Dec. 13, 1960 C. F. HORNE 2,963,971

INITIATOR ASSEMBLY

Filed Oct. 2, 1957

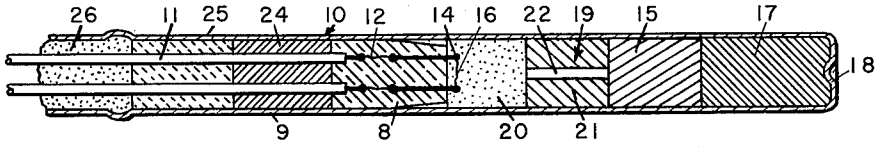


FIG. 1

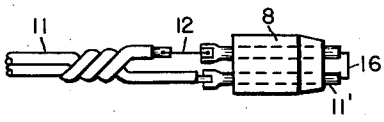


FIG. 2

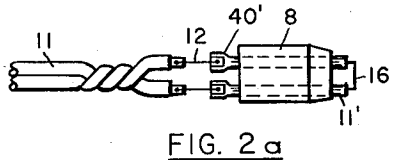


FIG. 2a

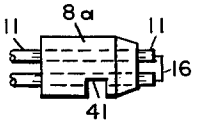


FIG. 3

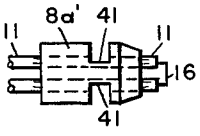


FIG. 3a

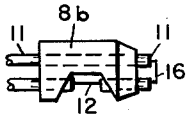


FIG. 4

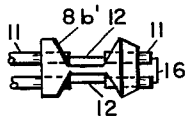


FIG. 4a

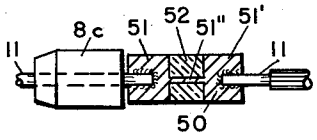


FIG. 5

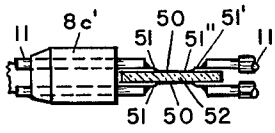


FIG. 5a

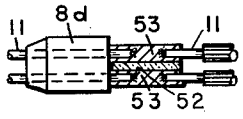


FIG. 6

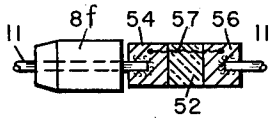


FIG. 7

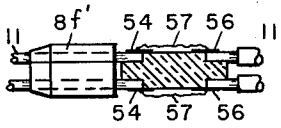


FIG. 7a

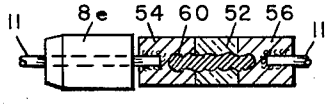


FIG. 8

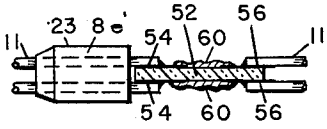


FIG. 8a

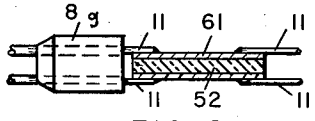


FIG. 9

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AGENT.

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2,963,971

INITIATOR ASSEMBLY

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Filed Oct. 2, 1957, Ser. No. 687,718

19 Claims. (Cl. 102—28)

This invention relates to improved electric initiators. In still another aspect, this invention relates to electric delay blasting caps that can be fired uniformly by current directly from high voltage power lines. In another aspect, this invention relates to an electric delay blasting cap assembly containing a fuse element in at least one leg wire for preventing damage to the cap together with concomitant failure, when high voltage currents are utilized. In another aspect this invention relates to fuse structure in at least one leg wire of an electric delay blasting cap, characterized by a tensile strength at least as high as that of the leg wire with which it is associated. In still another aspect this invention relates to a method for utilizing high voltage currents in firing electric delay blasting caps.

As is well known, an electric delay blasting cap comprises a shell, a detonating charge, a delay fuse in close proximity to the detonating charge, or to a primer which in turn is disposed in close proximity to the detonating charge, leg wires within the shell and connected therein at their terminal ends by a resistance or bridge wire at a point above the delay fuse, and at their other ends with lead wires from the power source, and an ignition composition around or in close proximity to the bridge wire which is ignitible by heat from the wire upon passage of electric current therethrough so that by its ignition it sets off burning of the fuse followed by detonation of the base charge, or the primer and then the base charge as the case may be.

Ordinarily, electric blasting caps are fired by a battery charge, or a blasting machine which is essentially a hand-driven dynamo and which delivers a short duration of current, e.g., for 20–25 ms. and exhibits a voltage generally in the order of about 100–400. Very frequently, however, blasting machines, batteries, or other ordinary current sources are not available at the scene of operations and resort is had to the available power line sources, generally 220 or 440 volts, which supply excessive amperage and power for firing electric blasting caps.

When so utilizing a high voltage power line there is a great tendency for the formation of an arc within the casing of the blasting cap which by development of heat, causes high pressure within the cap and consequently bursting of the cap shell before the slow burning fuse has burned down to the detonating charge or sometimes before it has been ignited. Such bursting of the cap shell has the effect of destroying the cap shell, moving the burning fuse away from the primer, or detonating charge, and for allowing the entrance of water into the delay, thereby causing failure to detonate, or misfires of the dynamite charge in the borehole.

Such arcing may occur along the path of the volatilized bridge wire after the bridge wire has been melted by the heat from the current passing through it. Arcing may also occur within the cap shell if the two lead wires are in too close proximity to one another or to the cap shell. In either case, the result is the bursting of the cap shell and scattering of the cap elements by the internal pressure, so that the fuse has either failed to ignite or it is extinguished after it is ignited.

This invention is concerned with an electric delay blasting cap assembly containing a fuse device for permitting use of high voltage firing currents without the occurrence of arcing and bursting of the cap shell and concomitant failure of the delay fuse to set off the detonating or base charge.

An object of this invention is to provide improved electric initiators. Another object is to provide a delay blasting cap especially adapted to firing by high voltage currents. Another object is to provide a novel fuse assembly in an electric delay blasting cap for the elimination of arcing of the firing current in the blasting cap and concomitant bursting and failure of the cap. Another object is to provide a method for utilization of high voltage currents in the firing of electric delay blasting caps. Other aspects and objects will be apparent in light of the accompanying disclosure and the appended claims.

In accordance with the invention there is provided an improvement in an electric delay initiator assembly containing leg wires within the cap shell, a bridge wire in the cap shell connecting the said leg wires, and associated ignition, delay and base charge compositions, the said improvement permitting high voltage current firing without loss of the cap from bursting, and comprising a fusible electrical conductor in at least one of the leg wires, within the cap shell; the said conductor and the bridge wire each being characterized by a fusion point such that it will fuse within a period of 120 milliseconds when the initiator is fired at a voltage sufficiently high to deliver a current of at least 10 amperes to the bridge wire; said bridge wire being fusible during said firing prior to fusion of the said conductor. Further in accordance with the invention an improvement is provided in a method for the utilization of high voltage currents in firing electric delay blasting caps which improvement comprises, maintaining an electrical conductor section in at least one of the leg wires, within the cap shell, having a fusion point such that it will fuse within a period of 120 milliseconds when firing the initiator at a voltage sufficiently high to deliver a current of at least 10 amperes to the bridge wire, and utilizing a bridge wire having a fusion point such that it will also fuse within 120 milliseconds when said initiator is fired as described, but prior to fusion of said conductor, whereby flow of current through said leg wire is terminated prior to the occurrence of sufficient arcing to cause bursting of the cap shell and concomitant failure of detonation of the base charge.

The invention is illustrated with reference to the attached drawings of which Figure 1 is a front elevational view of an electric delay initiator assembly of the invention, and Figures 2–9 are illustrative of various embodiments of conductor or fuse elements which can be inserted in one or both leg wires of the assembly to provide adequate tensile strength so that the lead wire is not pulled apart during handling of the cap due to the limited strength of the fuse element itself.

With reference to Figure 1, shell **9** of electric delay blasting cap **10**, generally a metal, can be of any suitable material. Leg wires **11** in shell **9** connect with lead wires from a power source (not shown) and each contains a conductor section **12**, preferably within ignition plug **8**. Leg wires **11** are connected in shell **9** at the terminal ends **14** below plug **8**, with a resistance or bridge wire **16**. A suitable primer **15** such as diazodinitrophenol is superposed on a base charge **17** such as pentaerythritol tetranitrate (PETN) in closed end **18** of shell **9**. Delay fuse **19** comprises any suitable assembly, such

as a lead tube **21** containing core **22** of a suitable delay powder, e.g., BaO_2/Se, superposed on primer **15**.

An ignition or flash composition **20** is disposed in operative communication with bridge wire **16** so as to be ignited by heat from wire **16** resulting from passage of electric current by way of leg wires **11**. Leg wires **11** extend upwardly from bridge wire **16** in shell **9** through ignition plug **8** through a sulfur plug **24**, a suitable waterproofing plug **25** and a sulfur topping plug **26** and are joined in any suitable manner with a power source outside shell **9** including a source of high voltage current.

Conductors, or fuses, **12** which each comprises a "link" in leg wire **11** within shell **9** are characterized by a fusion point such that they fuse within a period of about 120 milliseconds (ms.) when the cap is fired at a voltage sufficiently high to deliver a firing current of at least 10 amperes to the bridge wire. Bridge wire **16** is also characterized by a fusion point such that it will also fuse within 120 milliseconds under the said firing conditions except that, under those conditions, it will fuse prior to the fusion of conductors **12**. Thus, if bridge wire **16** and fuse elements **12** are of the same alloy, the cross-sectional diameter of bridge wire **16** will be somewhat smaller than that of each fuse **12**. In any event, it is a matter of selecting bridge wire **16** and fuse element **12** in respect of their relative fusion points, specific resistance, and the like. Fuse elements **12** and bridge wire **16** are selected so as to fuse preferably within 35–100 milliseconds after the high voltage firing current is applied.

Bridge wire **16** is advantageously a plain or gold-plated Nichrome wire (nickel/chromium/iron, 60/16/24), a diameter of about 0.00175 inch being representative of the preferred wire thickness. Further exemplary is a platinum/rhodium/ruthenium wire 79/15/6 having a diameter of about 0.001 inch.

The cross section of the fuse wire **12** is, of course, selected consonant with the size and fusion point of the bridge wire **16**. For example the diameter of a Nichrome fuse wire will be somewhat larger than the 0.00175 value of a Nichrome bridge wire, such as about .0056 inch in diameter.

In the preferred embodiment of the structure of this invention, the bridge wire and the conductor or fuse wire are of the same alloy, the diameter of the conductor wire being generally from about 0.001 to 0.008 inch greater than that of the bridge wire.

It is an important feature of the invention that the conductor wire and the bridge wire both fuse within a period of about 120 milliseconds. When longer periods are employed, that is to say, when the current flows for a period longer than 120 milliseconds, sufficient temperature has developed within the blasting cap as to cause development of sufficient heat and pressure to bring about bursting of the shell and failure of the detonation.

The following alloys are representative of those particularly advantageously applied as either or both fuse wire **12** and bridge wire **16**: Nichrome, karma, advance, platinum alloy, or any wire normally utilized for bridge wires in electric blasting caps. The fuse wire need not be of the same composition as the bridge wire but may be zinc, copper, aluminum or any wire commonly known to the art.

Ignition, delay, primer, and detonator compositions well known in the art for use in delay electric blasting caps can be employed in the practice of this invention. Thus, exemplary of these compositions are ignition compositions such as a loose charge of lead/selenium (72.4/27.6), dipped bridge compositions (matchhead type) such as paraphenylenediamine dipicrate/potassium chlorate/Snow Floss (trade name highly purified earthy formation of siliceous skeletons of diatoms) 24/56/20, lead mononitroresorcinate/potassium chlorate, 80/20, and the like; delay compositions such as barium peroxide-selenium 84/16, barium peroxide-tellurium, potassium permanganate-selenium, red lead-sulfur, and the like; primer compositions such as diazodinitrophenol, mercury fulminate, mercury fulminate/potassium chlorate, diazodinitrophenol/potassium chlorate, and the like; and detonator or base charge compositions such as pentaerythritol tetranitrate, cyclotrimethylene trinitramine (cyclonite), tetryl lead azide, and the like.

The conductor or fuse wires **12** are preferably disposed within ignition plug **8** in order that maximum support can be given by the plug assembly to the leg wires **11** in lieu of the loss in tensile strength that occurs when the lower tensile strength conductor wire **12** is inserted as a section in the wire **11**. However, if desired, conductors **12** can be positioned outside the ignition plug, but still within the shell **9** such as within sections **24**, **25** or **26**, which can be respectively a sulfur plug, a waterproofing plug, and a sulfur topping.

With reference to Figure 2, is shown an ignition plug **8** through which leg wires **11** extend, and outside of which one of the lead wires **11'** is directly connected with a leg wire **11** and the other is connected with a leg wire **11** through the fuse wire **12** which is preferably a Nichrome wire about .0056 inch diameter and ⅛ inch long, having a specific resistance of about 650 ohms./avg. mil foot. Bridge wire **16** is "matched" to wire **12** in that upon the passage of high voltage current (delivering at least 10 amperes to the bridge wire) through the leg wires and the bridge wire, they are both fused within 120 milliseconds, the bridge wire **16** being adapted to fuse prior to fusion of wire **12**. Figure 2*a* is similar to Figure 2 except that it is illustrative of a fuse conductor **12** in both leg wires **11**, all disposed within the shell **9** of Figure 1.

With reference to Figure 3, ignition plug **8***a* contains leg wires **11**, a section of one of which is cut away to provide a fuse section **41**. Figure 3*a* is similar to Figure 3 except that it illustrates fuse section **41** in both leg wires **11**.

In Figures 4, one leg wire **11** is completely severed and then rejoined by a fuse wire **12**. Figure 4*a* is similar to Figure 4 except that it illustrates a severance of both leg wires **11** and rejoining of each by a fuse wire **12**.

In the practice of the invention it is important that the fuse conductor exhibit sufficient tensile strength as to support the weight of the cap and associated explosive charge during the blasting operation. Frequently, the leg wires support the entire weight of the total explosive charge and in such instance the fuse conductor must exhibit a tensile strength sufficient for such support, say in the order of about 15 to 45 lb. dead weight, for each wire. I have found that although a soldered-in fuse wire or pair of wires can be utilized as above described, the tensile strength requirement often limits the size of the fuse conductor that can be used so that some alloys which exhibit high fusion points and high specific resistance values cannot be used because in such instance the large diameter for the requisite tensile strength may preclude heating to the fusion point.

Therefore, I have provided fuse conductors in the form of assemblies supported on a dielectric material by which the necessary tensile strength is provided by an insulating or dielectric composition which supports the fuse conductors free from any specific tensile strength requirement. Various embodiments of such type assemblies are illustrated with reference to Figures 5–8*a* of the drawings.

With reference to Figure 5, leg wire **11** is disposed in ignition plug **8***c* and is soldered to one end **51** of copper sheet **50**, which sheet is secured to dielectric element **52** to form a "laminate." An uninsulated end of the remaining portion of leg wire **11** is soldered to opposite end **51'** of sheet **50**. Section **51''** of the metal plate **50**, intermediate ends **51** and **51'** is constricted, the constricted portion serving as a conductor fuse of this invention. The copper plate portion is fastened to the dielectric material **52** in any suitable manner such as by

adhesion. Figure 5*a* is the same as Figure 5 except that it shows such a fuse wire assembly associated with both leg wires in the blasting cap. Thus, in Figure 5*a*, a single layer of dielectric material can serve to support two copper sheets insulated from each other for the purpose of supporting leg wires thereto to provide a fuse conductor of this invention.

Figure 6 shows a dielectric type assembly in conjunction with an ignition plug 8*d* in which two individual copper strips **53** are affixed in parallel on the surface of a dielectric member **52** and each of the pair of leg wires **11** is affixed to one of the individual strips to provide a supported fuse assembly. Thus, the strips **53**, each supported on dielectric material **52**, function as the fuse conductor in each of the leg wires **11**.

Figure 7 illustrates a now preferred assembly which comprises plug 8*f* containing separate leg wire portions **11** soldered to separate copper sheets **54** and **56**, each supported on dielectric material **52** and insulated from each other. Copper portions **54** and **56** are connected by a suitable fuse wire conductor **57**, which, as shown, is individually supported by dielectric material **52** and can be made of any desirable dimension independently of any tensile strength requirements therefor. Figure 7*a* is similar to Figure 7 except that it further illustrates such a laminate type assembly in both leg wires.

Figure 8 is illustrative of a painted fuse element of this invention, which is the same as that of Figure 7 except that in lieu of fuse element **57** a finely-divided conductive paint strip **60** covers the dielectric material **52** along the locus intermediate the copper plates **54** and **56**. A preferred conductive material **60** is silver, the preferred paint comprising a suspension of from about 30–50 weight percent of finely divided silver in suitable liquid medium.

Figure 9 is illustrative of an embodiment the same as that of Figure 6 except that the two lead wire-fuse assemblies are on opposite sides of the dielectric material. Thus, fuse conductors **61**, each constituting a separate metal strip as a section of a lead wire **11**, are supported on opposite sides of dielectric member **52**.

The invention is further illustrated with reference to the following examples;

EXAMPLE I

Firing data were obtained employing a short length Nichrome wire (¼ inch) of 0.0025 inch diameter soldered directly into one leg wire as a fuse element of the invention. The entire fuse wire element was sealed within the cap shell by a filling of asphalt, polyester resin (Stypol), or sulfur. The firing was carried out at 220 volts with a line resistance of 15 ohms.

Table 1

Test No.	No. of Trials	Result of Firing
1	10	10 Normal—All Shot.
2	10	10 Normal—All Shot.
3	6	6 Normal—All Shot.

The delay caps fired in each one of these tests employed a loose ignition composition around the bridge wire, lead-selenium, and a barium peroxide/selenium delay fuse. The primer was diazodinitrophenol and the base charge was pentaerythritol tetranitrate (PETN).

EXAMPLE II

Several tests, the same as those described with reference to Example I were made, the cap assembly being the same except that a Nichrome wire fuse element, ¼ inch in length was soldered in each lead wire, within the cap shell, as illustrated with reference to Figure 2*a*. One test was made in the absence of any fuse wire as a control. Data summarizing the tests are set forth in Table 2.

Table 2

FIRING VOLTAGE, 220 VOLTS

Test No.	Fuse Wire	Line Resistance, Ohms	Current Amperes [1]	No. in Parallel	No. of Trials	Results of Firing
		0.2	1,100	1	30	Normal, 9H, 20C—6 Failed.
		2.0	110	1	30	Normal. 29H—All Shot.
		5.0	32.7	1	30	29H, 1C—All Shot.
		10.0	18.8	1	30	20 Normal, 3H, 7P—8 Failed.
4	(Control Test)	0.2	1,100	5	6	1 Normal, 29H—All Shot.
		0.2	1,100	10	5	1 Normal, 42H, 7C—All Shot.
		0.2	1,100	20	3	1 Normal, 56H, 2C, 1P—6 Failed.
		23.5	9.4	1	5	5 Normal—All Shot.
		25.0	8.8	1	25	25 Normal—All Shot.
		15.0	14.6	1	27	4 Normal, 7H, 14P, 2C—9 Failed.
		[2] 9.9	11.1		1	1B—1 Failed.
		0.2	1,100	1	40	40 Normal—All Shot.
		2.0	110	1	40	Do.
		5.0	32.7	1	40	Do.
5	Nichrome [3]	10.0	18.8	1	40	Do.
		0.2	1,100	5	8	Do.
		0.2	1,100	10	4	Do.
		0.2	1,100	20	2	Do.
		0.2	1,100	1	10	10 Normal—All Shot.
		5.0	32.7	1	8	8 Normal—All Shot.
6	Nichrome [3]	10.0	18.8	1	10	10 Normal—All Shot.
		15.0	14.7	1	10	Do.

[1] Delivered to bridge wire. This assumes no transformer impedance.
[2] Firing voltage was 110 volts.
[3] 0.009 inch diameter.

Normal (firing)—No holes in the shells. Cap shell not broken at ignition section.
H—Holes in the shells at ignition section.
C—Shells cut off at ignition section.
P—Plugs pushed or blown from the shells.

EXAMPLE III

Several firing tests were made, differing from those described with reference to tests 5 and 6 of Example II in that a matchhead type ignition composition, paraphenylenediamine dipicrate/potassium chlorate/Snow Floss 24/56/20, with 10% nitrocellulose (lacquer) was employed in lieu of the loose ignition mixture of the caps tested. "Snow Floss" is a trade name for a highly purified (substantially white) soft earthy formation of silice-

ous skeletons of microscopic aquatic plants called diatoms. The data are summarized as follows:

Table 3

FIRING VOLTAGE, 220 VOLTS

Test No.	Fuse Wire	Line Resist.	No. in Parallel	No. of Trials	Result
7	Nichrome [1]	5.0	1	10	10 Normal—All Shot.
		10.0	1	10	Do.
		15.0	1	10	Do.
8	Nichrome [2]	0.2	1	40	40 Normal—All Shot.
		2.0	1	40	Do.
		5.0	1	40	Do.
		0.2	5	8	Do.
		0.2	10	4	Do.
	Nichrome [2]	0.2	1	20	20 Normal—All Shot.
		2.0	1	20	Do.
		5.0	1	20	Do.
		10.0	1	20	Do.
		15.0	1	20	Do.
		0.2	5	4	Do.
		0.2	10	2	Do.
		0.2	20	1	Do.

[1] 0.009 inch diameter—¼" length.
[2] 0.009 inch diameter—⅛" length.

EXAMPLE IV

Several tests were made employing a metal clad laminate type fuse sealed within the cap, illustrated with reference to Figure 5*a* of the drawings. The delay cap tested was otherwise the same as that of the tests of Example II.

Table 4

FIRING VOLTAGE, 220 VOLTS

Test No.	Fuse Strip [1]			Line Resist.	No. in Parallel	No. of Trials	Result
	Metal	Width	Length				
9	Copper	.060"	¼"	10.0	1	5	4 Normal—All Shot.
10	Copper	.040"	¼"	0.2	1	5	5 Normal—All Shot.
				2.0	1	5	Do.
				10.0	1	5	Do.
11	Copper	.010"	¼"	0.2	1	4	4 Normal—All Shot.
12	Copper	.010"	¼"	15.0	1	3	3 Normal—All Shot.
	Copper	(.018-.040)	¼"	5.0	1	5	5 Holes—All Shot.
				15.0	1	5	5 Normal—All Shot.
13	Steel	0.062"	¼"	5.0	1	2	2 Normal—All Shot.
				15.0	1	2	Do.

[1] Laminate ⅛" wide and 1/16" thick (paper base with phenolic resin binder) contained, copper plate 0.00135 inch thick, on each side, which was reduced in width in a central section to form the fuse strip described. Each leg wire was secured to the copper plates by soldering, see Figure *5a*.

Normal (firing)—No holes in the shells. Cap shell not broken at ignition section.
Holes—Holes in the shells at ignition section.

EXAMPLE V

Several firing tests were made employing regular ignition delay caps described with reference to Table 2 and matchhead type ignition caps, the same as those of Table 2 except for the matchhead igniter.

Table 5

FIRING VOLTAGE, 220 VOLTS [1]

Test No.	Ignition	Line Resist.	No. in Parallel	No. of Trials	Result
14	Regular	0.2	1	5	5 Normal—All Shot.
		15.0	1	5	Do.
15	Regular	0.2	1	20	20 Normal—All Shot.
		5.0	1	20	Do.
		10.0	1	20	Do.
		15.0	1	20	Do.
		0.2	5	4	Do.
		0.2	10	2	Do.
		0.2	20	1	Do.
16	Matchhead	0.2	1	20	Do.
		5.0	1	20	Do.
		10.0	1	20	Do.
		15.0	1	20	Do.
		0.2	5	4	Do.
		0.2	20	1	Do.

[1] The fuse assembly was a laminate of Table 4 to which was secured on each side, and at opposite ends, two separate copper plates, the resulting gap being about ⅛ inch. A 0.0056 inch diameter Nichrome wire (⅛ inch in length) connected each plate pair as specifically illustrated with reference to Figure 7*a*.

EXAMPLE VI

The following is a tabulation of data obtained when employing a copper laminate utilizing a painted strip

(⅛ inch long) of conductive paint as the fuse element, as illustrated with reference to Figure 8*a*, i.e., a fuse was disposed in each lead wire, within the cap. The firing conditions and cap assemblies were otherwise the same as those described with reference to Table 2 (regular ignition) or Table 3 matchhead ignition.

Table 6

FIRING VOLTAGE, 220 VOLTS

Test No.	Ignition	Line Resistance	No. in Parallel	No. of Trials	Result
17	Regular (loose ignition mixture) (Pb/Se) (72.4/27.6)/Si/Snow Floss 97/2/11.	0.2	1	20	20 Normal—All Shot.
		5.0	1	20	Do.
		10.0	1	20	Do.
		15.0	1	20	Do.
		0.2	5	4	Do.
		0.2	20	1	Do.
18	Matchhead—Paraphenylenediamine dipicrate/potassium chlorate/Snow Floss 24/56/20 with 10% nitrocellulose (lacquer). BaO_2/Se/SF (70/30/10) as auxiliary ignition mixture.	0.2	1	20	Do.
		10.0	1	20	Do.
		0.2	5	4	Do.
		0.2	10	2	Do.
		0.2	20	1	Do.

EXAMPLE VII

Several firing tests were made employing a delay electric blasting cap described with reference to Example II at firing voltages of 220 and 440 volts, utilizing a copper laminate fuse of Figure 7*a* in each leg wire within the cap, i.e., a dielectric plate with a pair of copper plates secured on each side, separated from each other, and connected with a Nichrome fuse wire.

Table 7

Test No.	Firing Voltage	Line Resistance	No. of Trials	No. Caps in Parallel	Result
19	440	0.2	20	1	20 N—All Shot.
		10.0	20	1	Do.
		20.0	20	1	Do.
		30.0	20	1	Do.
		0.2	4	5	Do.
		0.2	2	10	Do.
		0.2	1	20	Do.
20	440	0.2	10	1	10 N—All Shot.
		10.0	10	1	Do.
		20.0	10	1	Do.
		30.0	10	1	Do.
		0.2	2	5	Do.
		0.2	1	10	Do.
21	220	0.2	10	1	Do.
		5.0	10	1	Do.
		10.0	10	1	Do.
		15.0	10	1	Do.
		0.2	2	5	Do.
		0.2	1	10	Do.

N—Normal, no holes in the shells.
Each Nichrome fuse wire was .0056 inch in diameter and ⅛ inch long. The laminate (dielectric element) in each instance was ½ inch long, ⅛ inch wide and 1/16 inch thick. The caps of test 20 were filled around the fuse composition with an asphalt waterproofing composition and topped with sulfur. The caps of tests 20 and 21 were filled around the laminate use with Stypol (a styrene-polyester modified with vinyl toluene).

EXAMPLE VIII

Data in Table 8 were obtained from firing delay blasting caps described with reference to Example II except that a metal clad laminate type fuse assembly was utilized in each leg wire within the cap. Firing voltages were 220–440 volts. In tests 22 the dielectric plate, or strip, contained on the entire surface of each side, a Nichrome foil 0.00016 inch thick. The foil as the fuse element was ⅛ inch wide and 9/16 inch in length. The fuse assembly was the same in tests 23 except that the foil fuse element was Karma, and was 3/32 inch wide and 0.0008 inch thick.

Table 8

Test No.	Firing Voltage	Line Resistance	No. of Trials	No. Caps in Parallel	Result
22	220	0.2	5	1	5N—All Shot.
		15.0	10	1	10N—All Shot.
	440	0.2	5	1	5N—All Shot.
		30.0	10	1	10N—All Shot.
23	220	0.2	5	1	5N—All Shot.
		15.0	10	1	7N, 3H—All Shot.
	440	0.2	5	1	5N—All Shot.
		30.0	10	1	6N, 4H—All Shot.

N—Normal firing, no holes in the shells.
H—Holes in the shells at ignition charges.

EXAMPLE IX

The following test data were obtained from firing a delay cap described with reference to Table 2 except that the fuse assembly was that described with reference to Figure 3*a*, i.e., the ignition plug was slotted so as to partially cut through each wire pin to form the said fuse assembly.

Table 9

Test No.	Firing Voltage	Line Resistance	No. of Trials	No. Caps in Parallel	Result
24	220	0.2	10	1	10N—All Shot.
	440	0.2	10	1	Do.

Each resulting fuse portion had a cross sectional area of .00025 sq. in. and was 3/32 inch long. The original pin wires were #22 Nichrome wire, i.e., .025 inch diameter.

EXAMPLE X

The following tabulation shows the relationship of time of current flow to the effect of the current on shell destruction. As indicated, a period of from about 37–117 milliseconds (ms.) was utilized during which time all caps shot, although in some instances there were holes formed in the shell of the ignition section. The data illustrate the necessity for the fuse or conductor section to fuse within a period of about 120 ms. Thus, had the flow of initially applied current been maintained for a period in excess of about 120 ms., bursting of the shell and failure of the cap would have resulted.

Table 10

Voltage	Line Resistance	No. of Caps in Parallel	Duration, ms.	No. of Trials	Result
220	0.2	1	37–62	10	10N.
440	0.2	1	37–62	10	10N.
440	0.2	5	37–62	1	5N.
220	0.2	5	62–87	1	5N.
220	0.2	5	87–117	1	4N, 1H.

N—Normal.
H—Holes.

In the foregoing Tables 1 and 3–10 the current, in each test, dependent upon the line resistance was as follows:

Line Resistance, Ohms	Current Amperes [1]	
	220 Volts	440 Volts
0.2	1,100	2,200.
2.0	110	
5.0	44	
10.0	22	44.
15.0	14.6	
20.0		20.0.
30.0		14.6.

[1] This assumes no transformer impedance.

The diameter of the fuse element of the invention is any suitable value which correlated with the bridge wire composition will fuse before the cap fails or bursts. Nichrome wire is the preferred fuse element, the diameter generally being within the range of about 0.0025 to about 0.142 inch, preferably below about 0.009 inch.

Illustrative of preferred cross-sectional area values of fuse elements of the invention are as follows:

Fuse Material	Cross-sectional Area of Fuse Section, sq. in.
Steel	.000093.
Copper	.0000135.
Karma (Ni, 73%, Cr, 20%+Al+Fe)	.00005.
Nichrome (Cr/Ni/Fe, 60/16/24)	.00001235–.0001583.

Although one fuse element can, in most instances, be satisfactorily employed in a blasting cap in accordance with invention, it is preferred that a fuse element be included in each leg wire. If only one fuse element is employed, there may occur an arc between the leg wire and shell above the fuse with a resulting flow of current across the ignition composition and on through the other leg wire to cause development of an arc followed by bursting of the cap, and failure.

When each wire contains a fuse element, there is a breaking of the circuit even though there has been an arc between the leg wire and the shell. Arcing between leg wire and shell can take place particularly in view of the close quarters in the cap shell to provide for a small distance in which the arc can be formed. However, use of one fuse element is always satisfactory provided the leg wires are adequately insulated from each other and from the shell wall.

As will be evident to those skilled in the art, various modifications can be made or followed, in the light of the foregoing disclosure and discussion, without departing from the spirit or scope of the disclosure or from the scope of the claims.

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

1. In an electric blasting cap comprising a shell, a pair of leg wires extending into said shell, a bridge wire in said shell connecting said leg wires, and an ignition composition in said shell in operative communication with said bridge wire to be ignited by heat developed by passage of electric current through said bridge wire, the improvement comprising a fuse element inserted in at least one of said leg wires within said shell, said fuse element and said bridge wire each being fusible within 120 milliseconds at a temperature developed by heat formed from passage of electric firing current through said leg wires at a voltage sufficiently high to deliver at least 10 amperes to the said bridge wire, and the diameter and fusion point of said bridge wire being correlated with the diameter and fusion point of said fuse element so that during said passage of firing current to deliver at least 10 amperes to the said bridge wire, said bridge wire is caused to reach its fusion temperature before said fuse element reaches its fusion temperature, whereby during said 120 milliseconds period, said bridge wire is fusible prior to fusion of said fuse element.

2. A delay blasting cap of claim 1 containing said fuse element in each of said leg wires.

3. In a delay blasting cap of claim 1, a portion of one of said leg wires reduced in cross-sectional area as said fuse element.

4. In a delay blasting cap of claim 1, a wire as said fuse element.

5. In a delay blasting cap of claim 1, an assembly including said fuse element comprising a dielectric material; said fuse element rigidly supported on said dielectric material; and said leg wire, associated with said fuse element, also rigidly supported on said dielectric material whereby said fuse element is supported free from tension from said leg wire.

6. In a delay blasting cap of claim 5, first and second metal members, each electrically insulated from the other, affixed to said dielectric material; a first portion of a leg wire affixed in electrically conductive relation with one of said members, and a second portion of said leg wire being affixed in electrically conductive relation with the other of said metal members; and said fuse element affixed in electrically conductive relation with both of said metal members.

7. In a delay blasting cap of claim 6, a Nichrome wire as said fuse element.

8. In a delay blasting cap of claim 6, a metal foil as said fuse element.

9. In a delay blasting cap of claim 5, a metal member affixed to said dielectric material, and separate portions of one of said leg wires connected with said member;

and a portion of said metal member intermediate the points connecting said leg wire portions, adapted as said fuse.

10. In a delay blasting cap of claim 9, said intermediate portion comprising a restricted portion of said metal member.

11. In a delay blasting cap of claim 5, a metal strip supported on said elongated dielectric material, and said metal strip connected as said fuse element with one of said leg wires as a section thereof.

12. In a delay blasting cap of claim 5, said assembly comprising a pair of metal strips, each as one said fuse, electrically insulated from each other and affixed to spaced apart areas on said dielectric material, and a first section of each leg wire affixed to one end of each said strip and a remaining section of each said leg wire being affixed to the other end of each said strip.

13. In a delay blasting cap of claim 5, said assembly containing a conductive layer deposited on said dielectric material, as said fuse.

14. In a delay blasting cap of claim 13, said layer comprising a body of metal particles.

15. A delay blasting cap of claim 5 containing said fuse element in each of said leg wires.

16. The improvement of claim 15, wherein the said voltage is about 100 volts.

17. The improvement of claim 15, wherein said voltage is about 220 volts.

18. The improvement of claim 15, wherein said voltage is about 440 volts.

19. An electric delay blasting cap adapted for firing at high voltage currents which comprises a shell; a pair of leg wires longitudinally extending into said shell; an electrical resistance wire in said shell connecting said leg wires; an ignition composition in said shell in operative communication with said resistance wire to be ignited by heat developed by passage of electric current through said resistance wire; a base detonatable explosive in said shell in an end of said shell away from said lead wires; a primer composition intermediate said ignition composition and said base charge and spaced from said base charge so as to detonate said base charge when heated; a slow burning heat-sensitive material as a delay fuse intermediate said ignition composition and said primer and ignitable by heat from ignition of said ignition composition; said fuse being in operative communication with said primer, when burning, to cause detonation of same by heat from said burning; a fuse element in at least one of said leg wires in said shell; said fuse and said resistance wire, each being fusible within 120 milliseconds at a temperature developed by heat formed from passage of electric firing current through said leg wires at a voltage sufficiently high to deliver at least 10 amperes to the said resistance wire, and the diameter and fusion point of said resistance wire being correlated with the diameter and fusion point of said fuse element so that during said passage of firing current to deliver at least 10 amperes to the said resistance wire, said resistance wire is caused to reach its fusion temperature before said fuse element reaches its fusion temperature, whereby during said 120 milliseconds period, said resistance wire is fusible prior to fusion of said fuse element.

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