

[54] **MODIFIED PRESPLITTING TECHNIQUE**

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[22] Filed: **Dec. 11, 1970**

[21] Appl. No.: **97,206**

[52] U.S. Cl. **102/23, 102/70.2 R**

[51] Int. Cl. **F42d 1/06**

[58] Field of Search **102/22-24, 70.2**

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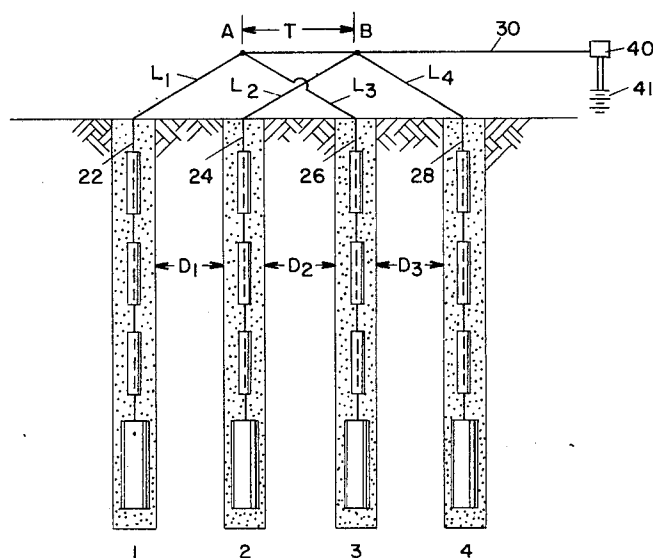
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[57] **ABSTRACT**

A presplitting method is provided in which the blasting agents in alternate holes and interjacent holes of a blasting hole array are connected together to form two separate blasting circuits. The blasting charges in each blasting circuit are detonated simultaneously with a preestablished interval between blasting of the charges in each circuit. The combination of oppositely directed forces resulting from detonation of the blasting charge in two alternate holes causes compressive stress at an interjacent hole at the time of detonation of a blasting charge in the interjacent hole resulting in better presplitting with reduced noise and vibration.

6 Claims, 5 Drawing Figures



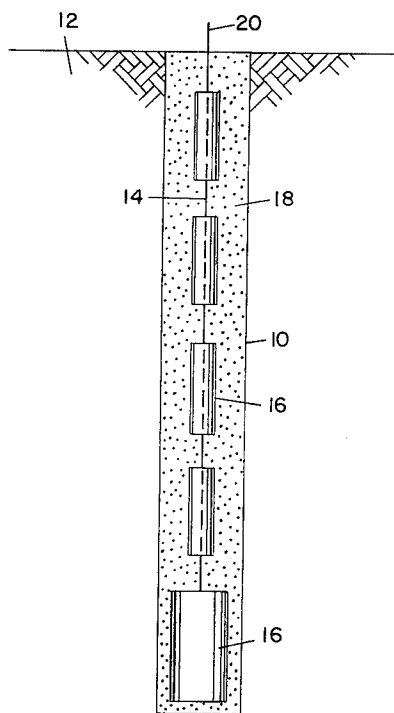


FIG. 1

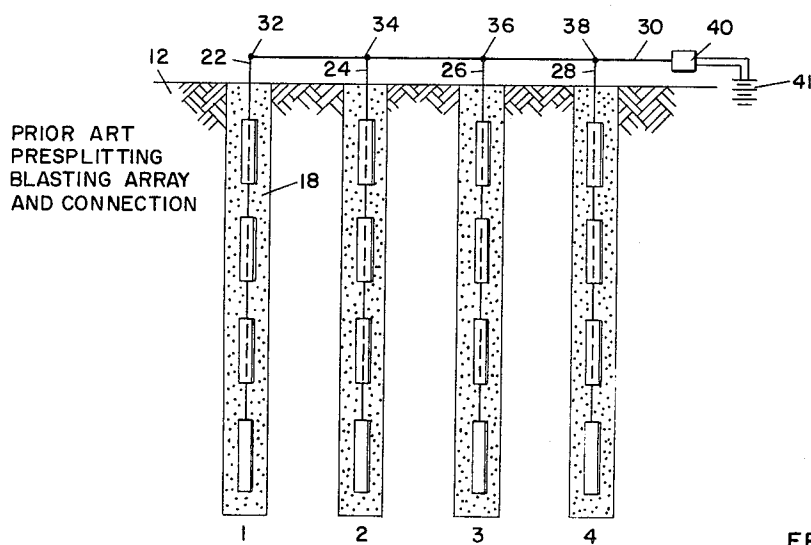


FIG. 2

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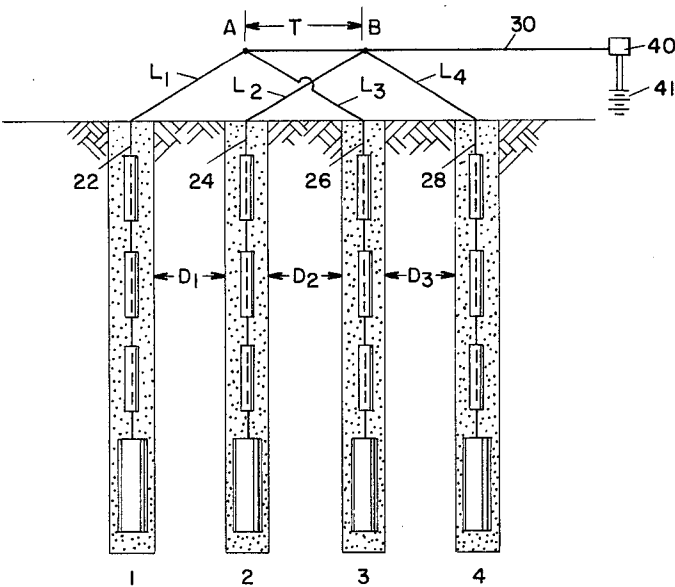


FIG. 3

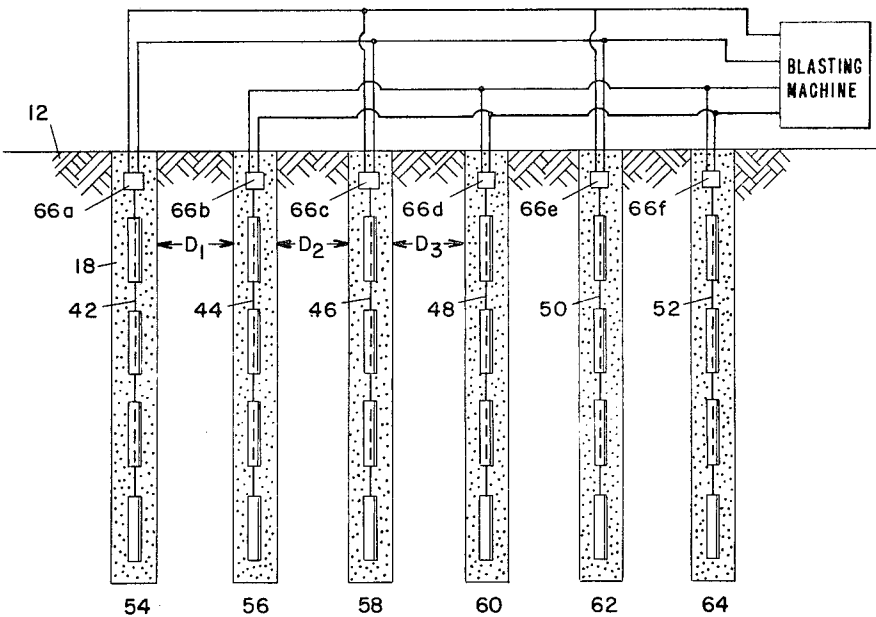


FIG. 4

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MODIFIED PRESPLITTING TECHNIQUE

This invention relates to a modified and improved method of blasting generally referred to in the blasting art as presplitting. More particularly, this invention relates to a method of presplitting in which the blasting charge of alternate and interjacent holes of a blasting array are connected to form two blasting circuits and the charges in each blasting circuit are detonated simultaneously at a preestablished time interval to achieve more efficient presplitting. In another aspect, this invention relates to a system for presplitting a rock formation.

Presplitting is a method of blasting in which a shear plane or break line is established in a rock formation to be blasted. This break line can be generated to prevent over-break of the rock formation during subsequent blasting operations permitting the rock to be broken and removed as required. Presplitting permits blasting of a smooth rock face at a predetermined alignment.

When employing presplitting as a blasting method a plurality of holes are first drilled in a rock formation, generally in a straight line. The holes are charged with a suitable blasting agent, usually in comparatively small amounts, say on the order of about three-fourths of a pound of explosive per foot of blast hole. The holes are spaced from about 6 inches to about 4 feet apart. When the blasting agent is initiated, a presplit crack or break line is formed in the rock along the line defined by the line of the predrilled holes. Due to the close spacing of the holes and the low amount of blasting agent in each hole, this split in the formation can be accomplished with relatively little or no damage to the surrounding formation. This technique of blasting is highly desirable for use near buildings, utilities, and near the edges of proposed roadways.

In present methods of presplitting a series of holes are drilled along a desired presplit line as heretofore described. A detonating fuse is placed in the hole and is generally referred to as a downline. A blasting agent usually in the form of several small charges is secured along the length of the downline within each hole. The free-end of each downline, i.e., the end of the downline extending out of the top of the hole is connected to a detonating fuse trunk line. The distance between connections of the downlines to the detonating fuse trunk line establishes the time delay interval between initiation of explosive charges in successive holes. A blasting cap is attached to the free-end of the detonating fuse trunk line and is initiated by suitable means such as a battery or a blasting machine to start the presplitting process. In this typical prior art method of presplitting, the shock from initiation of the blasting agent in the first hole moves through the formation and arrives at the second hole substantially simultaneously with the initiation of the blasting agent in the next hole to produce a shearing force of sufficient intensity to split the rock formation. Thus, presplitting by prior art methods is accomplished by cooperation of explosive energies of two holes.

In accordance with the modified presplitting method of this invention, a series of blast holes are drilled along a desired presplit line with a substantially constant distance between the holes. Each of these drilled holes is charged with a suitable amount of blasting agent. The blasting agent in each alternate hole along the desired

presplit line is connected to an initiator means capable of simultaneously initiating the blasting agent in each hole. The connection of the alternate holes to the initiator means forms a first blasting circuit. The blasting agent in each hole interjacent the alternate holes is connected to an initiator means capable of simultaneously initiating the blasting agent in each interjacent hole. The connection of the blasting agents of the interjacent holes to an initiator means forms a second blasting circuit. The blasting array described is employed for presplitting by activating the initiator means for the first and second blasting circuits at a time interval substantially equal to the time for transit of a shock wave, through the rock formation from an alternate hole to an interjacent hole.

The following drawings more fully illustrate this invention.

FIG. 1 is a schematic view of a bore hole charged with several blasting charges.

FIG. 2 is a schematic view illustrating the prior art method of connecting blasting charges in a borehole for presplitting a rock formation.

FIG. 3 is a schematic view of one embodiment of a blasting arrangement which can be employed with the presplitting method of this invention.

FIG. 4 is a schematic view of preferred embodiment of a blasting arrangement which can be employed to accomplish the presplitting method of this invention.

FIG. 5 is a wiring diagram for a blasting machine which can be employed to provide power to the two blasting circuits employed in the presplitting method of this invention.

In FIG. 1 a typical blasting hole 10 is shown drilled into a rock formation 12. A blasting agent comprising a detonating cord downline 14 having blasting charges 16 secured thereto is shown in place in the hole. The hole is filled with gravel stemming 18. The free-end 20 of the detonating cord downline 14 can be attached to any suitable initiator means (not shown).

FIG. 2 illustrates a typical blasting hole array and blasting agent connection employing prior art methods of presplitting. The free-end of each downline 22, 24, 26 and 28 is connected to a detonating cord trunk line 30 at junctions 32, 34, 36 and 38. The length of detonating cord between any two junctions on the trunk line is equal. Each hole is charged with an equivalent amount of explosive. The end of trunk line 30 is secured to a blasting cap 40. Blasting cap 40 is initiated by a suitable source of electrical power such as battery 41. When blasting cap 40 is fired, detonating fuse 30 detonates along its length and, in turn, initiates detonation of the blasting agent in holes 4, 3, 2 and 1 respectively.

FIG. 3 illustrates a suitable connection of the blasting agents in the blasting array shown in FIG. 2 employing the modified presplitting method of this invention. Connection of the blasting agents is critical in achieving the desired blasting result. In FIG. 3 the free-ends of downlines 22, 24, 26 and 28 are shown as lines L_1 , L_2 , L_3 and L_4 . Lines L_1 , L_2 , L_3 and L_4 are all of the equal length. The free ends L_1 and L_3 of downlines 22 and 26 are joined together and are connected to trunk line 30 at junction A. Free-ends L_2 and L_4 of downlines 24 and 28 are joined together and are connected to trunk line 30 at junction B. The distances between each blasting

hole shown as D₁, D₂ and D₃ are substantially equal. The length of the detonating cord between junction A and B on trunk line 30 is T. T is established based on the shock transit time for the rock formation. Shock transit time, is the time required for a shock resulting from the detonation of a blasting agent in a first hole to travel through the rock to the edge of an adjacent hole. T is established so that the time for the detonation of the detonating cord to reach the blasting charge in successive holes is substantially the same as the shock transit time. Thus, as shown in FIG. 3, when blasting cap 40 is fired, the blasting agent in each of holes 2 and 4 is fired first and the blasting agent in each of holes 1 and 3 is then fired at about the time the shock wave from holes 2 and 4 reaches the periphery of blast holes, 1 and 3.

FIG. 4 illustrates the preferred connecting arrangement to be employed when using the modified presplitting method of this invention. In this arrangement downlines 42, 44, 46, 48, 50 and 52 are illustrated with their free-ends each terminating below the surface of the rock formation 12 at blasting caps 66a, 66b, 66c, 66d, 66e, and 66f, respectively. It is preferred that blasting caps be fully contained within the blasting holes, i.e., below the surface of the rock formation being blasted so as to minimize noise resulting from the blast. Blasting caps 66a, 66c, and 66e of blasting holes 54, 58 and 62 are connected electrically in parallel forming a first blasting circuit. Blasting caps 66b, 66d, and 66f of blasting holes 56, 60 and 64 are connected electrically in parallel forming a second blasting circuit. Holes 54, 58 and 62 are referred to as alternate holes. Holes 56, 60 and 64 are referred to as interjacent holes. Blasting circuits 1 and 2 are connected to a power source means capable of supplying current for energization of blasting circuits 1 and 2 at a time interval substantially equal to the shock transit time determined for the rock formation.

The following examples more fully illustrates the presplitting method of this invention. Examples 1, 3, 5, 8, 9, 11 and 13 illustrate the method of this invention. Examples 2, 4, 6, 7, 10, 12 and 14 are controls illustrating prior art presplitting methods.

EXAMPLE 1

Four holes are drilled in a rock formation. The holes have a diameter of 3 inches, are 8 feet deep and are arranged in a straight line. The holes are spaced 3 feet apart. The holes are charged with three sticks of "Karvite" five-eighths inch in diameter and 24 inches long. Karvite is a trade name for a dynamite manufactured by Hercules Incorporated. The Karvite sticks are taped end to end to a 12 foot length of detonating cord. The free-ends of the detonating downlines from holes 1 and 3 and from holes 2 and 4 are taped together forming two common junctions. These junctions are secured to a trunk line of detonating cord with a distance of 3.2 feet between the junctions. The schematic layout of this arrangement is illustrated in FIG. 3. A blasting cap is taped to the free-end of the detonating cord trunk line. The blasting cap is initiated and the charges detonated. The difference in the length of the detonating cord trunk line between holes 1 and 3, and 2 and 4 permits the blasting agent in each of holes 2 and 4 to be detonated about 165 microseconds before the blasting

agent in each of holes 1 and 3. A good break line results.

The foregoing example is repeated employing the prior art method of presplitting.

EXAMPLE 2

Four holes are drilled in another sector of the rock formation in which the presplit of Example 1 is made. The hole size and the explosive charge weight and placement are the same as in Example 1. The free-end of each length of detonating cord downline is joined to a detonating cord trunk line. The length of detonating cord between adjacent junctions of each downline and the trunk line is three feet. A blasting cap is taped to the free-end of the trunk line. The blasting array described is represented schematically in FIG. 2. The blasting cap is initiated and the charges detonated. All holes "rifled," i.e., the force from the detonation was principally directed through the open-end of the blasting hole. No break line is produced.

EXAMPLE 3

Six holes are drilled in a rock formation in a straight line. The holes are spaced 3 feet apart, have a diameter of 3 inches and are 20 feet deep. An 18 foot length of detonating cord having 50 grains of PETN/foot of cord is used as a downline. One stick of 60 percent high pressure gelatin dynamite having a diameter of 2.0 inches and a length of 12 inches is taped along the last 12 inches of the detonating cord. Eight sticks of dynamite having a diameter of seven-eighths inch and a length of 24 inches and sold under the trade name "Hercosplit WR" by Hercules Incorporated, are taped to the detonating cord, end to end, from the stick of high pressure gelatin dynamite along the length of the cord. A blasting cap is taped to the free-end of the detonating cord. The detonating cord downlines with explosive charges secured thereto are installed in each hole. The cap wires from the blasting caps of holes 1, 3 and 5 are connected electrically forming a first parallel circuit. Cap wires from the blasting caps of holes 2, 4 and 6 are connected together forming a second blasting circuit. These two circuits are connected to two-points of the three point blasting machine illustrated in FIG. 5. The blasting machine is set to energize the cap loads of the first and second circuits with a 180 microsecond delay between energization of the two circuits. The circuits are energized detonating the blasting charges in the holes. A good break line results. Very little noise results from the detonation.

EXAMPLE 4

Six holes are drilled in another sector of the rock formation in which the presplit of Example 3 is made. The hole dimensions and blasting agent weight and placement are the same as in Example 3. The end of each length of detonating cord downline is connected to a detonating cord trunk line such as illustrated in FIG. 2. The length of detonating cord between adjacent junctions of each downline and the trunk line is 3 feet. A blasting cap is taped to the free-end of the detonating cord trunk line. The blasting cap is initiated and the blasting charges detonated. A good break line results. A loud noise is heard from the detonation.

EXAMPLE 5

Example 3 is repeated except that the distance between holes is increased from 3 feet to 4 feet and the time interval between energization of the first and second blasting circuit is increased to 240 microseconds. The blasting circuits are energized and a good presplit results. Only a low noise can be heard during presplitting.

EXAMPLES 6-7

Example 4 is repeated except that the distance between the holes is increased to 4 feet. The entire shot "rifled." An extremely loud noise is heard. This example is repeated. The entire shot "rifled" a second time with an extremely loud noise.

EXAMPLE 8

Example 5 is repeated. A good presplit again results. Only a low noise is heard from the detonation.

EXAMPLES 9-14

The following examples are used to illustrate comparative vibration levels employing the preferred blasting arrangement of this invention as illustrated in FIG. 4 using the electronic blasting machine and the vibration levels employing the prior art presplitting method as illustrated in FIG. 2. In each blasting test conducted, seven holes, 18 inches in diameter are drilled to a depth of 18 feet and are spaced apart in a straight line. The holes in Examples 9, 10, 11 and 12 are charged with 4.45 pounds of explosives. The blasting holes of Examples 13 and 14 are charged with 6.1 pounds of explosives. Vibration levels are measured with a seismograph. Examples 9, 11 and 13 employ the blasting machine and method of this invention. Examples 10, 12 and 14 are control tests and are connected as shown in FIG. 2 employing the prior art presplitting blasting array. Results of blasting are set forth in Table I.

TABLE I

Ex. No.	Pre-Split Hole Centers (feet)	Means of Initiation	Distance of Seismograph From Blast (feet)	Vibration Component	Peak ⁽²⁾ Particle Velocity (in./sec.)
9	2	EPM ⁽¹⁾	15	Transverse	4.0
				Vertical	5.8
				Longitudinal	3.5
10	2	Detonating Cord	15	Transverse	3.2
				Vertical	7.0
				Longitudinal	4.5
11	3	EPM ⁽¹⁾	40	Transverse	1.0
				Vertical	0.9
				Longitudinal	1.8
12	3	Detonating Cord	40	Transverse	1.0
				Vertical	1.4
				Longitudinal	2.4
13	4	EPM ⁽¹⁾	40	Transverse	1.4
				Vertical	2.4
				Longitudinal	2.2
14	4	Detonating Cord	40	Transverse	0.7
				Vertical	4.4
				Longitudinal	1.0

⁽¹⁾Electronic Pre-Splitting Machine

⁽²⁾Peak particle velocity is a measurement of maximum kinetic energy imparted to a body, and is the rate at which particles of a mass are vibrating.

Vibration levels are shown in Table I as peak particle velocity. The criteria for damage to a structure from vibration resulting from blasting is based on the maximum vibration of any one component. On this basis, the increased vibration of the prior art blasting method over the method of this invention varies from an increase of 20 percent, comparing the vertical vibration components in Examples 9 and 10, to an increase of 83 percent comparing the vertical vibration components in Examples 13 and 14.

In the presplitting method of this invention, the blasting array of holes is divided into two circuits of alternate holes and interjacent holes. Each of the blasting agents in each circuit is connected together in a parallel arrangement so that each blasting charge connected in parallel arrangement is detonated substantially simultaneously. The two circuits of blasting charges are detonated with a pre-established time interval between the initiation of the two circuits of charges in these holes. The time interval is substantially equal to the shock transit time for the particular rock formation between the holes. The term "shock transit time" as used herein is defined as the time interval required for the passage of a shock front through the rock formation from one hole to an adjacent hole. This is approximately equal to the sonic transmission velocity of rock.

While not bound by any theory, it is believed that the improved presplitting result of this invention results from oppositely directed forces from two alternate holes cooperating to cause compressive stress in the rock formation at an interjacent hole between two alternate holes. By initiating the charge in an interjacent hole, for example, at the approximate time of arrival of the shock wave from the alternate holes, it is believed that greater shearing forces are obtained from the shock waves resulting in an increase in the efficiency of the presplitting operation.

The presplitting method of this invention is preferably conducted employing a blasting machine. A preferred blasting machine is a machine having in combination:

a. at least two firing circuits connected in parallel, each firing circuit having a firing capacitor charged through a resistance means, a transformer having a primary coil and a secondary coil and a first silicon controlled rectifier, one lead of the primary coil being connected at the junction of the firing capacitor and the resistance means and the other lead of the primary coil being connected to the anode of the first silicon controlled rectifier and one lead of the secondary coil being connected to the cathode of the first silicon controlled rectifier and the other lead of the secondary coil being connected to the gate of a second silicon controlled rectifier, said firing capacitor being charged when a first D.C. power source is positioned conductive between the firing capacitor and a first switch means;

b. at least two energy storage circuits connected in parallel each circuit comprising a second capacitor connected in parallel with second silicon controlled rectifier the second capacitors being charged through a blocking diode when a second D.C. power source is positioned conductive between the second capacitors and a second switch means, said second silicon controlled rectifier receiving induced potential from the

secondary coil of a transformer as a result of discharge of firing capacitor through the primary coil of the transformer of a corresponding firing circuit when the first silicon controlled rectifier is in its conducting state,

c. at least two blasting circuits connected in parallel each blasting circuit comprising output terminals connected to blasting initiator means within the blasting circuit, said output terminals receiving the output from the second capacitor of a corresponding energy storage circuit when the second silicon controlled rectifier is in the conducting state, and

d. at least two timing circuits connected in parallel, each timing circuit comprising resistance means, a capacitor, and a unijunction transistor, a pulse from each unijunction transistor passing to the silicon controlled rectifier in a corresponding firing circuit initiating discharge of a second capacitor of an energy storage circuit into a blasting circuit when a third D.C. power source is positioned conductive between the timing circuits and a third switch means, the resistance-capacitance time constant for each successive timing circuit increasing in an amount necessary to delay discharge of the capacitors in the energy storage circuits into successive blasting circuits in the machine whereby current passes into the blasting circuits for initiating the blasting initiator means connected thereto at precisely controlled time intervals.

OPERATION OF THE BLASTING MACHINE

The timing and firing circuits of FIG. 5 are connected to battery B_1 through switch S_1 . When switch S_1 is closed current flows through blocking diodes D_1 , D_5 , D_6 and resistors R_1A , R_1B , and R_1C into capacitors C_1 , C_2 and C_3 charging said capacitors to the voltage level of battery B_1 . This combination of blocking diodes and resistors for each firing circuit provides isolation for each of these circuits individually, from electrical transients generated during the rapid discharge of capacitors C_1 , C_2 and C_3 . Following the charging of the firing capacitors the energy storage circuits are charged.

The energy storage circuits are connected to battery B_2 through switch S_2 . The energy storage circuits are charged by closing switch S_2 . Current flows through blocking diodes D_8 , D_9 and D_{10} into capacitors C_4 , C_5 and C_6 .

The firing circuit is operated to activate discharge of energy stored in the energy storage circuits in blasting circuits A, B and C as follows. Switch S_3 , the firing switch is closed. Current flows to relay switch K_1 closing this switch whereby current from battery B_4 flows into the timing circuits. Current flows through resistor R_2A into capacitor CT_1 , through variable resistor R_2X into capacitor CT_2 , through resistor R_3X , through the coil of relay K_2 and current is supplied to the moveable contact of relay K_2 . Capacitors CT_1 and CT_2 are connected to unijunction transistors Q_1 and Q_2 respectively. These capacitors are charged to the trigger level of the unijunction transistors Q_1 and Q_2 . The resistance-capacitance time constants for the first timing circuit (R_2A-CT_1) and the second timing circuit (R_2X-CT_2) are adjusted so that Q_1 reaches its trigger level at a precise time prior to Q_2 reaching its trigger level. Upon reaching its trigger level Q_1 becomes conductive permitting capacitor CT_1 to discharge through the emitter

and base of Q_1 sending an electrical pulse to the gate of SCR_1 and across resistor R_4A . The electrical pulse at SCR_1 makes it conductive thus completing the discharge path from capacitor C_1 through the primary coil T_1P of the transformer. Current is induced into the secondary coil T_1S and produces a positive pulse at the gate of silicon controlled rectifier SCR_3 causing SCR_3 to become conductive and completing the discharge path of capacitor C_4 through the blasting cap load connected across terminals A and the parallel resistor R_1A .

At a predetermined time after capacitor C_4 has discharged into blasting circuit A (terminals shown only) the unijunction transistor Q_2 reaches its trigger level. This time interval is determined by the resistance-capacitance time constant of capacitor CT_2 and moveable resistor R_2X . Unijunction transistor Q_2 becomes conductive when it reaches its trigger level permitting capacitor CT_2 to discharge through the emitter E and base B_1 of Q_2 across R_4X and to the gate of silicon controlled rectifier SCR_2 making it conductive. Current from battery B_4 can then flow through resistor R_3X , through the coil of relay K_2 and through SCR_2 . Current flowing through the coil of relay K_2 causes its contacts to close permitting current to flow to unijunction transistors Q_3 and Q_4 repeating the timing and firing sequences as heretofore described and discharging capacitors C_5 and C_6 into blasting circuits B and C.

While the circuit diagram of a suitable blasting device of this invention has been illustrated for use with up to three blasting circuits A, B and C, it is understood that for purposes of the method of this invention only two of these blasting circuits are employed to obtain detonation of the initiators connected to the blasting circuit.

A blasting machine is prepared as set forth in FIG. 5. The parts parameters utilized in this blasting machine and described in the foregoing section are as follows:

B_1	45 battery
B_2	450 volt battery
B_3	12 volt battery
B_4	24 volt battery
K_1, K_2	Magnecraft relay 12 volt, D.C., W 131 PCX-9
R_2A, R_2B	Resistor, 10K Ω
R_2X	Variable resistor 100K Ω
R_2C	Variable resistor 10K Ω
R_3A, R_3X, R_3B, R_3C	Resistor 470 Ω
$D_1 - D_7$	Diodes, General Electric IN1492
$D_8 - D_{10}$	Diodes, 2000 volt at 1 amp.
$SCR_1 - SCR_4$	Silicon controlled rectifier General Electric 2 N 1596
C_1, C_2, C_3	Capacitors, 25 mfd at 50 volts D.C.
C_4, C_5, C_6	Capacitors, 850 mfd at 450 volts, D.C.
CT_2, CT_3, CT_4, CT_5	Capacitors, 0.1 mfd at 200 volts, D.C.
CT_3, CT_4, CT_5, CT_6	Capacitors, Cornell Dubilier Type WMF, 0.1 mfd at 200 volts
T_1, T_2, T_3	Transformer, SPRAGUE 11212
Switches	
S_1	Switch, Cutler Hammer Type 8801 K22 S.P.S.T.
S_2	Switch, Square D Class 9001 Type PR2 - TA 2
S_3	Switch, Grayhill Type 2001 S.P.S.T., N.O.
$SCR_5 - SCR_7$	Silicon controlled rectifier General Electric 178 M
Q_1, Q_2, Q_3, Q_4	Unijunction Transistor, General Electric 2N-1671A

What I claim and desire to protect by Letters Patent is:

1. A method of presplitting a rock formation comprising:

- a. forming a series of holes spaced a substantially constant distance apart along a desired presplit line,
- b. charging each hole with a blasting agent,
- c. connecting the blasting agent of alternate holes to initiator means for simultaneously initiating the blasting agent of each alternate hole, said connection forming a first blasting circuit,
- d. connecting the blasting agent of interjacent holes to initiator means for simultaneously initiating the blasting agent of the interjacent holes and forming a second blasting circuit,
- e. activation of the initiator means for the first and second blasting circuits at a predetermined time interval, said time interval between activation of the initiator means of the first and second blasting circuit being substantially equal to the shock transit time established for the rock formation between adjacent holes and generated by detonation of a like blasting agent to the blasting agent charged to the holes, whereby the blasting agents in the first blasting circuit are detonated simultaneously and the second blasting circuits are detonated simultaneously at the predetermined time interval, presplitting the rock formation along the desired presplit line.

2. A method of presplitting a rock formation comprising:

- a. forming a series of holes spaced a substantially constant distance apart along a desired presplit line,
- b. charging each hole with a blasting agent,
- c. connecting the blasting agent in each hole to an electrically activable initiator means for initiating said blasting charge,
- d. electrically connecting the initiator means of each alternately spaced hole in parallel forming a first blasting circuit and electrically connecting the initiator means of each interjacent hole in parallel forming a second blasting circuit,
- e. connecting the first and second blasting circuits to blasting machine,
- f. activating discharge of current from the blasting machine into the first and second blasting circuits at a time interval substantially equal to the shock transit time established for the rock formation between adjacent holes generated by detonation of a like blasting agent to those in each hole whereby the blasting agents of the first blasting circuit are detonated simultaneously and the blasting charges of the second blasting circuit are detonated simultaneously at the predetermined time interval splitting the rock formation along the desired presplit line.

3. The method of claim 2 wherein the electrically activable initiator means is a blasting cap and the blasting cap is positioned fully within each hole.

4. A system for presplitting a rock formation comprising:

- a. a plurality of blasting holes in a blasting hole array spaced a substantially constant distance apart along a desired presplit line,

- b. a blasting agent positioned within each blasting hole,
- c. electrically activable initiator means for initiating detonation of each blasting agent,
- d. a first blasting circuit comprising a parallel connection of initiator means in alternate blasting holes in the blasting hole array,
- e. a second blasting circuit comprising a parallel connection of initiator means in interjacent blasting holes of the blasting hole array, and
- f. an electrical energy supply means capable of supplying sufficient energy to the first and second blasting circuits at a predetermined time interval equal to the shock transit time of the rock formation to activate the initiator means for each blasting agent whereby the blasting agents in the first and second blasting circuits are detonated at the predetermined time interval presplitting the rock formation.

5. The system of claim 4 wherein the electrically activable initiator means is a blasting cap, said blasting cap being positioned fully within each hole.

6. The blasting system of claim 5 wherein the electrical energy supply means is a blasting machine having in combination:

- a. at least two firing circuits connected in parallel, each firing circuit having a firing capacitor charged through a resistance means, a transformer having a primary coil and a secondary coil and a first silicon controlled rectifier, one lead of the primary coil being connected at the junction of the firing capacitor and the resistance means and the other lead of the primary coil being connected to the anode of the first silicon controlled rectifier and one lead of the secondary coil being connected to the cathode of the first silicon controlled rectifier and the other lead of the secondary coil being connected to the gate of a second silicon controlled rectifier, said firing capacitor being charged when a first D.C. power source is positioned conductive between the firing capacitor and a first switch means;
- b. at least two energy storage circuits connected in parallel each circuit comprising a second capacitor connected in parallel with second silicon controlled rectifier the second capacitors being charged through a blocking diode when a second D.C. power source is positioned conductive between the second capacitors and a second switch means, said second silicon controlled rectifier receiving induced potential from the secondary coil of a transformer as a result of discharge of firing capacitor through the primary coil of the transformer of a corresponding firing circuit when the first silicon controlled rectifier is in its conducting state,
- c. at least two blasting circuits connected in parallel each blasting circuit comprising output terminals connected to blasting initiator means within the blasting circuit, said output terminals receiving the output from the second capacitor of a corresponding energy storage circuit when the second silicon controlled rectifier is in the conducting state, and
- d. at least two timing circuits connected in parallel, each timing circuit comprising resistance means, a capacitor, and a unijunction transistor, a pulse

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from each unijunction transistor passing to the silicon controlled rectifier in a corresponding firing circuit initiating discharge of a second capacitor of an energy storage circuit into a blasting circuit when a third D.C. power source is positioned conductive between the timing circuits and a third switch means, the resistance-capacitance time constant for each successive timing circuit increases-

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ing in an amount necessary to delay discharge of the capacitors in the energy storage circuits into successive blasting circuits in the machine whereby current passes into the blasting circuits for initiating the blasting initiator means connected thereto at precisely controlled time intervals.

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