United States Patent

Driscoll

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[54] **ELECTRIC INITIATORS FOR HIGH ENERGY FIRING CURRENTS**

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[52] **U.S. Cl.** ..... **102/28 R**

[51] **Int. Cl.** **F42b 3/18**

[58] **Field of Search** ..... 102/28, 28 M

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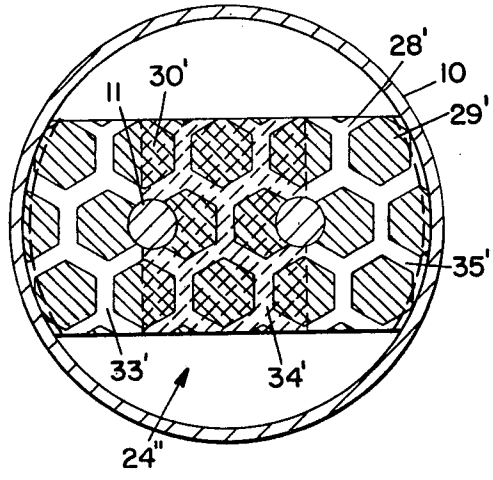
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[57] **ABSTRACT**

Electric delay type initiators for firing under high energy firing current conditions, containing a combination of shunt means and ignition composition, providing for diversion of excess firing current from the ignition area, and hence for protection of the assembly against failure caused by arcing across the lead wire terminals and bursting of the cap shell. The shunt is an electrically conductive material, electrically connecting with the lead wires, outside the ignition area, and has a sufficiently high resistance to permit flow of normal (no-arc) firing current through the firing circuit; but, in response to flow of an arc-forming firing current, it provides a path of sufficiently reduced resistance across the lead wires during the circuit reform period to divert flow of the firing current across the lead wires and hence from the ignition area for flow from the system.

27 Claims, 5 Drawing Figures



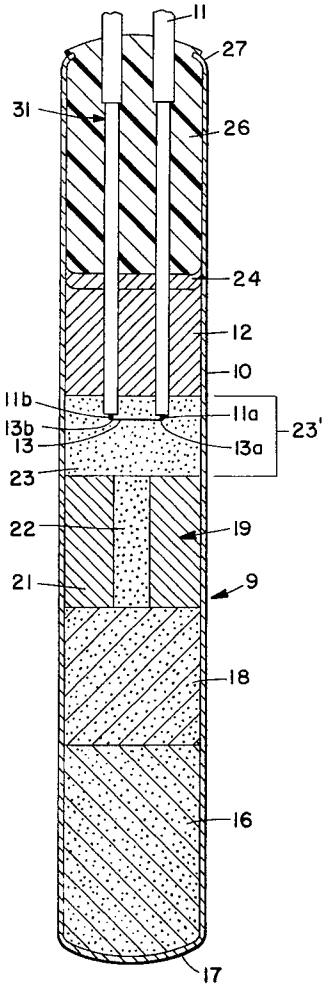


FIG. 1

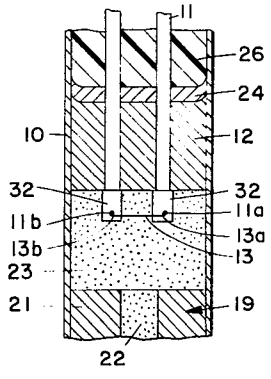


FIG. 1D

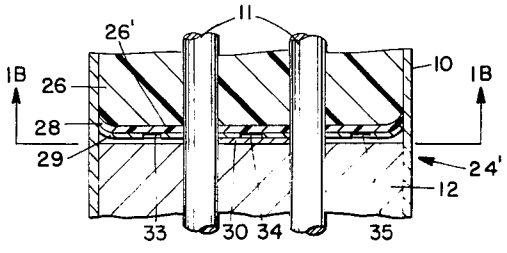


FIG. 1A

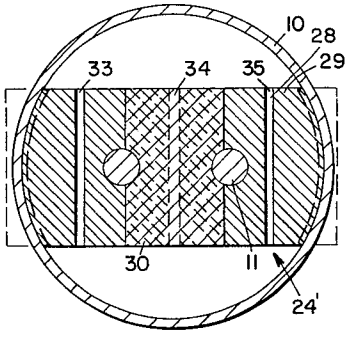


FIG. 1B

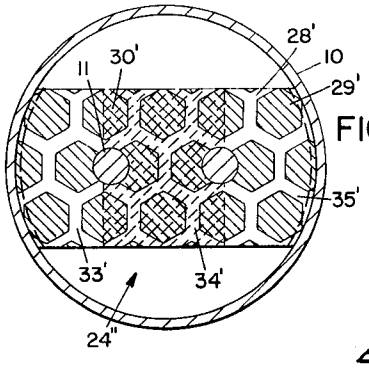


FIG. 1C

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ELECTRIC INITIATORS FOR HIGH ENERGY FIRING CURRENTS

This invention relates to improved electric initiators. In one aspect, this invention relates to electric initiators for firing under high energy firing current conditions. In another aspect, this invention relates to delay initiators of the blasting cap type for firing under high voltage firing current conditions and containing a combination of shunt structure and ignition system for diverting flow of excess firing current from the ignition area.

As is well known, electric initiators, generally of the blasting cap, or squib, type, contain an ignition charge and one or more of delay, primer, and base charge components operatively responsive to ignition of the ignition charge. An electric delay type blasting cap generally comprises a closed shell; a dielectric plug, within the shell, in closing relationship therewith as an ignition plug; a base charge within the shell and spaced from the ignition plug; a primer composition intermediate the base charge and the dielectric plug; a slow-burning delay type composition intermediate the primer composition and the dielectric plug; an ignition composition intermediate the delay composition and the dielectric plug; a pair of electrically conductive, or lead, wires extending into the shell through the dielectric plug toward, and terminating in, the ignition composition; and a resistance, or bridge, wire within the ignition composition and connecting the terminal ends of the leg wires. The base charge is detonatable in response to detonation of the primer composition, which, in turn, is detonatable in response to heat and flame from burning of the delay composition; and the delay composition is ignitable in response to ignition of the ignition composition which, in turn, is ignitable in response to heat developed by passage of firing current through the leg wires and the resistance wire, as the firing circuit. In other forms, the delay type initiator can be of the squib type in which case the base charge is a material that burns as a flash in response to heat and flame from burning of the delay fuse, and the assembly does not necessarily require a primer charge.

Ordinarily, electric delay type initiators are fired by a battery charge, or a blasting machine, which delivers a short duration of current. Very frequently, however, blasting machines, batteries or other ordinary current sources, are not available at the site of blasting operations and resort is had to the available power line sources, generally at high voltages in the order of 220 to 440 volts. In other instances, it is desirable from the standpoint of energy requirements that such high voltage firing currents be utilized.

When so utilizing high voltage power lines, the amount of firing current often becomes excessive due to the high energy limits of the voltage source. Under those circumstances, after vaporization of the bridge wire, there is often the formation of an arc across the terminal end of the lead wires in the ignition area (also referred to herein as the bridge wire, or lead wire, terminals) due to the close proximity of those wire terminals and the plasma that is formed. Arc formation in turn generates heat to cause development of sufficiently high pressure in the ignition area to cause bursting of the shell before the delay fuse has completely burned, or sometimes before it has been ignited. Such bursting of the cap shell has the effect of "blowing out"

the flame from the ignition, or from the burning fuse, to cause the initiator to become inoperative, and hence there is failure of the shot. Further, such bursting of the shell often causes flow of flame and gases to the emplaced main explosive charge outside the shell with uncontrolled burning of the main charge and accompanying impairment of the overall shooting operation.

During a short period immediately subsequent to the initial vaporization of the bridge wire, the resulting metal vapor forms a conductive path of low electrical resistance across the lead wire terminals. However, there is soon dissipation of the path of metal vapor after which there is a period of time during which the resistance across the lead wire terminals is very high and the path across the terminals is substantially electrically non-conductive, and remains so for a period of time until the burning of the ignition composition has progressed sufficiently to generate conductive gases and/or form conductive metal slag across the lead wire terminals for thus reforming the circuit. That period during which the path across the lead wire terminals is substantially electrically non-conductive is that interim referred to herein as the reform time. It is after the firing circuit has been thus reformed that the arcing firing current causes the undesirable arcing across the lead wire terminals with accompanying impairment of the shooting operation. Hence, when referring herein to an arcing, or an arc-forming, firing current, it is meant to include any firing current having an energy level which causes arcing across the bridge wire terminals after reform of the firing circuit; and when referring herein to a no-arcing, or no-arc forming, firing current, is is meant to include any firing current having an energy level less than that which causes arcing across the bridge wire terminals following the reform period. The arcing and non-arcing firing conditions are determined not only by the degree of voltage and amperage of the firing current, but are also often dependent upon the specific ignition composition. However, dependent upon the resistance of the firing circuit and the duration of the firing voltage, the arcing firing current is generally a combination of voltage and amperage, AC or DC, from within the ranges of from 10 to 5,000 volts and 5 to 1,000 amperes, and the no-arcing firing current is of course at a lower energy level in any given case.

By way of further illustration of operation utilizing high energy firing currents, a plurality of delay electric blasting caps is often hooked in series, series-parallel, or in parallel, into a suitable high voltage line, often a 440-volt line carrying in the order of 200 amperes. In that manner, by correlation of the number of delay caps with the particular amperage-time duration of the firing circuit, the amount of firing current utilized in each cap assembly is less than that which will cause arc formation across the lead wire terminals following the circuit reform; and in such event there will be no arcing and hence no impairment of the shot due to arcing. However, it often happens that the energy of the firing current exceeds that of the no-arc current of one or all of the caps in the firing circuit and thus under the set firing conditions there is arc formation following the circuit reform time and subsequent failure of at least some of the caps; or, if the energy of the firing current in the entire hook-up is greater than that of the no-arc-

ing firing current for all caps, all caps may fail. Further, inasmuch as there are often power fluctuations in such high energy power lines, there are times when there may be a surge of high voltage such that an amount of firing current is delivered to the individual caps in excess of he no-arcing amount with impairment of all or several of the shots.

This invention is concerned with electric delay type initiators for firing under high energy firing conditions, containing shunt structure and ignition system providing for diversion of excess firing current from the ignition area and hence for protection of the assembly against failure caused by arcing across the bridge wire terminals and bursting of the cap shell.

In accordance with the invention, an electric delay type initiator assembly is provided for firing under high energy firing current conditions. The assembly contains an electrically conductive material disposed outside the ignition area long a path in electrically conductive contact with the lead wires as a shunt for diverting flow of an arcing firing current from the firing circuit. The shunt has an electrical resistance sufficiently high to be sufficiently electrically non-conductive of a no-arcing firing current to permit flow of same through the firing circuit; but, in response to flow of an arc-forming firing current through the firing circuit the shunt material, during the circuit reform period, provides a decrease in electrical resistance across the path to a level below that across the lead wires in the ignition area to thereby conduct the arc-forming firing current for diversion from the assembly. The requisite resistance decrease time from the standpoint of preferred practice, is less than the circuit reform time.

I have further discovered that the circuit reform time can be adjusted so as to be of longer duration hence affording selection of the shunt material from those within a broader range of resistance decrease times. Thus, in one embodiment, the circuit reform time of the ignition composition can be increased by the presence of an inert diluent in the ignition composition to decrease the burning rate, and hence to decrease the rate of generation of conductive plasma for imparting conductivity to the burning ignition composition across the bridge wire terminals. In another embodiment involving adjustment of the circuit reform period, the lead wire terminals are insulated so that after vaporization of the bridge wire, the terminals are protected temporarily against electrical contact with the burning ignition composition and conductive plasma to thereby extend the circuit reform time.

The invention is further illustrated with reference to the drawings, of which FIG. 1 is a cross-sectional view of a delay type initiator containing a combination of shunt structure and ignition system of the invention; FIG. 1A is a partial view of the assembly of FIG. 1 except that it (FIG. 1A) illustrates an often preferred form of shunt structure providing for a predetermined width of effective shunt surface intermediate the leg wires; FIG. 1B is a view taken along the line 1B—1B of FIG. 1A; FIG. 1C is a view of still another often preferred form of shunt structure which can be substituted in FIG. 1A for the structure of FIG. 1B, and also providing for a strip type shunt of predetermined effective width intermediate the lead wires; and FIG. 1D is a partial view of the initiator assembly of FIG. 1 additionally showing insulation at the lead wire terminal ends in the entire ignition area for purpose of increasing firing circuit reform time. Like parts in the drawings are designated by like numbers.

Referring to FIG. 1, elongated shell **10**, of delay electric blasting cap assembly **9**, is generally metallic and often formed from aluminum, bronze, or copper. Base charge **16** in closed end **17** of shell **10** is any suitable high explosive such as PETN (pentaerythritol tetranitrate), and a suitable primer composition **18** such as diazodinitrophenol, is superposed on base charge **16**. Delay fuse **19** is any suitable delay assembly such as a lead tube **21** containing a core **22** of delay composition such as BaO_2/Se, BaO_2/Te, and the like, superposed on primer composition **18**. Ignition charge **23** is any well known ignition composition for electric blasting caps, such as for example, Pb-Se, Pb-Te, red lead-boron, red lead-manganese boride and the like, having ignition characteristics described more fully hereinafter, and is superposed on delay assembly **19**; and dielectric plug **12** is superposed on ignition composition **23** in closing relationship with shell **10** as an ignition plug member. An electrically conductive member **24**, as a shunt more fully described hereinafter, is superposed on ignition plug **12** and dielectric plug member **26** is injection molded above shunt **24** in the top, and open end **27**, of shell **10** as a closure plug therefor.

Conductor, or lead, wires **11** extend into shell **10** through open end **27**, closure plug **26**, shunt **24**, and ignition plug **12** into ignition composition **23**, in ignition area **23'**, into electrical contact at their terminating ends **11***a* and **11***b* with bridge wire **13** at the terminal ends **13***a* and **13***b* thereof, respectively. Shunt member **24** is any suitable material having electrical conductive properties described hereinafter and disposed outside the ignition area, or zone, **23'**, transverse to the shell **10** axis in electrical contact with lead wires **11**, and if desired, also with the inner wall of shell **10**.

Ignition charge **23** is ignited in response to passage of firing current through the firing circuit **31**, i.e., in response to heat developed by passage of the firing current through bridge wire **13** via leg wires **11**. Delay fuse **22** is ignited in response to heat from burning of ignition composition **23**, primer composition is detonated in response to heat from burning of delay fuse **21**, and base charge **16** is detonated in response to detonation of primer composition **18**.

The electrically conductive shunt material in accordance with the invention can be one which provides the required resistance decrease by one of several routes dependent on the characteristics of the particular material. Thus the electrically conductive material can have a negative temperature coefficient of resistance sufficiently great to accomplish the requisite resistance lowering; or it can be one which ignites to form a burning front of sufficiently low resistance across the lead wires. Additionally, the shunt material can be one which will break down under the high voltage of the arc-forming firing current; or it can be a low melting conductive material which will melt and form a solid conductor across the lead wires under the arc-forming firing current conditions. In still another form, the shunt material can be a thin vapor-deposited metal film which will conduct, vaporize, and strike an arc

across the lead wires. Of the various routes, that now preferred comprises a shunt material which will ignite and burn to form a low resistance burning front so as to set up a voltage breakdown across the bridge wire-leg wire terminals to cause fusion of the leg wires. In all events, there is a reduction in shunt resistance developed subsequent to introduction of the excess firing current into the assembly and it is the resistance decrease correlated with the reform time of the firing circuit, as above described, which makes the shunt structure-ignition system operable in accordance with the invention.

Although, the shunt material is necessarily disposed in electrically conductive relationship with the separate lead wires, it is not required that the shunt material extend the entire distance between the lead wires. It can be of any suitable dimension, and in any location within the shell so long as it is outside the ignition area, i.e., outside the shell portion containing the ignition composition, and connects with the separate lead wires in electrically conductive relationship therewith.

Although any suitable material having the above-described electrical conductor characteristics can serve as a shunt material in accordance with the invention, often preferred shunt assembly structures are those of FIGS. 1A–1B, and of FIG. 1C, in each of which a suitable shunt material is positioned on a well known antistatic member as a base element therefor.

FIG. 1A is a section of the assembly of FIG. 1 containing adjacent portions of ignition plug **12** and closure plug **26** except for shunt assembly **24'** in place of shunt **24**. Shunt assembly **24'** comprises as a material strip; or disc, **28** supported on the lead wires intermediate plugs **12** and **26** at the facing end **26'** of plug **26**. Dielectric strip **28** extends across the interior of shell **10** in contact with opposing inner wall shell portions thereof and in direct contact with lead wires **11** which extend therethrough; and strip **28** can be a strip extending across a central portion of the shell or, alternatively, a disc substantially closing the shell interior.

Layer **29** of assembly **24'** is a material of low electrical resistance such as a suitable metal, conductive ink type coating, or the like, intermediate strip **28** and ignition plug **12** and extending from direct electrical contact with separate inner wall portions of shell **10** and across the central interior thereof.

Conductor layer **29** is divided into three separate portions by spaced apart electrically non-conductive gaps **33**, **34** and **35**, each extending completely across layer **29** and in parallel. Gap **34** extends intermediate the lead wires **11**, gap **33** is disposed intermediate a shell **10** inner wall portion and the lead wire closest to that wall portion, and gap **35** is disposed intermediate the opposite wall portion of the shell and the other lead wire closest thereto. Each of gaps **33** and **35** is of sufficient width to provide a path of resistance for a static charge to follow in lieu of its passage through the ignition composition, and thus it must be of such dimension to have a breakdown potential lower than that of the ignition composition but sufficiently high to provide resistance to flow of stray currents. Gap **34** precludes short circuiting of firing current across the lead wires.

A strip **30** of shunt material of the invention is supported on layer **29** across gap **34** in electrical contact with layer **29** and hence with lead wires **11**, and, in the embodiment shown, in direct contact with lead wires **11**. The effective shunt **30** in the embodiment of FIG. **1A** is that portion of strip **30** superposed on gap **34**; and, by adjustment of the width of gap **34**, the effective resistance, and resistance decrease time of shunt **30**, is regulated over a broad range. If desired, strip **30** can be a layer of suitable shunt material filling the gap **34**. The embodiment of FIG. **1A** is further illustrated with reference to FIG. **1B** which is a view along the lines **1B—1B** of FIG. **1A** and further illustrates the width of gap **34** as the effective width of shunt **30**.

The combination of dielectric strip **28** and conductive layer **29** can be a printed tape, i.e., a dielectric strip **28** on which the conductive material **29** is printed on spaced apart surfaces of the strip **28** to provide the requisite gap structures **33**, **34** and **35**. Such printed tape structure is a well known type of antistatic device for electric blasting caps.

Another printed tape often utilized to provide gap structure for overlapping by a shunt material intermediate the lead wires, i.e., in lieu of a printed tape **29–29** of FIG. **1A**, is that disclosed in U.S. Pat. No. 3,333,538 of Schnettler, and comprises a plurality of hexagonally shaped electric conductors printed on a dielectric strip in uniformly spaced apart relationship so as to be separated by gaps of the same width. Gap structure of the tape of U.S. Pat. No. 3,333,538 is provided between the lead wires, and between the shell walls and the lead wires and performs the same function as that of gaps **33**, **34** and **35** of FIG. **1A**. The entire disclosure of U.S. Pat. No. 3,333,538 describing the assembly of hexagonally shaped bodies and the dielectric strip on which they are printed, and the function of the entire printed tape structure to impart antistatic properties to an electric blasting cap type initiator is incorporated herein by reference.

FIG. **1C** is further illustrative of shunt structure system containing the above described tape assembly of the Schnettler patent, U.S. Pat. No. 3,333,538. Referring to FIG. **1C**, which is a view the same as that of FIG. **1A** except that it shows shunt assembly **24''** in lieu of shunt **24'**, printed tape **28'—29'** comprises dielectric strip **28'** which can be the same as strip **28** of FIG. **1A**, and a plurality of electrically conductive hexagonal surfaces **29'** spaced apart to provide gap pluralities **33'**, **34'** and **35'**, corresponding respectively, and equivalently, to gaps **33**, **34** and **35** of FIG. **1A**, in accordance with specifications therefor set forth in the Schnettler patent U.S. Pat. No. 3,333,538.

More specifically, and as disclosed in U.S. Pat. No. 3,333,538, the plurality of electrically conductive bodies uniformly disposed on the surface of the dielectric material member are equilateral hexagons of substantially the same size except for such equilateral hexagons intercepted as described hereinafter, and disposed in a pattern of separate sets of parallel rows; all adjacent hexagons in each row being equally spaced apart from each other, and from adjacent hexagons in each adjacent row, such that the directly opposing sides of all adjacent hexagons in said pattern are parallel, and equally spaced from each other whereby all hexagons of said pattern are separated by gaps of substantially the same width; any said conductive body at the end of a row of said bodies and intercepted by said inner shell wall having its shape concomitantly altered, and being

in electrical conductive contact with the said wall along the entire resulting line of interception; the shortest distance from each of said electrical conductor wires to said shell wall being on the line of centers of said conductor wires along said dielectric member and equal to the sum of the shortest distance between parallel sides of one of said equilateral hexagon conductive bodies and the width of one of said gaps, and the distance between said conductive wires being at least equal to said sum; and said pattern of conductive bodies being disposed on said dielectric member such that the rows of one of said separate sets of parallel rows are parallel to the above said line of centers of said electrical conductor wires.

Shunt material **30'**, which can be same as shunt material **30** of FIG. **1A**, is disposed on conductive layer **29'** of the printed tape **28'—29'**, in overlapping relationship with the gap structure **34'** intermediate the lead wires.

In the fabrication of one form of electric blasting cap assembly of the invention, the cap shell, open at one end, is charged through the open end with base charge, primer, delay and ignition compositions, in that order. An ignition plug is formed by molding a pair of pin wires in the requisite shaped dielectric material. The pin wires are then bridged with suitable resistance wire at the terminal ends thereof to be emplaced in the ignition composition. The resulting plug assembly is then inserted forwardly, bridge wire end first, into the shell through the open end thereof until the rearward side of the plug is substantially flush with the open end of the shell. The shunt assembly is then emplaced around the pins and onto the rearward face of the ignition plug and the lead wires outside the shell are then welded to the pin wires after which the resulting ignition plug-shunt assembly is forced forwardly into the shell and onto the ignition composition with the bridge wire and terminal lead wire ends emplaced within the ignition composition. The closure plug is then injection molded in the open end of the shell and onto the shunt assembly as a closure to complete the blasting cap assembly.

In have further discovered that by the presence of an inert diluent ingredient in the ignition composition, the burning rate of the ignition composition is decreased sufficiently to lengthen the time required for generation of a burning front of gases and/or conductive slag for reforming the firing circuit. Hence in this manner, the reforming time can be extended to allow more time for the requisite shunt resistance decrease and afford selection of a suitable shunt material from a correspondingly broader range of resistance decrease times for any given ignition composition. Exemplary of now preferred diluent materials for use as inert ingredients for extension of reform time are diatomaceous earth, ground glass, mica, polyethylene powder, phenolic microballoons, bulking agents and the like; and an amount of inert diluent from about 1 to 50 weight percent of the ignition composition is generally utilized. Snow Floss (see Table 3) is a now preferred inert diluent, and is generally utilized in a proportion of from about 2 to 30 weight percent of the ignition composition.

I have further discovered that circuit reform time for the ignition composition can be increased by the presence of electrical insulation lead wire terminals within the ignition area, as illustrated with reference to FIG. **1D**. As shown in FIG. **1D**, the entire length of each of the lead wire end terminals within the ignition area is covered with insulation material **32** for insulating those terminal ends so as to deter arc formation across those terminals when an arc-forming current is passed through the firing circuit. The period of complete deterrent action is determined by the heat stability of the particular insulation material, the arc-forming firing current energy level, and the thickness of the insulation layer which is generally from about one-half to 15 mils. In this manner the circuit reform time is longer as a function of the properties of the insulation material **32** to insulate the terminal lead wire ends from electrical contact with the burning ignition composition. Exemplary insulation materials **32** include silicone rubber, high temperature enamels, Glyptal and any of various commercially available resin insulator materials.

The invention is illustrated with reference to the following examples.

EXAMPLE 1

The following tabulation illustrates various types of shunt materials of the invention:

TABLE 1

Type of Shunt	Electrical Properties (at 110 volts, 10 amps.) initial resistance (ohms)	resistance decrease time (ms.)	shunt resistance after resistance decrease time (ohms)
I. Negative temperature coefficient of resistance			
A. Thermistors*	100	10	10
B. Graphite-filled conductive ink type coatings Graphite-silver ink (10/90, wt.)	40	250	5
II. Low melting point conductive ink type coating which melt and form low resistance solid conductors under high current loads			
Lead powder/high resistance silver ink (50/50 wt.)	10	250	5
III. A conductive ink type coating which will ignite and form a low resistance burning front			
Pb/Se/silver ink (54/21/25, wt.)	10	0.5 60	
Pb/Se/silver ink (57.6/22.4/20, wt.)	30	100	0.8
IV. A thin metal coating which will conduct, vaporize and strike an arc between the leg wires			
About 0.00005 inch vapor-deposited Al layer of Mylar	22	1 140	
About 0.0001 inch vapor-deposited Al layer on Mylar	15	100	1

*Semi-conductors of ceramic material made by sintering mixtures of metallic oxides such as oxides of manganese, nickel, cobalt, copper, iron and uranium.

EXAMPLE 2

Several ignition compositions were tested for circuit reform time. Each composition was tested as an ignition charge in each of a plurality, or group, of from 5 to 10 electric delay blasting caps under each of the two sets of firing current conditions shown. In all tests, the caps were the same except for the ignition composition variances. The reform time in each instance was measured by observation of the firing current on an oscilloscope and noting the plateau of no current flow across the bridge wire terminals. Six compositions were tested and the averaged data for each group are summarized as follows:

TABLE 2

Group	Ignition Composition* (wt. basis)	Circuit Reform time, milliseconds (ms) 110 volts 10 amps. (AC)	440 volts 300 amps. (AC)	with insulation at** bridge wire terminals 440 volts 300 amps. (AC)
A.	Pb/Se (72/28)	20 instantaneous		—
B.	Pb/Se/SF (70.56/27.44/2)	50	.05	2
C.	Pb/Se/SF (64.8/25.3/10)	10,000	0.4	—
D.	Pb_3O_4/B (97/3)	—	1.2	—
E.	Pb_3O_4/B/SF (87.3/2.3/10)	—	1.6	—
F.	Pb_3O_4/B/SF (73.6/6.4/20)	—	3.2	21.2

*Pb = lead; Se = selenium; Pb_3O_4 = red lead oxide; and SF = Snow Floss (a diatomaceous earth comprising siliceous skeletons of microscopic aquatic plants of sufficient purity to be substantially white - see U.S. 3,048,507).

**A layer of silicone rubber type insulation, having a thickness of 7 mils, around each bridge wire terminal and covering each terminal lead wire along a length of about 0.2 inch, as illustrated with reference to FIG. 1D.

The above tests illustrate circuit reform time of the subject ignition compositions and the relationship thereto of inert diluent (SF), and electrical insulation of the bridge wire terminals. Thus at 440 volts and 300 amps. (AC), the reform time in the A, B, and C groups increased from 0 to 0.4 ms. with increase of from 0 to 10 percent diluent, and in the D, E, and F groups, it increased from 1.2 to 3.2 ms. with increase of from 0 to 20 percent diluent; and with insulation at the bridge wire lead wire terminals in the B group, the reform time increased from 0.05 to 2 ms., and, in the F group, from 3.2 to 21.3 ms.

EXAMPLE 3

In another set of tests, several electric delay blasting caps the same as those of groups B–F of Example 2, except that each contained a shunt element in accordance with the invention, were respectively fired in groups B′–F′, incl., of at least 5 shots in each group, at 440 volts and 300 amps. (AC). In the groups B′ and C′ and one group E′ (see Table 3), the shunt assembly was that of FIG. 1A in which, as regulated by the width of gap 34 (FIG. 1A), the effective width of the shunt was 0.020 inch. In the remaining series, viz. E′ and the six F′ groups, the shunt assembly was that of FIG. 1C, the total effective gap 34′ width intermediate the bridge wires being 0.010 inch and hence the effective width of the shunt. The averaged data for the above tests are summarized in Table 3 and the blasting caps tested, all of which were the same except for the shunt means (see Table 3), are summarized as follows:

Cap Shell	
Shell material	Commercial Bronze
Dimensions, inches	
Length	3.12
Outside diameter	0.278
Inside diameter	0.256
Base Charge, grams	
PETN/Graphite (98/2)	0.41
Primer Charge, grams	
Diazodinitrophenol	0.33
Two layers, grams	
Top, lower density	0.08
Bottom	0.25
Delay Composition	
BaO_2/Te/Se (40/40/20)	1″× ⅛″ core in lead tube
Ignition Composition	See Table 2
Ignition Plug	Bakelite
Shunt (Assembly of FIGS. 1A or 1C - see Table 3)	
Effective width	⅛″
Thickness	0.002–0.007″
Lead Wires (Copper)	22 B&S Gauge
Bridge Wire	
Nichrome	
Diameter	0.0016″
Ohm/ft.	1.65
Top Closure	Injection molded plastic

TABLE 3

Group (see Table 1 for composition)	Circuit Reform time of ignition composition ms.	Material	Initial resistance (ohms)	Resistance decrease time (ms.)	Results
B′(1)	0.05	Metal Ink Type Coating [Silver Ink/Pb-Se (65/25.2–9.8)]	0.2	1	6S 3F
C′(1)	0.4	"	0.2	1	8S 2F
E′(1)	1.6	"	0.2	1	10S
E′(2)	1.6	metal ink type coating [Silver Ink/Pb-Se (25/54–21)]	15	2	5S 6F
F′(2)	3.2	"	15	2	10S
F′(2)	3.2	metal ink type coating [Silver Ink/Pb-Se (20/57.6–2 2.4)]	35	4	4S 2F
F′(2)	21.2(3)	"	35	4	6S
F′(2)	3.2	Vapor-deposited aluminum coating on Mylar(4). Al layer thickness, about 0.05 mil.	22	6	3S 6F
F′(2)	3.2	vapor-deposited aluminum coating on Mylar(4). Al layer thickness, about 0.1 mil.	15	5	6S 3F
F′(2)	21.2(3)	"	15	5	8S

S = Shot F = High voltages Failure (Ruptured shell)

(1) Shunt structure of FIG. 1A

(2) Shunt structure of FIG. 1C

(3) Insulated bridge wire-lead wire terminals (Silicone type rubber, about 4 mils thickness)

(4) Trade name (E. I. duPont de Nemours & Co.) designating a polyester film, about 7 mils thickness.

The above data (Table 3) demonstrate high voltage failures that are obtained when the firing circuit reform time of the ignition composition is less than the resistance decrease time of the shunt, and show uninterrupted series of successful shots obtained when the firing circuit reform time exceeds the shunt resistance decrease time. The data also demonstrate that resistance decrease time is longer at the higher initial resistance levels.

Thus, in the groups B′, C′, and E′ in which the shunt resistance decrease time was 1 millisecond, 3 of 9 shots failed when the circuit reform time was 0.05 ms., and there were two failures of 10 shots when the firing circuit reform time was 0.4 ms., but still less than the resistance decrease time of the shunt. However, all of a series of 10 shots were successful when the circuit reform time was 1.6 milliseconds, which was longer than the resistance decrease time of the shunt (1 millisecond).

Similarly, in the tests of the remaining groups of Table 3, there were failures in each series in which the resistance decrease time of the shunt was greater than the circuit reform time of the ignition composition; but

in those groups in which the resistance decrease time of the shunt was less than the circuit reform time of the ignition composition, there were no failures.

When referring herein to a conductive ink type coating, it is meant a coating of uniformly distributed particles of a conductive material, applied as an ink, or paint, together with any other required shunt material ingredients incorporated therein. The conductive ink is a suspension of the conductive material, in a suitable binder material such as an epoxy resin together with a solvent, when required, for maintaining fluidity. The proportion of binding material may often constitute one-third or more of the ink. A layer of the ink and any other required shunt materials incorporated therein is emplaced and then heat cured (with solvent removal) to form the resulting dry solid ink type coating. In preferred practice, the suspended conductive particles of the ink are metal, thus providing for metal ink type coatings.

Operability of the shunt material depends not only upon its ability to provide the requisite low electrical resistance path across the lead wires in response to flow of an arc-forming firing current through the circuit, but also upon its initial resistance for permitting flow of no-arc firing current, and its resistance decrease time which must be less than that of the circuit reform time for the particular ignition composition. Thus the resistance across the shunt during flow of a no-arc firing current must be sufficiently high for the shunt to be substantially non-conductive of the no-arcing firing current, or, in any event, to be sufficiently non-conductive of the no-arc firing current to permit flow of same through the circuit for the intended firing even though the firing current initially introduced into the circuit may be shunted in an insignificant proportion as a function of the small extent to which the shunt is conductive of the no-arc firing current. On the other hand, in response to the flow of an arc-firing current, the resistance across the shunt must be lower than that across the lead wire terminal ends after the reform period, in order that the flow of arc-forming firing current then be diverted across the shunt. Further, the change from the initial shunt resistance to the low resistance for shunting must take place during the reform period.

Although the shunt material is often of a single ingredient type such as a supported metal layer, or a ceramic type conductor, it can in many instances constitute a combination of ingredients having different electrical resistances as illustrated in Table 3 with reference to metal ink-type coating shunts, and the particular ingredients and their relative proportions are selected so as to be compatible with the ignition composition to be utilized. Thus, a shunt material formed from silver ink/Pb-Se (25/54–21) functioned successfully (all shots) in an assembly in which the ignition composition was red lead/B/SF (73.6/6.4–20). Had the lower resistance ink ingredient content been too high, the initial shunt resistance would have been correspondingly low and there would have been undue loss of no-arc firing current across the lead wires to impair the shots; and had the higher resistance Pb-Se ingredient content been too high the initial shunt resistance would have been unduly high with corresponding extension of the resistance decrease time to beyond the circuit reform time. By way of further example, the ingredient proportions of the shunt material, although not suitable for optimum use of the shunt in the group B′ tests would have been suitable had the SF content of the particular ignition composition been higher to provide a correspondingly longer reform time.

The electrically conductive shunt material of the invention may have an initial electrical resistance as high as 1,000 ohms, the higher resistance levels being more applicable to correlation with circuit reform time when the lead wire terminals are insulated as described herein. More often, the initial shunt resistance is generally within the range of 0.2 to 40 ohms, and generally from about 10 to 35 ohms, with decrease during flow of arcing firing current to a value as low as about 0.1 to 5 ohms, at a suitable resistance decrease time generally from 1 to 15 ms., as measured at 440 volts. Concurrently, the reform time of the firing circuit is a longer period, often in the range of from 5 to 20 ms.

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

1. In an electric delay type initiator assembly for firing under high energy firing current conditions including as an electrical firing circuit a pair of electrical lead wires extending into the ignition area and connecting therein with a resistance wire disposed in operative contact with an ignition composition to ignite said composition in response to heat generated by flow of the high energy firing current through said resistance wire, the improvement comprising means for shunting an arcing firing current from said ignition area after initial flow of same through the firing circuit and before expiration of the circuit reform time, to thereby protect said assembly against arcing across the lead wire terminal ends within said ignition area and accompanying failure of the assembly, said means comprising an electrically conductive material disposed outside, and electrically insulated from, said ignition area along a path in electrically conductive contact with said lead wires as a shunt for diverting flow of an arcing firing current from said ignition area, said shunt having an electrical resistance sufficiently high to be sufficiently non-conductive of a no-arcing firing current to permit flow of same through said circuit, but, in response to flow of an arcing firing current through said circuit, said shunt providing a decrease in electrical resistance across said path to less than that across the lead wires in said ignition area, and the resistance decrease time of said shunt and the circuit reforming time being correlated so that said shunt undergoes said decrease in electrical resistance during the period of said circuit reforming, to thereby conduct the arcing firing current for diversion from said assembly.

2. An initiator assembly of claim 1 wherein said shunt material is a metal ink type coating.

3. An initiator assembly of claim 2 wherein said coating is a uniform distribution of particulate silver together with lead and selenium.

4. An initiator assembly of claim 1 wherein said shunt material is a metal layer supported on a dielectric material.

5. An initiator assembly of claim 4 wherein said metal layer is a vapor-deposited aluminum on said dielectric material.

6. An initiator assembly of claim 1 wherein said ignition composition contains an inert diluent in sufficient amount to increase the circuit reform time.

7. An initiator assembly of claim 6 containing Snow Floss as said diluent.

8. An initiator assembly of claim 7 containing from 2 to 30 weight percent of said Snow Floss.

9. An initiator assembly of claim 1 wherein the entire length of the terminal ends of said lead wires within said ignition area are coated with a layer of dielectric material as electrical insulation therefor to increase the circuit reform time.

10. An initiator assembly of claim 9 wherein the thickness of said layer of insulation material is from about 0.5 to 15 mils.

11. In an initiator assembly of claim 10, a silicone type rubber as said dielectric material.

12. An initiator assembly of claim 1 wherein said ignition composition is a member of the group consisting of a Pb/Se, Pb/Se/SF, Pb_3O_4/B, and Pb_3O_4/B/SF.

13. An initiator assembly of claim 1 wherein said ignition composition is a Pb_3O_4/B/SF, and said shunt material is a member of the group of a metal ink type coating formed from a silver ink and Pb/Se, and a vapor-deposited layer of aluminum on a dielectric support member therefor.

14. An initiator assembly of claim 13 wherein the terminal ends of said lead wires in the ignition are coated with a dielectric material to increase the circuit reform time.

15. An initiator assembly of claim 14 wherein said insulation material is a silicone type rubber.

16. An initiator assembly of claim 1 wherein said shunt material has a resistance of from about 0.2 to 1,000 ohms under no-arcing firing current conditions, and in response to flow of an arc-forming firing current provides a decreased resistance across said path of from 0.1 to 5 ohms and has a resistance decrease time of from about 1 to 15 milliseconds as measured at 440 volts, and said ignition composition having a circuit reform time of from 2 to 20 milliseconds.

17. In an initiator of claim 1, an elongated shell and said ignition composition contained therein, a dielectric plug member within said shell in closing relationship therewith intermediate said ignition composition and one end of said shell as an ignition plug; said lead wires extending into said shell through said shell end and said ignition plug into the ignition area; a dielectric material superposed on the surface of said ignition plug farthest from said ignition area in direct contact with said lead wires; an electrically conductive material of low resistance on the surface of said dielectric material facing said ignition plug and disposed in two spaced apart sections with each said section in direct electrical conductive contact with a separate one of said lead wires, whereby an electrically non-conductive space, or gap, is disposed adjacent said spaced apart sections intermediate said lead wires; and said shunt material is disposed adjacent said ignition plug across said space in electrically conductive contact with each of said conductor sections.

18. An initiator assembly of claim 17 wherein said shell is formed from a metal; an additional pair of said low electrically resistant material sections on said surface, and each of said additional sections adjacent a separate one of the first said sections and spaced apart therefrom and extending into direct electrical contact with the inner wall of said shell, whereby an electrically non-conductive space, or gap, is disposed between each of the last said sections and the section adjacently spaced therefrom; and each gap of said assembly being of sufficient width to have a break-down of potential lower than that of said ignition composition to protect said assembly from premature firing by static electric charges.

19. An initiator assembly of claim 18 wherein said shunt material is a metal ink type coating and said ignition mixture is a Pb_3O_4/B containing Snow Floss as a diluent in amount sufficient to extend the reform time of said ignition composition.

20. An initiator assembly of claim 19 wherein said shunt coating is a silver ink/Pb-Se (65/25.2–9.8) and said ignition composition is Pb_3O_4/B/SF (87.3/2.3/10).

21. In an initiator of claim 1, an elongated metal shell and said ignition composition contained therein; a dielectric plug member in closing relationship with said shell intermediate said ignition composition and one end of said shell as an ignition plug; said lead wires extending into said shell through said shell end and through said dielectric plug into the ignition area; a dielectric material superposed on the surface of said ignition plug farthest from the ignition area in direct contact with said lead wires; a plurality of electrically conductive bodies uniformly disposed on the surface of said dielectric material facing said ignition plug; all of said conductive bodies being equilateral hexagons of substantially the same size, except for such equilateral hexagons intercepted as described hereinafter, and disposed in a pattern of separate sets of parallel rows; all adjacent hexagons in each row being equally spaced apart from each other and from adjacent hexagons in each adjacent row, such that the directly opposing sides of all adjacent hexagons in said pattern are parallel, and equally spaced from each other, whereby all hexagons of said pattern are separated by gaps of substantially the same width; any said conductive body at the end of a row of said bodies and intercepted by said inner shell wall having its shape concomitantly altered, and being in electrical conductive contact with the said wall along the entire resulting line of interception; the shortest distance from each of said lead wires to said shell wall being on the line of centers of said lead wires along said dielectric material and equal to the sum of the shortest distance between parallel sides of one of said equilateral hexagon conductive bodies and the width of one of said gaps, and the distance between said conductor wires being at least equal to said sum; said pattern of conductive bodies being disposed on said dielectric material such that the rows of one of said separate sets of parallel rows are parallel to the above said line of centers of said electrical conductor wires; and the voltage breakdown in said ignition area being greater than that between each said lead wire and said shell along said dielectric material; and said shunt material disposed intermediate said ignition plug surface and said electrically conductive bodies in closing relationship with the total gap space separating said conductive bodies intermediate said lead wires, and in contact with said conductive bodies so as to be in electrical contact with said lead wires.

22. An initiator assembly of claim 21 wherein said shunt material is one of the group of a metal ink type coating formed from a silver ink and Pb-Se incorporated therein, and a vapor-deposited aluminum sup-

ported on a dielectric material; and said ignition composition is a Pb_3O_4/B/SF.

23. An initiator assembly of claim 22 wherein said ignition composition is Pb_3O_4/B/SF (73.6/6.4/20), said shunt material is a vapor-deposited aluminum layer of about 0.1 mil thickness supported on Mylar, and the lead wire terminal ends in such ignition area are coated with a layer of a silicone type rubber material of about 4 mil thickness.

24. An initiator assembly of claim 22 wherein said shunt material is a silver ink/Pb-Se (25/54–21), and said ignition composition is Pb_3O_4/B/SF (73.6/6.4/20).

25. In an electric delay type blasting cap assembly of claim 1 a closed elongated metal shell; a high explosive base charge in one end of said shell, a primer charge superposed on said base charge, a slow burning delay type charge superposed on said primer charge, and said ignition composition superposed on said delay charge; a dielectric closure member within said shell, as an ignition plug, superposed on said ignition composition; said pair of lead wires extending into said shell, through the opposite end thereof and through said ignition plug into said ignition area, and said resistance wire disposed within said ignition charge.

26. An initiator assembly of claim 1 wherein said shunt material is a conductive ink type coating.

27. In an assembly of claim 25, a dielectric material superposed on the surface of said ignition plug farthest from said ignition area in direct contact with said lead wires, and said electrically conductive material disposed on the surface of said dielectric material facing said ignition plug.

* * * * *

PO-1050
(5/69)

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,683,811 Dated August 15, 1972

Inventor(s) Hiram E. Driscoll (Case 3)

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Col. 5, Line 32 & 33 of p.p.;
"a material strip;" -- should read -- "a dielectric material strip,"

Col. 6, Line 22 of p.p.;
"29-29" -- should read -- "28-29"

Col. 8, Table I of p.p.; (Approx. Line 52 - across from Pb/Se/silver ink (54/21/25, wt.)
"10 0.5 60" -- should read -- "10 - 60 0.5"

Col. 8, Table I of p.p.; (Approx. line 61 - across from About 0.00005 inch vapor-deposited Al layer of Mylar)
"22 1 140" -- should read -- "22 - 140 1"

Also, please note Tables I and II

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. U.S.P. 3,683,811 Dated August 15, 1972

Inventor(s) Hiram E. Driscoll (Case 3) - 2 -

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

TABLE I

Type of Shunt	Electrical Properties (at 110 volts, 10 amps) initial resistance (ohms)	resistance decrease time (ms.)	shunt resistance after resistance decrease time (ohms)

-- should read --

Table 1

Type of Shunt	Electrical Properties (at 110 volts, 10 amps.) Initial Resistance (ohms)	Resistance Decrease Time (ms.)	Shunt Resistance after Resistance Decrease Time (ohms)

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. U.S.P. 3,683,811 Dated August 15, 1972

Inventor(s) Hiram E. Driscoll (Case 3) - 3 -

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

TABLE 2

Group	Ignition Composition* (wt. basis)	Circuit Reform time, milliseconds (ms) 110 volts 10 amps. (AC)	440 volts 300 amps. (AC)	with insulation at** bridge wire terminals 440 volts 300 amps. (AC)
A	Pb/Se (72/28)	20	instantaneous	—
B	Pb/Se/SF (70.56/27.44/2)	50	< .05	2
C	Pb/Se/SF (64.8/25.3/10)	10,000	0.4	—
D	Pb_3O_4/B (97/3)	—	1.2	—
E	Pb_3O_4/B/SF (87.3/2.3/10)	—	1.6	—
F	Pb_3O_4/B/SF (73.6/6.4/20)	—	3.2	21.2

-- should read --

Table 2

Group	Ignition Composition* (wt. basis)	Circuit Reform Time, Milliseconds (ms) 110 volts 10 amps. (AC)	440 volts 300 amps. (AC)	With insulation at** Bridge Wire Terminals 440 volts 300 amps. (AC)
A.	Pb/Se (72/28)	20	Instantaneous	-
B.	Pb/Se/SF (70.56/27.44/2)	50	.05	2
C.	Pb/Se/SF (64.8/25.3/10)	10,000	0.4	-
D.	Pb_3O_4/B (97/3)	-	1.2	-
E.	Pb_3O_4/B/SF (87.3/2.3/10)	-	1.6	-
F.	Pb_3O_4/B/SF (73.6/6.4/20)	-	3.2	21.2

Signed and sealed this 9th day of January 1973.

(SEAL)
Attest:

EDWARD M.FLETCHER, JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents