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PYROELECTRIC EFFECT IN A SUBMINIATURE HIGH VOLTAGE IMPACT FUSE

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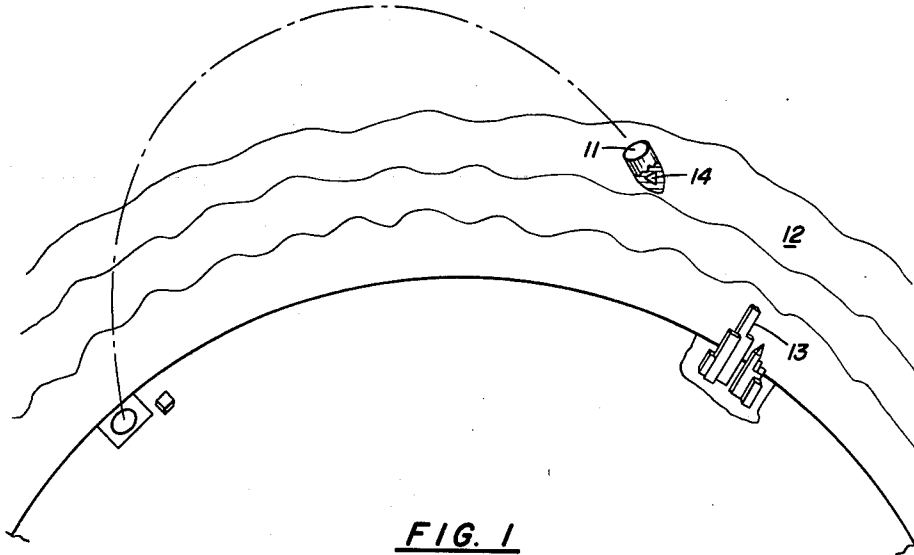


FIG. 1

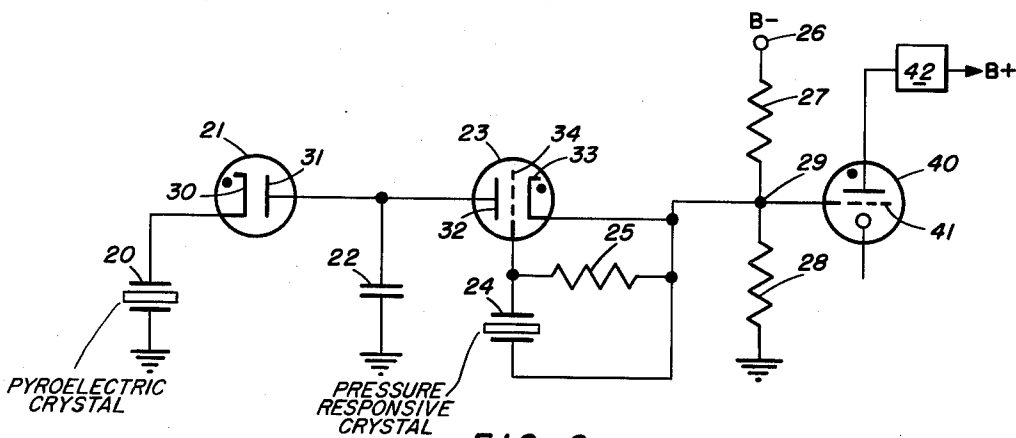


FIG. 2

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PYROELECTRIC EFFECT IN A SUBMINIATURE HIGH VOLTAGE IMPACT FUSE

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3 Claims. (Cl. 102-70.2)

This invention relates to an impact fuse and more particularly to a subminiature high voltage impact fuse suitable for use on a ballistic missile whereby the thermal heating of the missile nose cone on atmosphere re-entry will cause the fuse to be armed.

It is well known, in the field of missiles and the artillery sciences, to utilize an impact fusing device located in the warhead of the projectile such that the forces created on impact will cause the subsequent detonation of an explosive charge. These impact fusing devices have taken many forms such as an acceleration responsive device actuated by the sudden decrease in the projectile velocity, switching means which are forced together by impact, explosive devices detonated by impact and certain crystalline and polycrystalline materials which, when compressed by impact forces, will generate an electric current. While simple and often of positive operation the afore-mentioned devices suffered from certain particular disadvantages, not the least of which was a tendency to detonate the explosive charge upon receiving a minor and accidental shock while being handled resulting in an explosion which often proves costly in terms of personnel and material. Attempts have been made to solve the problem of accident detonation by providing the fusing circuit with means for disabling the detonator until just immediately prior to firing the gun or launching the missile. Efforts in this direction have proved only more or less satisfactory because it is still generally required that the system be armed sometime prior to actual discharge or launching.

It has been recognized that it would be extremely desirable if the projectile could be launched in an unarmed condition and during flight internal mechanism would actuate the detonator circuit such that target impact would result in the usual explosive detonation. This would provide for maximum safety in handling the weapon during the entire period preceding the launching of the projectile. In modern nuclear and thermo-nuclear warheads it is even more desirable that means be provided to maintain the detonator in an unarmed condition until considerable time after the projectile is launched and during that period of flight when the projectile or missile is passing over friendly territory so as to further reduce any possibility of an accidental or premature explosion of the warhead.

The instant invention fulfills this existing need and is particularly adaptable, although not necessarily limited, to an intercontinental ballistic missile. This invention contemplates the use of a fuse actuated by impact with a target, which fuse is unarmed until immediately prior to said impact. This is accomplished by utilizing a crystalline material exhibiting pyroelectric properties and carried within the nose cone of a missile, so that the thermal heating effect of the atmosphere, as the missile nose cone passes therethrough on re-entry, will cause the aforesaid crystalline matter to generate a voltage which is subsequently applied to a detonator by a ceramic impact trigger. Thus it will be seen that a missile may be launched in an unarmed condition, will cover most of its flight path in an unarmed condition and then, on atmosphere re-entry, just prior to target impact, the great increase in nose cone temperature will cause the firing sys-

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tem to then, and only then, be armed. It will be understood that this will result in the maximum degree of safety to those personnel involved in the handling, transportation, and launching of such a device. Further, a high degree of safety will be provided for those friendly areas over which the missile may fly during part of its flight.

Therefore, the present invention has as an object a fuse which will remain in an unarmed condition until just prior to the intended time of detonation.

Another object of this invention is to provide a fuse that is very light in weight and will occupy an extremely small space.

Still another object is to provide a fuse with a high degree of safety for attendant personnel.

Yet another object is to provide a fuse which will be armed on re-entry through the earth's atmosphere.

A still further object is to provide a fuse with a minimum of moving parts and a high degree of reliability.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

FIG. 1 is a diagrammatic view in partial cross section of a ballistic missile nose cone, utilizing the present invention, shown on atmosphere re-entry; and

FIG. 2 is a schematic diagram of the circuitry utilized in the instant invention.

Referring to the drawings and more particularly to FIG. 1, wherein is shown an intercontinental ballistic missile nose cone 11 re-entering the atmosphere of the earth 12 and about to hit a target 13. Within the nose cone of missile 11 there is contained a subminiature high impact fuse 14, the operation of which will be described in detail hereinafter. The missile completes the majority of its flight at a high altitude above the influence of the atmosphere of the earth and when nearing the end of this flight re-enters the atmosphere as shown in FIG. 1. It is well known that the nose cone of the missile when passing through the relatively denser lower layers of the atmosphere will, due to friction with the air molecules, heat up to a high temperature. The present invention contemplates, as described hereinafter, the utilization of the resultant heat produced on re-entry to affect a pyroelectric crystal such that a sizeable voltage will be generated and utilized on impact, or at any other desired time, to detonate the missile warhead.

It is noted that at the time the missile is launched, and during its exit from the atmosphere of the earth, the velocity of the missile is relatively slow, since it is still accelerating, until such time as it is considerably removed from any effects of atmospheric friction. Thus, the extreme nose cone heating which is utilized in the instant invention to arm the impact fuse, is developed only during the re-entry stage of the missile flight and not during its initial passage through the earth's atmosphere.

Referring now to FIG. 2 wherein is disclosed the particular circuitry employed in one embodiment of the present invention, it will be seen that a crystal 20 is connected between the cathode 30 of a gas diode 21, which may be a KP-97A tube, and electrical ground, the plate 31 of the diode 21 is also connected to ground through capacitor 22. The crystal 20 may be any piezoelectric crystal exhibiting the properties of pyroelectricity. The particular embodiment described herein makes use of a barium titanate ceramic. However, it is to be understood that any other crystalline material exhibiting the properties of pyroelectricity could be used as a means for voltage generation. It is noted that crystals of this nature exhibit the characteristic of an increasing volt-

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age on their surface as the ambient temperature is increased. The particular crystal utilized herein exhibits a voltage curve which will follow the temperature curve of its environment until such temperature reaches a value in excess of 1000° F. This point is termed the "upper Curie point." At such time the crystal voltage, in the case of barium titanate, will be in the order of magnitude of 250 volts. The effect described above is essentially a change of polarization on certain of the crystal faces with change in temperature. The coefficient describing the magnitude of this effect is P_j where $j=1, 2, \text{ or } 3$ and P_j is expressed in units of

$$\frac{\text{Coulombs}}{(\text{cm.}^2)(\text{C}^\circ)}$$

As an example, the magnitude of P_3 for barium titanate ceramic is

$$P_3 = 10^{-8} \frac{\text{Coulombs}}{(\text{cm.}^2)(\text{C}^\circ)}$$

The subscripts 1, 2, and 3 refer to the components of the polarization vector along the three crystal axes.

A gas filled triode 23, which may be a KP-97 tube is provided with its anode 32 connected to the junction between capacitor 22 and the anode 31 of tube 21. The grid 34 of triode 23 is connected through a resistor 25 to the cathode 33 of the same tube. A ceramic trigger crystal 24 is connected in parallel across the aforesaid resistor 25.

A voltage divider connected between a negative voltage supply 26 and the electrical ground is provided and comprises resistors 27 and 28. The junction 29 between these two resistors is connected to the cathode 33 of triode 23 and also to a utilization device which may be, and is shown as, the firing grid 41 of thyatron 40. The ceramic trigger 24 is of the type that will generate a small pulse when impacted on a target area. The thyatron 40 is representative of any of a number of devices which will control the firing current of a detonator 42 when subjected to a change in control voltage. It is to be understood that any other similar utilization device could be incorporated herein.

The operation of the instant invention can be most easily understood by considering first the existing circuit conditions at the time a missile is launched and then considering such changes as may occur upon re-entry of the nose cone into the earth's atmosphere and immediately following target impact. It will be realized that the entire circuit as shown in FIG. 2 to the left of the junction 29 is in a quiescent condition at the time of launch and during the vehicle's flight through the majority of its trajectory. A negative voltage is applied to the voltage divider composed of resistors 27 and 28 which maintains a negative voltage at point 29, connected to the control grid of, in this example, a thyatron, which negative voltage is sufficient to maintain the thyatron in a non-conductive condition. For the particular pyroelectric crystal utilized in the disclosed embodiment the B- or negative voltage may be selected so that when applied across the voltage divider a voltage of -200 volts will be applied to the thyatron grid. This negative voltage will be sufficient to absolutely prevent the thyatron from conducting and thereby prevent the operation of the detonator circuit, but is less than the voltage developed across capacitor 22 on re-entry.

As the nose cone re-enters the atmosphere of the earth and is heated by the air friction, the pyroelectric crystal, which is positioned in physical proximity to the nose cone surface, will follow the warming curve of the nose cone until the ceramic is heated beyond its upper Curie point. The resultant voltage increase of the crystal 20 will charge capacitor 22 through the unidirectional diode 21 which diode will prevent the subsequent discharge of capacitor 22 in a reverse direction. It is to be understood that any other non-reversing diode could be used

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in place of the illustrated gas diode 21. At such time, and only at such time, as the capacitor 22 is charged by the pyroelectric crystal on atmosphere re-entry, is the circuit armed and capable of causing warhead detonation. Thus, the circuit exhibits a built-in safety characteristic.

The gas triode 23 is selected to have a very low ionizing potential which is supplied by the ceramic trigger crystal 24 on impact with the target area. One disadvantage with a ceramic trigger is that the extreme heat generated on re-entry tends to polarize the crystal and thus make it much less effective. However, by the time the entire atmosphere of the earth has been passed through, this crystal will have partially depolarized and thus will be able to generate a feeble pulse on impact. This pulse will be enough to actuate the sensitive triode 23 thereby connecting the capacitor 22 to point 29 of the voltage divider. The discharge of capacitor 22 through triode 23 and resistor 28 will momentarily raise point 29 to a positive potential which will allow thyatron 40 to fire, resulting in warhead detonation. The voltage at point 29 need only be momentarily raised to a positive potential as the grid of a thyatron, once conduction begins, loses control of the tube operation.

From the above description, it will be appreciated that until such time as the system is subjected to extremely high temperatures, generated by nose cone re-entry into the earth's atmosphere, it will be impossible for any accidental shock or vibration to detonate a missile or warhead equipped with the fusing system herein described, inasmuch as two separate events are required to occur in a predetermined sequence. First the pyroelectric crystal must be heated to an extreme temperature to arm the system and secondly, an impact must actuate the ceramic trigger so as to apply a voltage, generated by the first of the two mentioned steps, to a thyatron or similar device in the actual firing circuit.

One considerable disadvantage overcome by the present invention is that of polarization of the ceramic trigger which normally occurs when a device of that nature is subjected to the temperatures incident to nose cone re-entry through the atmosphere. Such polarization reduces the effectiveness of the ceramic trigger to such a point that, as previously pointed out, only a very feeble pulse can be generated by a crystal of the usual size. Therefore, to insure positive operation under the described conditions, using only an impact trigger as a detonating voltage source, would require that its size be prohibitively large. Further, when in an unpolarized state prior to launching of the missile, this trigger would be extremely sensitive to any shock or vibration, greatly increasing the danger to ground personnel in the handling of an already hazardous missile.

It should be understood that the circuit of the instant invention would, of course, provide satisfactory operation if the ceramic trigger were to be replaced with an inertia switch, proximity or time device. In other words, the invention may be employed with any trigger suitable for the purpose. Further, the gas triode disclosed herein could be replaced with a magnetostrictive switch.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. A self-contained, self-arming, impact responsive, missile detonator comprising in combination a thermally actuated pyroelectric crystal connected through non-reversing diode means to an electric storage means, said storage means connected through triode switching means to the control grid of a thyatron tube, said control grid being maintained by voltage divider means at a negative voltage, and said switching means being controlled

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by an impact responsive ceramic trigger means whereby heating of said pyroelectric crystal means will energize said electric storage means and a subsequent impact shock will cause said ceramic trigger means to actuate said switching means resulting in electrical energy from said storage means overcoming the negative voltage applied to the grid of said thyatron, causing said thyatron to conduct.

2. A circuit as set forth in claim 1 wherein the said pyroelectric crystal comprises a barium titanate ceramic.

3. A self-contained, self-arming, impact responsive, missile detonator comprising in combination: a pyroelectric crystal and a storage means arranged to have a unidirectional current conductor connected therebetween, a first fast acting electronic valve means having an input, an output and a control terminal, the input terminal and said storage means being connected in circuit relationship, a pressure sensitive voltage generating crystal connected in circuit relationship to said control terminal such that a change in pressure on said pressure respon-

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sive crystal will impress a signal on said control terminal causing said valve means to conduct, a biased trigger means having a control grid and an output means, the output terminal of said valve means being connected to said control grid causing said trigger means to conduct when said valve means conducts, and a detonator connected to said output means being actuated by said trigger means.

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