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DETONATOR

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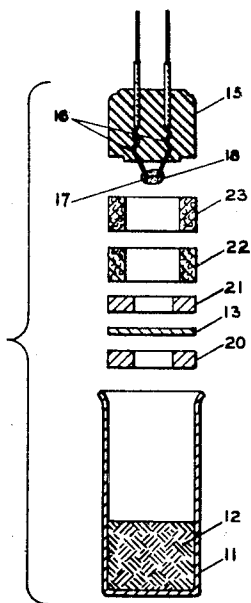


FIG. 1

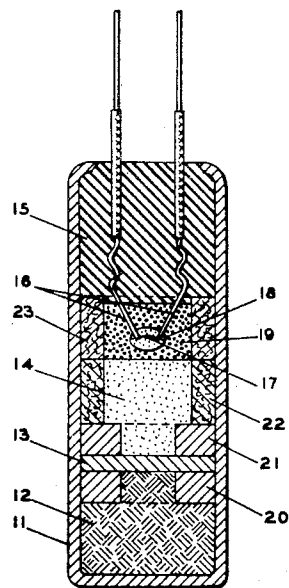


FIG. 2

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## DETONATOR

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This invention relates to improved electric firing devices and more particularly to electric firing devices having low firing energy requirements and reliable time delays of very short periods.

In the prior art delay electric firing devices, the desired delay action has been accomplished by various means. In one type of detonator a slow-burning material is placed between the ignition element and the detonating charge. This material may be nongaseous and burn at a rate of about five-tenths of an inch per second. In a second type of delay electric detonator, a faster-burning, gaseous-producing material is used between the ignition element and the detonating charge. In still a third type, a slow-burning material is ignited directly from the bridge wire, a sufficient quantity of the material being used so that the desired delay time is consumed in burning down to the detonating charge.

These prior art delay electric firing devices are not adaptable to give firing devices which have a short, yet definite, time of delay such as of the order of 10 milliseconds, which have a very small diameter and a small length, which have an exceedingly low energy requirement for ignition, and which are waterproof and rugged.

The first of the above referred to prior art types is applicable only when the delay time is more than about one-tenth of a second. In order to lower the delay time, it would be necessary to reduce the length of the fuse element; this results in substantially instantaneous and unpredictable shots due to the fact that gases from the ignition element force their way past the fuse charge and ignite the detonating charge directly.

The second above referred to prior art type is applicable for short time delays in general, but is not practical in small devices because it requires high loading pressure, and therefore heavy construction, in order to give regularity of burning time. This type, wherein a faster-burning, gaseous generating material is used, also requires a vent to release the gas, or very heavy construction to withstand the heavy pressures created.

The third of the above referred to prior art types is not applicable where the ignition firing energy is very low. By virtue of its nature, it does not possess the required ignition energy sensitivity.

Now, in accordance with the present invention, an electric firing device has been produced which has a reliable, short time delay; has a very low ignition energy requirement; is waterproof and rugged; and has small overall dimensions.

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Generally described, the firing device of this invention comprises a tubular shell containing a detonating charge in juxtaposition to, but separated from, a heating charge by a heat-conducting element, and an electric ignition assembly with a low ignition energy requirement adapted to ignite the heating charge.

Described more specifically, the device of this invention comprises a tubular shell containing the following elements in the indicated order, starting at the bottom or closed end of the shell; a suitable detonating charge pressed in place in the bottom of the shell; a heat-conducting element such as a thin metallic disc pressed against the detonating charge; a heating charge of a suitable composition adjusted in combination with the metallic disc to give the desired delay time and pressed against the metallic disc and separated from the detonating charge; a suitable ignition assembly having a very low ignition energy requirement and adapted to ignite the heating charge disposed below it, the ignition assembly being rigidly secured in the upper portion of the tubular shell in a waterproof manner by means of a suitable plug member.

Having now described the nature and purpose of this invention in general terms, there follows a more detailed description of a preferred embodiment thereof with reference to the accompanying drawing, wherein like numerals are used to designate similar parts wherever they occur in the figures, and in which: Fig. 1 is a cross-sectional view of the separate elements of the detonator (the burning charge and heating charge are omitted) indicating the order in which they are to be assembled; and Fig. 2 is an enlarged cross-sectional view of the assembled detonator.

Referring now to the drawing, and more particularly to Fig. 2, the electric firing device of this invention comprises a metallic tubular shell 11 containing a detonating charge 12; a metallic disc 13 pressed against the detonating charge, a heating charge 14 placed above the metallic disc, and an ignition assembly spaced above the burning charge and comprising a dielectric bridge plug 15 carrying leg wires 16 across which is connected a bridge wire 17 having a low energy requirement and around which is formed a highly sensitive ignition mixture 18 in the form of a matchhead, which in turn is surrounded by a burning charge 19. The bridge plug 15 is of a hard material of a diameter substantially greater than the normal inside diameter of the shell and is sealed in the shell by insertion under pressure whereby expansion of the shell is effected, a wa-

terproof friction joint is formed, and the entire assembly is maintained under pressure.

A tight seal is obtained between the detonating and heating charges by placing annular, washerlike members 20 and 21, respectively below and above the metal disc, and in a tight-fitting relationship to the inside of the shell. They also serve to effect first initiation of the detonating charge near the center of the shell axis since the shortest heat-conducting path will be confined to a central portion of the long axis of the detonator.

An example of manufacturing a detonator encompassing a preferred embodiment of this invention, with particular reference to assembly of the elements as shown in Fig. 1, will give a better understanding of the nature of the invention. A detonating charge 12 of diazodinitrophenol was pressed at 2,000 pounds per square inch, to a height of about  $1\frac{3}{4}$  inch, into the base end of a bronze metallic tubular shell 11 having a wall thickness of about 0.0075 inch, inside diameter of 0.256 inch, length  $\frac{3}{4}$  inch, and slightly flared at its open end. A brass washer 20 followed by a brass disc 13, 0.0015 inch thick, was pressed against the detonating charge at 5,000 pounds per square inch so that the washer was sunk into the base charge and the disc was tight against the charge in the center of the washer. A second brass washer 21, several thousandths of an inch larger in diameter than the inside diameter of the shell, was pressed at about 5,000 pounds per square inch on top of the disc to hold it in place and to form a seal through which gas could not pass from the burning charge to the base charge. A compressed, bonded fiber ferrule 22, 0.250 inch O. D. x 0.190 inch I. D. x 0.140 inch long, was placed in the shell and filled with a 0.26 gram heating charge 14 consisting of lead-selenium-aluminum-barium nitrate, 60-32-6-10 parts by weight.

After this operation, the shell was ready for insertion of the ignition assembly. The ignition assembly was made as follows. A pair of insulated leg wires 16 having the lower portion thereof uninsulated were molded in a plug 15. The uninsulated wires projecting from the ignition end of the plug were bent inwardly to provide a spacing of about 0.02 inch. A bridge wire 17 was welded to the leg wires 16. The bridge wire was about 0.0005 inch in diameter and had a total resistance of about 4-5 ohms. The plug 15 was of a thermosetting resin which was sufficiently rigid to cause expansion of the shell 11 when pressed thereinto, and which thereafter was not subject to cold flow due to the pressure exerted by the expanded shell 11 to an extent sufficient to cause loss of waterproof quality. The plug was formed to have an outside diameter of about 0.26 inch and an overall length of about 0.31 inch. A slight shoulder and bevel were provided at the upper end for crimping the shell thereover to give a good closure and a shoulder was provided at the ignition end to tightly receive a fiber sleeve 23, 0.14 inch long, 0.25 inch outside diameter, 0.19 inch inside diameter, made of a medium hard vulcanized fiber composition.

After bridging the leg wires, the bridge wire and terminal tips were dipped in a slurry of a very sensitive ignition composition containing diazodinitrophenol and potassium chlorate, whereby a small matchhead 18 was formed. The matchhead was allowed to dry and then provided with a protective coating of nitrocellulose from a solution of it in butyl acetate. It is important to point out that an ignition composition should be used which

has a high sensitivity to ignition energy when the detonator must be fired with very small energy requirements, such as of the order of a few thousand ergs, for example, 4,000-6,000 ergs. The diazodinitrophenol-potassium chlorate mixture has been found to be very satisfactory for this purpose, a mixture containing about 25-40 parts by weight of potassium chlorate being preferred. However, being gaseous and violent, the quantity must be kept at a minimum when used in a delay device. Otherwise, it may burst the shell instantaneously. The matchhead preferably will contain less than about 0.005 gram of the composition.

The fiber sleeve 23 was forced on the plug 15 to form a cavity around the matchhead. This cavity was loaded with a burning ignition mixture 19 of lead-selenium-nitrostarch, 71-27-2 parts by weight, wet with butyl acetate, and dried. This charge in the plug cavity serves several purposes: It adds mechanical support to the matchhead which alone has insufficient contact with the terminal wires to withstand setback in the event of use where it is subjected to high acceleration, and it forms a hot-burning mass upon ignition which in turn readily ignites the heating charge 14. About 2 parts by weight of nitrostarch with the heavy lead-selenium mixture is sufficient binder to prevent powder from falling out of the cavity even under extreme conditions. Too large an amount is to be avoided since it increases the pressure unnecessarily.

The completed ignition assembly, including the fiber sleeve 23 and charges 18 and 19, was forced into the shell 11 until the sleeve 23 was pressed against the sleeve 22. The shell was caused to bulge slightly but there was no tendency of the shell to split. The portion of the shell extending beyond the plug was crimped over and pressed against the upper circumferential edge of the plug. The resulting detonator was rigid and waterproof.

Detonators of this character were fired in a manner to give instantaneous ignition of the matchhead (about 0.1 millisecond), and delay times obtained were as follows: 9.1, 11.5, 10.1, 9.3, 8.6, 9.3, 8.6, 7.5, 12.1, 10.9, 11.8, 9.6, 6.9, and 9.9 milliseconds; average—9.7 milliseconds.

Thus, in accordance with this invention and as specifically described with reference to a preferred embodiment thereof, electric detonators have been produced having reproducible and reliable short delay periods of the order of a few milliseconds, the detonators being small in overall dimensions, waterproof, rugged, and having a low ignition energy requirement.

In this invention a highly energy-sensitive ignition assembly, comprising a very small bridge wire and an energy-sensitive ignition composition surrounded by a burning charge, is utilized to substantially instantaneously ignite a heating charge. The composition and quantity (including column length) of the heating charge are adapted to give, in combination with the heat-conducting metal disc, a predetermined time delay in the firing of the device.

Among the advantages resulting from the use of the heat-conducting, separating member are: It is a physical barrier which prevents erratic firing due to burning material being forced suddenly through the heating or burning fuse or charge and prematurely igniting the base charge as may result otherwise from sudden pressure produced by the matchhead ignition; it is a means of effecting a predetermined delay time

which may be varied by varying the thickness of the disc and/or using metals with different coefficients of heat conductivity; and it maintains the detonating charge in a compressed state.

The thickness, configuration, and composition of the heat-conducting separator may be varied. For example, the separator may be made of copper, brass or any other suitable material, which of course will be determined to be compatible with the other constituents of the detonator with which it will come in contact. Configurations other than that of a disc may be utilized, the particular shape being a matter of choice. In general, it will be in the form of a thin metallic sheet. It will be understood, too, that different means and methods may be used for securing the metal sheet in place as, for example, pressing a cupped sheet into the shell.

The composition and quantity of the heating charge may be varied in different ways to give the desired temperature and speed of burning. Preferred compositions have a lead and selenium base. Such materials as magnesium powder, aluminum powder, and barium nitrate are utilized to adjust the delay time as required. The time may be varied also by varying the density (pressure) of the heating powder.

For example, detonators made in accordance with the foregoing description, but utilizing a heating charge containing a lead-selenium composition of 74-26 parts by weight, in combination with a 0.0015 inch thick brass disc, gave delay times of about 30 milliseconds. Similar detonators, but containing in the heating charge additionally up to 6 parts magnesium, 6 parts aluminum, and 10 parts barium nitrate by weight, had delay times of about 5 milliseconds.

The ignition powder is a highly energy-sensitive composition. It is preferred to use a composition such as a mixture of diazodinitrophenol and potassium chlorate. However, other similarly sensitive compositions may be used as will be understood in the art. Mercury fulminate, lead styphnate, barium azide, and tetracene are other substances that may be used. Of course, if it is not necessary to limit the firing energy to very low values, less sensitive ignition compositions may be utilized and the bridge wire may have greater energy requirements as found in conventional ignition assemblies, and still advantages of the heat-conducting metal separator may be realized. Its advantages are particularly important when low firing energies and short delay times constitute primary required characteristics of the detonator.

The bridge wire which is used in the detonators of this invention may be either noble metal or base metal resistant wire; thus, for example, platinum alloys or iron alloys may be used and such resistant wires are well known. Bridge wires which have been found to be particularly suitable are those made from metal alloys of

high specific resistivity, such as, for example, those known to the trade as Nichrome (a nickel chromium iron alloy containing 60% nickel, 24% iron, 16% chromium, 0.1% carbon), Chromel C

(a nickel chromium iron alloy containing 60% nickel, 16% chromium, and the balance mainly iron), and Ohmax (a chromium iron aluminum alloy containing 20% chromium, 8.5% aluminum, and the balance mainly iron). The resistant wire is affixed to the leg wires either by swaging, soldering, or welding. With very fine wires, welding is generally preferred. The bridge wire is preferably bowed slightly by crimping the leg wire terminals closer together after bridging; excessive crimping is to be avoided.

For low energy requirements, bridge wires with a diameter of the order of 0.0004-0.0006 inch, and with an average resistance of 4-6 ohms, are particularly effective. However, as already pointed out, when the requirements permit, bridge wires with other characteristics may be utilized, as will be well understood in the art.

It will be seen, therefore, that in accordance with this invention and as set forth in the foregoing description thereof, electric detonators having reproducible and reliable delay periods of as little as a few milliseconds; which are small in size, and are waterproof and rugged; and which may be characterized by a low ignition energy requirement may be manufactured in a simple and facile manner.

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

1. In a delay detonator having a tubular shell, a detonating charge, a heating charge, and an electric ignition assembly, the improvement which comprises a disc-like metal delay element interposed between a lower and an upper annular member, the lower annular member and the upper annular member being in forced fit within the shell and imbedded in the detonating charge and the heating charge, respectively, and the disc-like metal delay element having its bottom central portion in contact with the detonating charge and its upper central portion in contact with the heating charge.

2. The delay detonator of claim 1 in which the disc-like metal delay element is brass.

3. The delay detonator of claim 1 in which the disc-like metal delay element is copper.

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