latter instance, the conventional sequential delay periods for firing sets of holes are utilized, the important feature being that the initiating points within each hole of a set fire substantially instantaneously or within about 40 microseconds and that each set of holes be completely fired in not more than about 100 microseconds. Under these conditions, the benefits of the invention in approaching simultaneity are most fully realized.

I claim:

1. A system for detonating an explosive composition

to enhance its explosive characteristics in a borehole, said system having in combination:

- (a) initiating points longitudinally disposed within the explosive composition,
- (b) electrical circuit means connected to and adapted to detonate the initiating points,
- (c) control means for actuating the electrical circuit means to energize the initiating points and to detonate same substantially instantaneously or within 40 microseconds, and
- (d) said initiating points throughout the length of the explosive composition being sufficiently closely spaced so that the normal detonation rate of the explosive composition is not relied upon for consumption rate of said explosive composition throughout its length in the borehole.

2. A system for detonating an explosive composition to enhance its explosive characteristics in a borehole, said system having in combination:

- (a) initiating points longitudinally disposed within the explosive composition, said initiating points comprising a plurality of electric blasting caps substantially equally spaced from each other,
- (b) electrical energy storage circuit means connected to and adapted to detonate the initiating points,
- (c) electrical means for energizing the energy storage circuit means,
- (d) control means for actuating the energy storage circuit means to energize the initiating points and to detonate same completely at a time interval of not more than about 40 microseconds, and
- (e) said initiating points throughout the length of the explosive composition being sufficiently closely spaced so that the normal detonation rate of the explosive composition is not relied upon for consumption rate of said explosive composition throughout its length in the borehole.

3. A system for detonating an explosive composition to enhance its explosive characteristics in a borehole, said system having in combination:

- (a) initiating points longitudinally disposed within the explosive composition, said initiating points comprising a plurality of electric blasting caps and boosters therefore substantially equally spaced from each other,
- (b) electrical energy storage circuit means connected to and adapted to detonate the initiating points,
- (c) electrical means for energizing the energy storage circuit means,
- (d) control means for actuating the energy storage circuit means to energize the initiating points and to detonate same completely at a time interval of not more than about 40 microseconds, and

said initiating points throughout the length of the explosive composition being sufficiently closely spaced so that the normal detonation rate of the explosive composition is not relied upon for consumption rate of said explosive composition throughout its length in the borehole.

4. A system for detonating an explosive composition to enhance its explosive characteristics in a borehole, said system having in combination:

- (a) initiating means longitudinally disposed within the explosive composition, said initiating means comprising a multiple initiating point electrical initiating cord of high explosive adapted for substantially instantaneous detonation,
- (b) electrical circuit means connected to and adapted to detonate the initiating means,
- (c) control means for actuating the electrical circuit means to energize the initiating means and to detonate same substantially instantaneously or within about 40 microseconds, and
- (d) said initiating points throughout the length of the explosive composition being sufficiently closely spaced so that the normal detonation rate of the

explosive composition is not relied upon for consumption rate of said explosive composition throughout its length in the borehole.

5. A system for detonating an explosive composition to enhance its explosive characteristics in a borehole, said system having in combination:

- (a) initiating means longitudinally disposed within the explosive composition, said initiating means comprising a longitudinally arranged initiator having a multiplicity of electrical initiating points in contact with a layer of high explosive,
- (b) electrical circuit means connected to and adapted to detonate the initiating means,
- (c) control means for actuating the electrical circuit means to energize the initiating means and to detonate same substantially instantaneously or within about 40 microseconds, and
- (d) said initiating points throughout the length of the explosive composition being sufficiently closely spaced so that the normal detonation rate of the explosive composition is not relied upon for consumption rate of said explosive composition throughout its length in the borehole.

6. A system for enhancing the explosive characteristics of an explosive composition in multiple borehole blasting, said system having in combination:

- (a) initiating points longitudinally disposed within the explosive composition in each borehole of a set of boreholes,
- (b) electrical circuit means for the set of boreholes connected to and adapted to detonate the initiating points in each borehole,
- (c) control means for actuating the electrical circuit means for the set of boreholes to energize the initiating points disposed in each borehole and to detonate same substantially instantaneously or within about 40 microseconds, and
- (d) said initiating points throughout the length of the explosive composition being sufficiently closely spaced so that the normal detonation rate of the explosive composition is not relied upon for consumption rate of said explosive composition throughout its length in the borehole.

7. A system for enhancing the explosive characteristics of an explosive composition in multiple borehole blasting, said system having in combination:

- (a) initiating points longitudinally disposed within the explosive composition in each borehole of a set of boreholes, said initiating points comprising a plurality of electric blasting caps substantially equally spaced from each other,
- (b) electrical energy storage circuit means connected to and adapted to detonate the initiating points,
- (c) electrical means for energizing the energy storage circuit means,
- (d) control means for actuating the energy storage circuit means to energize the initiating points disposed in each borehole and to detonate same completely at a time interval of not more than about 40 microseconds, and
- (e) said initiating points throughout the length of the explosive composition being sufficiently closely spaced so that the normal detonation rate of the explosive composition is not relied upon for consumption rate of said explosive composition throughout its length in the borehole.

8. A system for enhancing the explosive characteristics of an explosive composition in multiple borehole blasting, said system having in combination:

- (a) initiating points longitudinally disposed within the explosive composition, in each borehole of a set of boreholes, said initiating points comprising a plurality of electric blasting caps and boosters therefor substantially equally spaced from each other,
- (b) electrical energy storage circuit means connected to and adapted to detonate the initiating points,

(c) electrical means for energizing the energy storage circuit means,

(d) control means for actuating the energy storage circuit means to energize the initiating points disposed in each borehole and to detonate same completely at a time interval of not more than about 40 microseconds, and

(e) said initiating points throughout the length of the explosive composition being sufficiently closely spaced so that the normal detonation rate of the explosive composition is not relied upon for consumption rate of said explosive composition throughout its length in the borehole.

9. A system for enhancing the explosive characteristics of an explosive composition in multiple borehole blasting, said system having in combination:

- (a) initiating means longitudinally disposed within the explosive composition in each borehole of a set of boreholes, said initiating means comprising a multiple initiating point electrical initiating cord of high explosive adapted for substantially instantaneous detonation,
- (b) electrical circuit means connected to and adapted to detonate the initiating means,
- (c) control means for actuating the electrical circuit means to energize the initiating means disposed in each borehole and to detonate same substantially instantaneously or within about 40 microseconds, and
- (d) said initiating points throughout the length of the explosive composition being sufficiently closely spaced so that the normal detonation rate of the explosive composition is not relied upon for consumption rate of said explosive composition throughout its length in the borehole.

10. A system for enhancing the explosive characteristics of an explosive composition in multiple borehole blasting, said system having in combination:

- (a) initiating means longitudinally disposed within the explosive composition, in each borehole of a set of boreholes, said initiating means comprising a longitudinally arranged initiator comprising a multiplicity of electrical initiating points in contact with a layer of high explosive,
- (b) electrical circuit means connected to the adapted to detonate the initiating means,
- (c) control means for actuating the electrical circuit means to energize the initiating means disposed in each borehole and to detonate same substantially instantaneously or within about 40 microseconds, and
- (d) said initiating points throughout the length of the explosive composition being sufficiently closely spaced so that the normal detonation rate of the explosive composition is not relied upon for consumption rate of said explosive composition throughout its length in the borehole.

11. A system for enhancing the explosive characteristics of explosive compositions in multiple borehole blasting, and to reduce the ground shock therefrom, said system having in combination:

- (a) initiating means longitudinally disposed within the explosive composition in each borehole of a first set of boreholes,
- (b) initiating means longitudinally disposed within the explosive composition in each borehole of at least a second set of boreholes,
- (c) electrical circuit means for each set of boreholes connected to and adapted to detonate each set of initiating means,
- (d) control means for sequentially actuating the electrical circuit means with a delay of 0.1 milliseconds or longer between each set of boreholes, and to energize the initiating means disposed in each set of boreholes and detonate same completely at a time interval of not more than about 40 microseconds

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for each borehole and at a time interval of not more than about 100 microseconds for each set of boreholes, and

(e) said initiating means for each borehole having a plurality of initiating points sufficiently closely spaced throughout the length of the explosive composition so that the normal detonation rate of the explosive composition is not relied upon for consumption rate of said explosive composition throughout its length in each said borehole.

12. The system according to claim 11 in which the initiating means comprises a plurality of electric blasting caps substantially equally spaced from each other.

13. The system according to claim 11 in which the initiating means comprises a plurality of electric blasting caps and boosters therefor substantially equally spaced from each other.

14. The system according to claim 11 in which the initiating means comprises a multiple point initiating cord of high explosive adapted for substantially instantaneous detonation.

15. The system according to claim 11 in which the

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initiating means comprises a longitudinally arranged initiator having a multiplicity of electrical initiating points in contact with a layer of high explosive.

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