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Hayashi

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[54] **ELECTRIC DETONATOR FREE FROM ACCIDENTAL ELECTROSTATIC FIRING**

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

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

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

[56] **References Cited**

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Primary Examiner—Stephen C. Bentley

[57] **ABSTRACT**

An electric detonator carrying a fuse head disposed in a tube and being fired by an electric current delivered through a pair of legs carried by a plug fitted at an open mouth of the tube. The plug is made of a moldable sealing material having a comparatively low electric resistance, and at least one of the legs is electrically connected to the plug, so as to allow the grounding of the tube through the plug and the leg.

14 Claims, 8 Drawing Figures

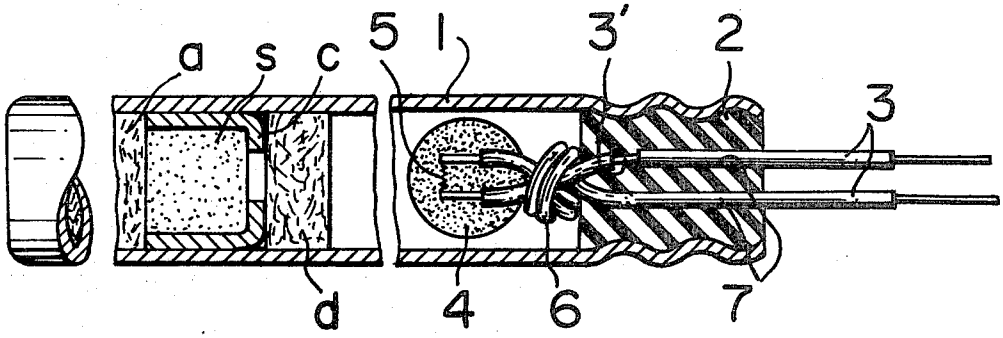


FIG. 1A

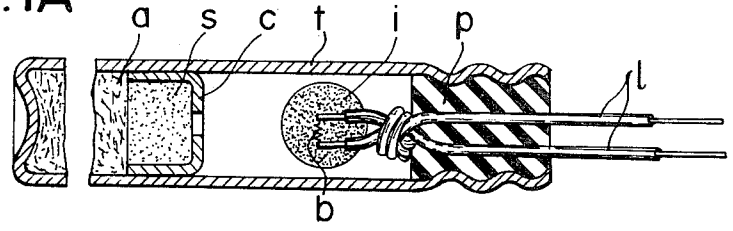


FIG. 1B

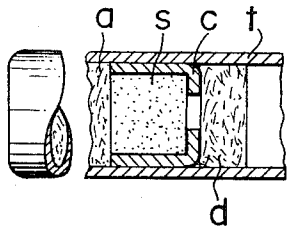


FIG. 1C

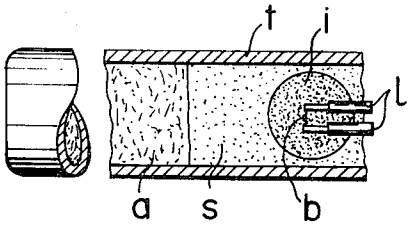


FIG. 2A

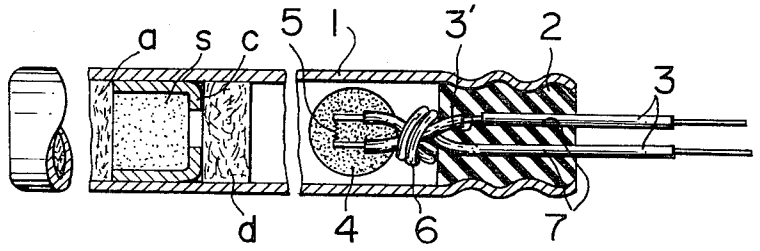


FIG. 2B

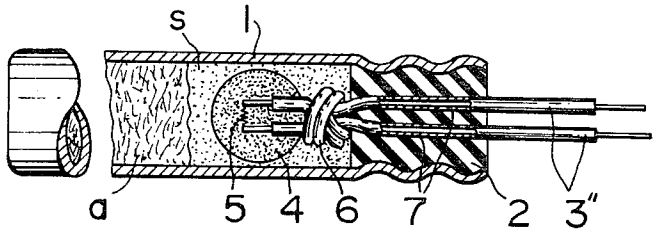


FIG. 3A

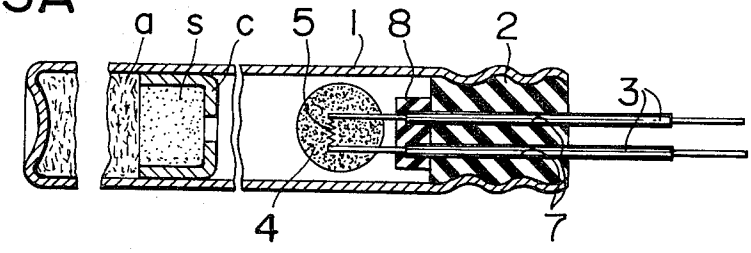


FIG. 3B

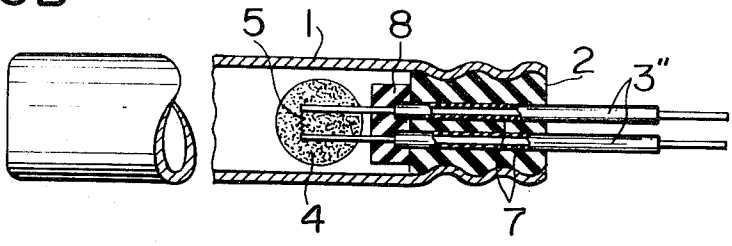
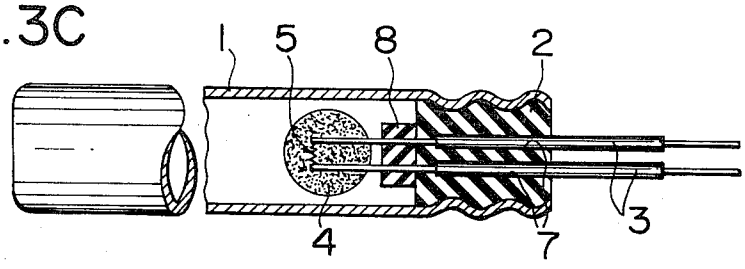


FIG. 3C



ELECTRIC DETONATOR FREE FROM ACCIDENTAL ELECTROSTATIC FIRING

BACKGROUND OF THE INVENTION

This invention relates to an electric detonator free from accidental electrostatic firing which is suitable for directly firing high explosive or indirectly firing it by priming an electric fuse, and more particularly to an electric detonator wherein the risk of accidental firing due to electrostatic phenomena is substantially completely eliminated so as to greatly improve the overall reliability and safety of electric detonators for purposes of either directly firing high explosive or indirectly firing it by priming an electric fuse.

With electric detonators, which are widely used for firing high explosive or for priming an electric fuse, it is one of the most important prerequites to make them completely immune to any accidental firing or explosion.

A known detonator comprises a small cylindrical tube closed at one end by a plug made of rubber-like insulating material, through which plug two copper wires, known as "legs of the detonator," are led. If such known detonators are used in dusty desert area or the so-called dry snow area, the detonators as assembled as ready for ignition are exposed to the accumulation of sand particles, dust particles, or snow flakes on the outer surfaces thereof. If such particles or flakes travel at a high speed through air, electrostatic charge tends to be generated on the particles and flakes, so that a considerably large amount electrostatic charge may be built up on the surface of the tube of the detonator as the amount of the particles and flakes increases. If such electrostatic charge accumulated on the outer surface of the tube exceeds a certain limit, an electric flashover may take place across the tube and the inner ends of the legs disposed therein. As a result, the detonator is discharged against expectation, for causing an accidental firing, which may lead to a serious accident.

Therefore, an object of the present invention is to obviate the aforesaid difficulties of the conventional detonator, by providing an improved electric detonator, which is substantially free from accidental firing. According to the present invention, a plug made of moldable sealing material having a comparatively low specific electric resistance is used to close the open end of a tube of the detonator, so as to prevent the build-up of an excessively high electric charge accumulation on the tube.

The moldable sealing material for the plug may be natural rubber, synthetic rubber, or a suitable synthetic resin, such as polyvinyl chloride, polypropylene, polyethylene, polycarbonate, silicone rubber, or polyurethane. The specific electric resistance of such moldable sealing material is adjusted to the aforesaid range by adding carbon particles or electrically conductive metallic particles therein.

BRIEF DESCRIPTION OF THE DRAWING

For a better understanding of the invention, reference is made to the accompanying drawings, in which:

FIGS. 1A, 1B, and 1C are partially cut away side views of known electric detonators;

FIGS. 2A and 2B are partial schematic sectional views, illustrating the construction of the essential portions of different embodiments of the present invention; and

FIGS. 3A, 3B, and 3C are partial schematic sectional views, illustrating other embodiments of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 1A, a known detonator comprises a tube *t* having a closed bottom and an open mouth, a base charge *a* disposed in the bottom portion of the tube, an inner cylinder *c* carrying an initiating explosive *s* disposed adjacent the base charge, a fuse head *i* made of a suitable priming composition and disposed at an intermediary position between the inner cylinder *c* and the open mouth of the tube *t*, and a plug *p* carrying legs *l* and fitted in the open mouth of the tube for closing it. In the known detonator, as shown in FIG. 1B, a suitable delay powder *d* is disposed adjacent the inner cylinder *c*, so as to delay the firing of the base charge from the firing of the fuse head. In the exemplary known detonator, as shown in FIG. 1C, neither an inner cylinder *c* nor a delay powder *d* is used, and the fuse head *i* is surrounded by an initiating explosive *s*.

The legs *l* of the known detonator are made of a pair of electrically insulated wires, and a bridging element *b* is connected across the innermost ends of the two legs *l*. The bridging element *b* consists of a very thin wire made of an alloy of iridium and platinum. A suitable priming composition is kneaded to form a paste, and the ball-like fuse head *i* is formed by applying the paste to the bridging element *b* and shaping it into the desired spherical form. Upon application of an actuating electric current of certain predetermined magnitude through the bridging element *b*, the heat energy emanating from such bridging element ignites the fuse head *i* as well as the entire detonator, so as to fire high power explosive disposed adjacent the detonator.

Although the fuse head *i* of the aforesaid structure is wisely used and applicable to the detonator of the invention, the present invention is not restricted to such form of the priming composition. More particularly, with the present invention, it is also possible to completely enclose the bridging element *b* with a suitable loose priming composition or loose charge, such as guncotton or a suitable igniting powder. The loose charge, of course, must be capable of being ignited by the heat from the bridging element *b* upon application of the electric actuating current therethrough.

The plug *p* of the conventional detonators is required to water-tightly fit in the open mouth of the tube *t*, while holding detonator legs *l* extending therethrough. To prevent the leakage of the electric actuating or igniting current, the plug *p* of conventional detonator is made of a suitable electrically insulating rubber-like material, such as natural rubber, synthetic rubber, polyethylene resin or other suitable synthetic resin.

As pointed out in the foregoing, if the known detonators, as shown in FIGS. 1A to 1C, used in dusty areas or areas with the so-called dry snow flakes, the movement of the particles or flakes at a high speed relative to each other and relative to the tube *t* tends to generate electrostatic charge on the particles as well as on the surface of the tube *t*. If a large amount of electric charge is stored on the tube *t* in excess of a certain limit, due to the accumulation of such charged particles or flakes, a high voltage gradient is caused across the tube *t* and the inner ends of the legs *l*. If an electric flashover is caused by such high voltage gradient, the

priming composition may be ignited or fired. As a result, the entire detonator is accidentally fired. It is apparent to those skilled in the art that any accidental firing is extremely dangerous, and the accidental firing must be prevented by all means.

Recently, ammonium nitrate-fuel oil explosives have been developed. With such newly developed explosives, powderly explosive material thereof is susceptible to flying caused by natural or artificial air flow, and the powderly explosive material may incidentally be brought to boreholes by the air flow as a primer cartridge, and if such powderly material is delivered at a very high speed, electrostatic charge is accumulated on such material in the borehole. If a detonator is inserted into the borehole under such conditions, the electrostatic charge may instantly be transferred onto the detonator upon its insertion in the borehole. Accordingly, the detonator is exposed to the risk of accidental firing at the very moment of its insertion, and such accidental firing may result in a serious accident, possibly fatal casualties.

To mitigate such difficulties, the inventor has disclosed, in his Japanese Utility Model Publication No. 13,113/1966, a means for preventing accidental firing, which comprises the formation of electrically conductive films on the surface of a fuse head *i*, the binding portion between legs *l* and the fuse head *i*, and the inner surface of a plug *p*, so as to allow the grounding of the fuse head *i* through the film thus formed and the leg. Since this method relies on the electric conductivity of the fuse head itself, it proved to be effective for incandescent type detonators, but it is not so effective for detonators having a fuse head with a comparatively low electric conductivity or for detonators of flashover gap type.

The inventor has carried out a series of studies and tests to mitigate the aforesaid difficulties of known detonators. As a result of it, he has succeeded in providing a means for completing a grounding path without passing through the fuse head. According to the present invention, the risk of accidental discharge or firing of an electric detonator can drastically be reduced by using a plug *p* having a comparatively low electric resistivity.

It has been believed heretofore that high reliability of firing action of detonators can be ensured by using a plug having a high electric insulating strength, which minimizes the partial loss of actuating electric current at the plug. To improve the insulating strength, the legs are also lined with a suitable insulating material. On the other hand, the inventor has confirmed through tests that, as long as the specific electric resistance of the plug material is 10 to 10^{10} ohm-cm, preferably 10^2 to 10^5 ohm-cm, reliable operation of the detonator can be ensured. More particularly, with the aforesaid range of the specific electric resistance, the partial leakage of the actuating current can be kept at a sufficiently low level to ensure the reasonable magnitude of the minimum actuating current and the minimum firing impulse. In fact, the detonators with the plug having the aforesaid specific electric resistance present performance characteristics which is substantially identical with that of conventional detonators.

Thus, the present invention provides a detonator which is completely free from accidental electrostatic firing, in which the electrostatic charge induced on the surface of the tube is diverted to the earth through a plug with a limited specific electric resistance and a leg of the detonator. There will be no excessive build-up of electrostatic charge at the tube, because of its diversion to the earth through the aforesaid path, so that the risk of accidental electrostatic firing is completely eliminated.

In short, the present invention provides an electric detonator free from accidental electrostatic firing, comprising, a tube having a closed bottom and an open mouth, a plug liquid-tightly fitted in the open mouth of the tube, a pair of electrically conductive legs carried by the plug, at least one of the legs being electrically connected to said plug, and a fuse ball binding the inner ends of the legs located inside the tube through a comparatively high electric resistance, said fuse head being made of igniting agent being ignitable upon application of electrical shock through said legs, said plug being made of a modable sealing material with a specific electric resistance of 10 to 10^{10} ohm-cm.

FIG. 2A illustrates the construction of an embodiment of the electric detonator according to the present invention. The detonator comprises a tube **1** having a closed bottom and an open mouth, a plug **2** fitted in the open mouth of the tube **1**, electrically conductive legs **3** carried by the plug **2** so as to electrically communicate the inside of the tube **1** with the outside thereof, a fuse head **4** secured to the inner ends of the legs located within the tube **1**, and a bridging element **5** extending across the inner ends of the legs **3**. The fuse head **4** is made of a suitable igniting agent, which is ignited by an actuating electric current applied to the bridging element **5** through the legs **3**.

The tube **1** is usually metallic, but it can also be made of a suitable synthetic resin material. In the case of the resin tube, however, it must be made of such synthetic resin material which has a low specific electric resistance comparable with that of the plug **2**. In the embodiment of FIG. 2A, the two legs **3** are electrically insulated wires and extend through corresponding holes **7** bored through the plug **2**, and the two insulated wires are tied together at the point **6** located inside of the tube **1**, relative to the plug **2**, so as to prevent the legs **3** from being pulled away from the plug **2**. The invention, however, is not restricted to such arrangement of the legs **3**. For instance, the two legs **3** may be integrally bonded to the plug **2** when shaping the latter, or instead of using two separate holes **7**, only one hole may be bored through the plug **2** for allowing the passage of the two legs through such one hole.

It should be noted in FIG. 2A that the insulation of at least one of the two legs **3** is partially removed at a point **3'** located within the plug **2**, so as to establish an electric contact or connection between the conductor of the leg **3** and the plug **2** at such portion **3'** where the insulation of the leg **3** is removed. With such electric contact or connection at the point **3'**, the tube **1** may be connected to the ground potential (not shown) through the comparatively low resistance of the plug **2** and the conductor of the leg **3**.

FIG. 2B shows a modification of the construction of FIG. 2A. In FIG. 2B, the material of the insulation **3''** of the legs **3** are such that the electric resistance of the insulation **3''** is low enough to ensure the desired grounding effect of the tube **1** through the insulation **3''**, but it should be high enough to prevent the leakage of the actuating electric current therethrough.

FIG. 3A shows another embodiment of the detonator according to the present invention, in which two legs **3**

are secured to a holding piece 8 located on the inner edge surface of a plug 2 closing the open mouth of a tube 1. In this embodiment, the holding piece 8 acts to prevent the legs 3 from being pulled away from the plug 2. In this respect, the holding plug 8 of FIG. 3A takes place of the binding portion 6 of the legs 3 in FIGS. 2A and 2B. The material for the holding piece 8 is similar to that of the sealing plug 2. To secure the legs 3 to the holding piece 8, bare conductor portions of legs 3 are penetrated through the holding piece 8 and then bent or deformed in such a manner that the bare conductors resist against pulling forces directed away from both the piece 8 and the plug 2.

In FIGS. 2A, 2B, and 3A, different dispositions of base charge *a*, initiating explosive *s*, delay powder *d*, and an inner cylinder *c* are shown. Any of such dispositions can be incorporated with the electric detonator, according to the present invention, but it is not essential in the present invention.

The holding piece 8 of this embodiment is required to have a specific electric resistance which is not greater than that of the coacting plug 2.

In the embodiment of FIG. 3B, the insulating lining 3'' of the legs 3 is made of a material having a comparatively low specific electric resistance which is not greater than that of the plug 2, so that the holding piece 8 need not have a comparatively low electric resistance.

FIG. 3C shows another modification, in which the insulating lining 3'' of at least one of the two legs 3 is at partially removed within the plug 2, so as to establish reliable electric contact or connection between the plug 2 and the conductors of the legs 3 for ensuring the desired grounding effect of the tube 1 through the plug 2 and the conductor of the leg 3. In this embodiment, as shown in FIG. 3C, the holding piece 8 can be made of highly insulating material, if so desired.

According to the present invention, it is important that the tube 1, as shown in any one of FIGS. 2A and 2B and FIGS. 3A to 3C, can electrically be grounded through the plug 2 and the leg 3, without passing through the fuse head 4. With the tube thus grounded without passing through the fuse head, the risk of accidental electrostatic firing is almost completely eliminated.

The invention will now be described in further detail, by referring to Example.

EXAMPLE

A number of test samples of the electric detonator, as shown in FIG. 3C, were made by using plugs 2 each being made of a moldable sealing material having a specific electric resistance of 10^3 ohm-cm. The moldable sealing material used consisted of 35 percent of natural rubber, 30 percent of fine carbon particles, 5 percent of vulcanization accelerator, 3 percent of age resistor, and 27 percent of calcium carbonate.

A high-voltage test was carried out on 50 test samples thus prepared. A capacitor with an electrostatic capacity of 0.8 microfarad was charged, so as to produce a voltage of 2,000 volts across the capacitor. The 2,000 volts potential thus generated was applied to each of the test samples across its tube 1 and its legs 3. None of the 50 test samples was fired by such high-voltage test; namely, none of the test samples caused its fuse head 4 to fire.

A minimum firing current test was carried out on fifty test samples thus made. The magnitude of the firing current for all the test samples proved to fall in a range of 400 mA to 560 mA. None of the test samples failed to be set afire. Thus, the test samples proved to have firing properties which is substantially identical with that of conventional detonators.

On fifty test samples thus made, a product of ignition test was made. It proved that each of the test samples was fired with a firing impulse of 58 volts, 3.35 mWS (milli-watt-second). Such results of the firing impulse test is comparable with those of conventional detonators.

To carry out a simultaneous blasting test, one hundred such test samples were connected in series, and a suitable firing current was forced therethrough. All of the one hundred test samples thus connected proved to fire simultaneously without any failure.

With suitable delay means, the test samples of the electric detonators were tested for staged firing of two to five stages, with each stage being 0.25 second long. The results are as follows.

Test stage	Actual delay	Average delay
2nd stage	0.20–0.30 second	0.253 second
3rd stage	0.45–0.56 second	0.504 second
4th stage	0.68–0.82 second	0.751 second
5th stage	0.94–1.08 second	1.009 second

The test results of the above table satisfy the stipulations of JIS K 4807 with an accuracy comparable with that of conventional detonators.

The safety level of the test samples was examined by means of explosive power tests with lead plates, impulse tests, and heat-resistance tests, and they demonstrated to have substantially the same level of safety as conventional detonators.

The water-resisting ability of the test samples of the electric detonator according to the present invention was measured by simmering 50 test samples in water at 2 atmospheric pressures for 1 hour, and simmering another 50 test samples in water at 2 atmospheric pressures for 5 hours. All the test samples showed satisfactory firing properties even after such simmering tests.

According to the present invention, the range of suitable specific electric resistance of the moldable sealing material for the plug is selected to be 10 to 10^{10} ohm-cm; because, if the specific electric resistance is below 10 ohm-cm, the firing impulse characteristics of the electric detonator is noticeably deteriorated and its minimum firing current is greatly increased to an impractical level, while if the specific electric resistance exceeds 10^{10} ohm-cm, the desired ability of eliminating the accidental electrostatic firing cannot be achieved. It is well known to those skilled in the art that the increase in the minimum firing current tends to deteriorate the simultaneous firing properties of the detonators.

In order to make excellent electric detonators, the specific electric resistance of the moldable sealing material for the plug should preferably fall in a range of 10^2 to 10^5 ohm-cm.

There is no difficulty in making the moldable sealing materials having such a specific electric resistance, along with excellent values of other physical properties, such as water-resistance and heat-resistance.

As described in the foregoing disclosure, according the the present invention, the risk of accidental electrostatic firing of electric detonators is completely elimi-

nated, and hence, there is provided a highly reliable electric detonator having a high level of safety along with excellent firing and other performance characteristics.

What is claimed is:

1. An electric detonator free from accidental electrostatic firing, comprising a tube having a closed bottom and an open mouth, a plug liquid-tightly fitted in the open mouth of the tube in electric contact with the tube, a pair of electrically conductive legs carried by the plug, at least one of the legs being electrically connected to said plug, and a fuse head ball binding the inner ends of the legs located inside the tube through a comparatively high electric resistance, said fuse head being electrically insulated from the tube and made of igniting agent being ignitable upon application of electrical shock through said legs, at least a part of said plug being made of a moldable sealing material with a specific electric resistance of 10 to 10^5 ohm-cm, said tube being made of a material whose specific resistance is not greater than that of the plug, so as to provide effective resistance between the legs and ground outside the tube which effective resistance is low enough to prevent accidental flashover across the legs and the tube.

2. An electric detonator according to claim 1, wherein said moldable sealing material is selected from the group consisting of natural rubber, synthetic rubber, polyvinyl chloride, polypropylene, polyethylene, polycarbonate, silicone rubber, and polyurethane.

3. An electric detonator according to claim 2, wherein the moldable sealing material contains an ingredient selected from the group consisting of carbon particles and electrically conductive metallic particles.

4. An electric detonator according to claim 1, wherein said moldable sealing material for the plug has a specific electric resistance of 10^2 to 10^5 ohm-cm.

5. An electric detonator according to claim 1 and further comprising a base charge disposed in said tube adjacent the closed bottom.

6. An electric detonator according to claim 5 and further comprising initiating explosive disposed within the tube adjacent the base charge.

7. An electric detonator according to claim 6 and further comprising an inner cylinder holding said initiating explosive therein.

8. An electric detonator according to claim 1, wherein each of said legs is lined with a layer of material having a specific electric resistance of 10 to 10^{10} ohm-cm.

9. An electric detonator according to claim 1, wherein said legs are lined with electric insulating material, at least one of the legs is partially bared by removing said electric insulating lining at a portion within said plug, so as to cause said bared portion of the leg to come in direct electric contact with the moldable sealing material of the plug.

10. An electric detonator according to claim 1 and further comprising a holding piece firmly holding said legs.

11. An electric detonator according to claim 8, wherein said holding piece is made of a material having a specific electric resistance of 10 to 10^{10} ohm-cm, and at least one of said legs is in direct electric contact with said holding piece material.

12. An electric detonator according to claim 11, wherein said material for the holding piece consists of a first ingredient selected from the group consisting of natural rubber, synthetic rubber, polyvinyl chloride, polypropylene, polyethylene, polycarbonate, silicone rubber, and polyurethane, and a second ingredient selected from the group consisting of carbon particles and electrically conductive metallic particles.

13. An electric detonator according to claim 10, wherein said holding piece is made of a moldable sealing material having a specific electric resistance of 10 to 10^{10} ohm-cm, and said legs are lined with a material whose specific electric resistance is also 10 to 10^{10} ohm-cm.

14. An electric detonator according to claim 10, wherein said holding piece is made of an electric insulating material.

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