March 3, 1964 J. SPOOL 3,123,002

FUSING DEVICE

Filed Jan. 20, 1956 2 Sheets-Sheet 1

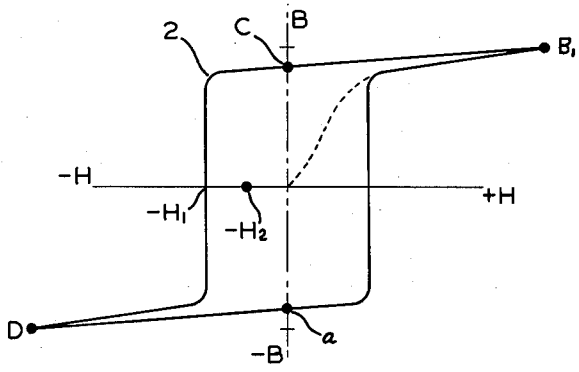


FIG. 1

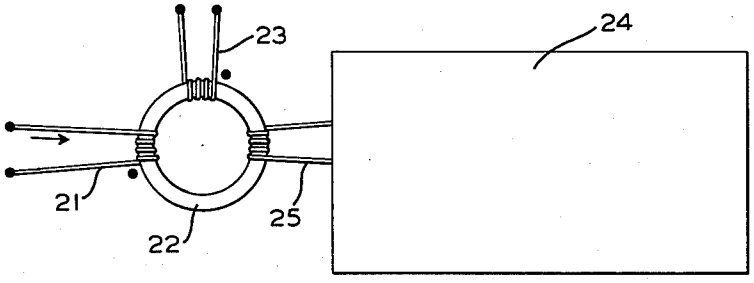


FIG. 2

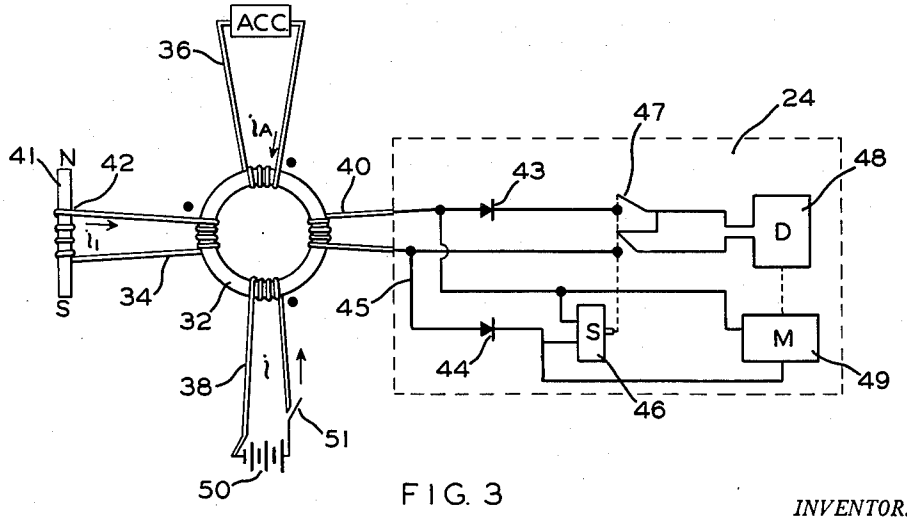


FIG. 3

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March 3, 1964 J. SPOOL 3,123,002

FUSING DEVICE

Filed Jan. 20, 1956 2 Sheets-Sheet 2

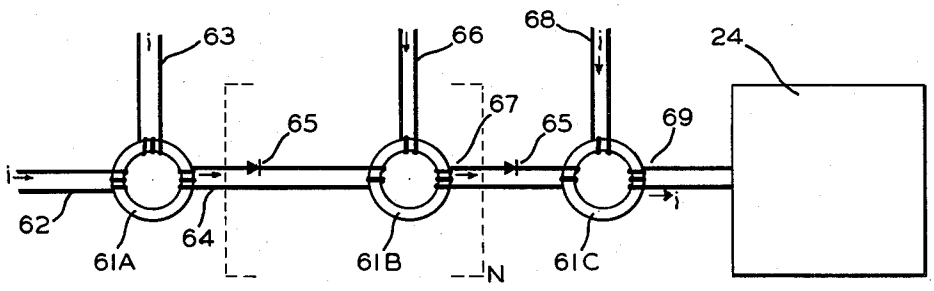


FIG. 4

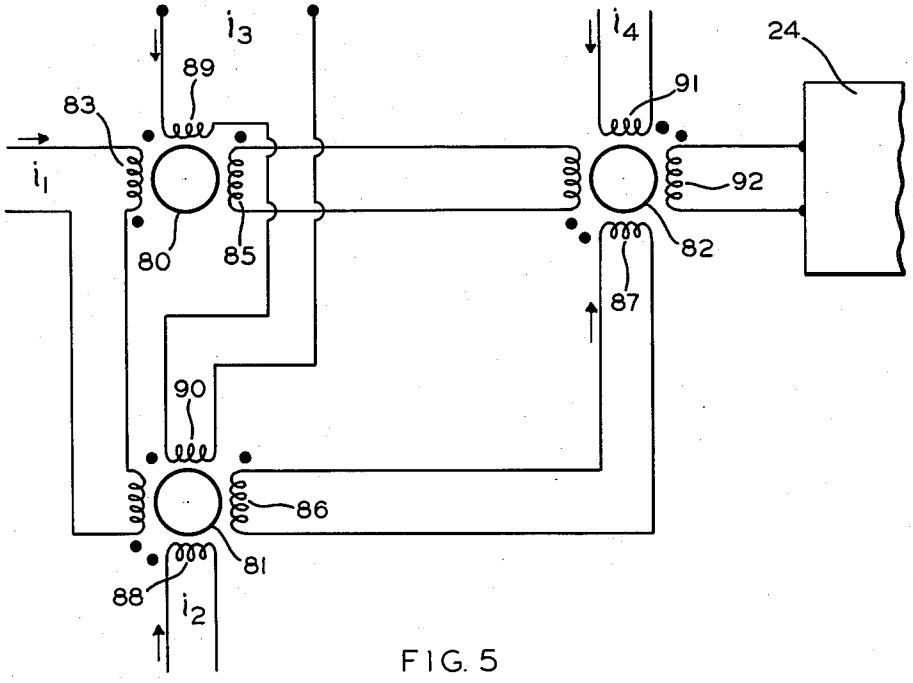


FIG. 5

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FUSING DEVICE

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2 Claims. (Cl. 102—70.2)

This invention relates to projectiles containing explosive means and more particularly to a means for fusing these projectiles utilizing magnetic elements.

The science of ordance is an ancient one, but one which has mushroomed in scope greatly over the past decade, for the conventional artillery fired projectiles have become only a small portion of the ordnance arsenal which now includes guided missiles and nuclear weapons. Within this science is the acute problem of initiating explosion of the projectile at the desired moment, but yet preventing the arming and/or explosion of the projectile during transit, storage and during flight until it reaches the target. With projectiles fired from non-rifled chambers, present firing and arming techniques are most inadequate. This includes mortars, rockets and guided missiles. With the rifled type of projectiles, one can utilize the centrifugal force developed in the projectile as it is accelerated. Thus one can be assured in that type that the arming will occur only coincident with firing. With non-rifled types, conventional techniques are to mechanically arm or rely upon acceleration forces to arm the projectile, so that upon contact the projectile explodes. Unfortunately the acceleration sensitive portion of the arming circuit may be actuated in transit through severe droppage, etc., thus resulting in a fully armed projectile at the time the mechanical pin or other such other structure is removed. Then again, with the guided missiles, it is desirable to require a sequence of operations of such complexity to occur prior to arming, that arming could statistically only obtain as a result of designed conditions or synthetic phenomena which occur after firing of the missile.

It is an object of the present invention to overcome the foregoing and related disadvantages of the projectile fusing and arming art.

It is a further object of the invention to produce a novel fusing means which is sensitive to a plurality of events that must occur before arming of the explosive of a projectile.

It is a still further object of this invention to utilize an element insensitive to nuclear radiation which is responsive to a sequence of events and thereafter transmits the information to the arming device of a projectile.

These and other objects of the invention will be apparent from the following specification and appended drawings in which FIGURE 1 is a diagram of an actual hysteresis loop of core material used in the novel fuse mechanism; FIGURE 2 pictorially shows a toroid core of the material of FIGURE 1 having a plurality of windings on a toroid; FIGURE 3 is a pictorial and schematic illustration of one form of the invention; and, FIGURES 4 and 5 pictorially show other modified forms of the invention.

In broad scope my invention utilizes the gating characteristics of a magnetic material having substantially square loop hysteresis characteristics to avoid the arming of a fuse until an appropriate or pre-determined sequence of events occur. Thus my invention broadly comprises a means responsive to a predetermined plurality of events, a magnetic gating element controlled by said means and arming means responsive to the output of the gating element for arming the detonator of an explosive train.

In a more limited sense, my invention has overcome the difficulties of the prior art by the production of a fuse mechanism comprising a plurality of individual windings

disposed about the cores of magnetic material having a generally rectangular hysteresis curve, said windings including a control winding connected to means responsive to at least one predetermined event, input windings connected to means for generating a pulse of current and output windings responsive to the current flow in said input windings, said output windings connected to arming means including both apparatus for arming and for exploding the detonator.

This magnetic material utilized in the gating element has a property of low coercive force and high residual magnetism, and may be readily magnetized in one direction or one remanence state representative of a binary "one," and in the opposite state representative of a binary "zero." A core fabricated of such a material can be placed in one of these two states of remanence by means of windings on the core to which a pulse is applied and the particular state existing within a core may be determined by the voltage pulse induced in other windings on the core when the flux state is reversed. An ideal core material for the gating circuit would have a generally rectangular hysteresis curve such as is shown in FIG. 1. With the binary "zero" state arbitrarily selected as point "A" on the curve, application of a positive magnetizing force "H" will cause the core to transverse the hysteresis loop to saturation point "B_1" and, on removal of the applied magnetizing force, returns to a point "C" which represents the binary "one" state. The ratio of the values of "C" "B_1" defines the squareness ratio. If the hysteresis loop were square, the squareness ratio would be "one," however for the purpose of this specification the core material is considered having a substantially rectangular hysteresis curve and is suitable for gating elements where it has a ratio of .4, although it preferably should be greater than 0.8. Similarly with the application of a negative magnetizing force "H" sufficiently greater than the negative magnetizing force $-H_1$, the core transverse its hysteresis curve to the maximum point of "D" dependent upon the magnitude of the negative magnetizing force. After removal of this negative force, the core returns to its residual "zero" state at "A." Change in state of the magnetic core from the "zero" state to the "one" state, or from the "one" state to the "zero" state induces an output voltage pulse in each of the windings in the core, however application of a magnetizing force tending to maintain the core in either existing remanence state would ideally produce no flux change, consequently, no output voltage pulse would be produced. Unfortunately, the poorer the rectangularity of the hysteresis curve, the greater the flux change when the core undergoes transition from its remanence state to its saturation point so that substantially rectangular hysteresis characteristics of the core material is most desirable. With decreasing rectangularity, it is apparent that small changes of "H" will then bring it into the instable region adjacent to the knee of the hysteresis curve, thus resulting in unpredicted changes of polarization state. Numerous materials are available which have substantially square hysteresis characteristics of which magnesium-maganese-ferrite (see British Patent No. 697,219) and nickel iron alloy (Deltamox manufactured by Allegheny-Ludlum Steel Corporation) are exemplary.

Referring now to FIG. 2, the broad scope of my invention is shown by a single toroid core **22** of the material of FIG. 1 having a plurality of windings. The control windings **21** are connected to a means responsive to a predetermined event, and, upon occurence of said event, current flows through the control windings **21** defining the state of the core to one opposite to that which will be produced by current flow in input windings **23**. Thus in fabrication of the combination, the core **22** would be set to an initial state identical to that which would result

upon the current flow through input windings 23, thus preventing any signals from windings 23 effecting a current flow in output windings 25, thus effectively isolating the arming device 24 shown as a black box from the circuit of windings 23. In this one sees the extreme and novel approach to the arming of explosive loaded projectiles, for one can prevent thus any effect of input circuit 23 on the output circuit 25 until a certain predetermined event or sequence of events has occurred, the result of which is manifested as current flow in the control windings 21. The current flow in the control windings results only from events which happen as a result of predefined phenomena isolating the effect of inadvertent or unexpected phenomena such as the closing of an impact switch, output from an accelerometer, stray electronic signals received when not in flight, etc.

In FIGURE 3 is shown an embodiment of the invention which is particularly useful for mortar, bazooka, rocket and other types of projectiles which are not imparted rotational motion during propulsion of the projectile and are of the non-guided type. A conventional way of arming mortar shells is by means of an accelerometer or other acceleration sensitive structure which initiates and moves the detonator into line with the explosive train so that the projectile can be subsequently exploded or detonated by impact. With such a fusing arrangement, it is readily seen the transport of projectiles could inadvertently arm the shell. The device of FIG. 3 although sensitive to acceleration requires further the occurence of an additional event in order to arm the projectile. The core 32 of the material having a substantially rectangular hysteresis characteristic has four different windings which are designated respectively, the flux control winding 34, the acceleration control winding 36, the input winding 38 and the output winding 40. Let us assume for purposes of discussion that the core is initially set in the "one" state, that is it has remanence of point "C" on the hysteresis curve of FIG. 1. Flux control winding 34 has current flow as a result of the changing of the magnetic field adjacent to permanent magnet 41 which has windings 42 about it. This magnetized material can be of barium ferrite or any of the other well known permanently magnetized materials, the level of magnetization being defined by design so as to obtain a current flow of appropriate magnitude (to be subsequently discussed) in flux control winding 34. In actual embodiment, the permanent magnet 41 can be ring shaped and form a section or portion of the actual war-head of the projectile. As the projectile leaves the barrel of the mortar or rocket chamber, the change in distribution of the magnetic field of magnet 41 induces a current flow i_1 in flux winding 34 by the flux cutting the windings about magnet 41. By design this current flow should be no greater than about .5 to .6 of that of the total current flow necessary to produce a negative magnetization force $(-H_1)$ sufficient to cause change in polarization of the core 32. Thus the current flow in windings 42 should cause a negative magnetization force of about $(-H_2)$ as shown in FIG. 1. In this construction, reliance on the simultaneous negative magnetization arising out of current flow in acceleration windings 36 and the current i_1 is necessary to produce $(-H_1)$. Thus negative magnetization induced by the flow of the current i_1 in flux windings 34 must be greater or equal to one-half of the flux necessary to change the polarization state of the core 32, but less than that value which would introduce the core into a state of instability which results as the core material approaches the knee region 2 of the hysteresis curve. As the projectile is fired from the chamber, it undergoes substantial acceleration which acceleration closes a mechanical contact or causes a strain in a piezoelectric, e.g., polarized barium titanate crystal, or similar material, so that upon reaching a predetermined value of acceleration, current i_A flows in acceleration windings 36, inducing a negative magnetization which conforms to the same limits as that imposed upon the current flow in windings 34. When the two phenomena of acceleration and change of flux occur substantially simultaneously, the core 32 undergoes a change of its polarization state from the "one" state to the "zero" state, thereafter assuming in flight the remanence point "A" of FIG. 1. Whereas in FIG. 2, the arming device was shown simply as a box 24, in FIG. 3 it is spelled out in detail, illustrating but not limiting, the scope of structures encompassed by the designation "arming device." Basically then the "arming device" is any apparatus which moves the detonator from its fused (inoperative) state to a position in line with the explosive train which movement is in response to an electrical signal. The change of state of the core 32 as a result of the simultaneous flux change of magnet and the output from the accelerometer induces current flow in output windings 40 which current flow arms the projectile by moving the detonator into line with the explosive train as explained below. The discussion hereafter of arming device 24 is thus understood to be merely illustrative and not limiting in any extent, as there are many variations of arming devices well known in the art, all of which can be used in combination with the gating circuit to produce a novel combination of exceptional utility. The output winding 40 branches into two circuits, each of which have diodes 43 and 44 to allow only unidirectional current flow. In the branch 45 the current flow initiates the switching motor 46 (see Electronics, January 1956, pp. 126–127) which closes the double pole double throw switch 47 so as to impose the detonator 48 in series with the output winding 40. Simultaneous with that the explosive motor 49 moves the physical position of the detonator 48 into line with the explosive train. It is to be noticed that in conformance with good ordnance practice, the double pole double throw switch retains the detonator in shorted position at all times until the explosive train is aligned. Thus with my device, the simultaneous outputs arising out of the change in magnetic flux distribution of the permanent magnet as the projectile leaves the chamber barrel and the output from the accelerometer which is present as it leaves the chamber fully arm the projectile so that the detonator will be responsive to whatever means is utilized to explode the charge. A single explosive means is set forth in the circuit including winding 38 series connected to a power source 50 and impact switch 51. At the moment the impact switch closes, the current flow in the input windings is such as to change the polarization state of the ferromagnetic material from the "zero" to the "one," producing an output in windings 40 which fires the detonator. The safety advantages of the structure of FIG. 3 is apparent, for here is a means of arming a projectile which can be armed only upon the simultaneous occurrence of a plurality of events which events can only occur simultaneously upon actual propelling of the projectile. Inherent in the advantage of combining the current flows arising out of simultaneous events to arm the projectile is the problem of current amplitude control. The modified fusing mechanism of FIG. 4 does not utilize simultaneous events, but rather a sequence of events to produce the arming of the explosive train. For simplicity of discussion, the arming device as 24 is again shown as in FIGURES 2 and 5 as a box. The gating element and associated circuitry of this modification is comparable to the AND circuit as embodied in a magnetic shift register. Basically, there are a plurality of cores 61 of core material having substantially rectangular hysteresis characteristics and each initially set in a designated polarization state. The dashed lines about core 61B and its attendent windings indicates that any number of cores may be used, depending upon the number of events which must occur in sequence before actual arming of the device. Assume for purposes of discussion that "N" is equal to 1 although it can be zero or any integer and all cores are in the "zero" state. The core 61A has control windings 62 and 63. Current must flow in windings 62 to change the

polarization state of the toroid 61A to "one" so that upon current flow in windings 63 toroid 61A is changed to a "zero." The resulting change of state will produce current flow in output windings 64 and change the state of the core 61B from "zero" to "one." The diode 65 isolates the output windings of the preceding core from induced current flow of the series connected unput windings. Not until the signal means of 66 generates a current flow in the input winding will the change of state of 61B result and cause current flow in output winding 67 which results in change of the state of 61C. This change of state can be used to arm the detonator relying upon current flow in input winding 68 to change the state of 61C to produce the final pulse of induced current in output winding 69 for detonation of the explosive charge. Thus it was necessary to have a total of four signals all in sequence to produce the exploding of the explosive. This is believed particularly desirable for application to guided missiles for the sequence of operation can be carried in such a fashion and with such a predetermined number of steps that statistically it would be impossible for those sequence of events to occur unless synthetically produced. Here we have then an arming system in accordance with this invention which does not require the precise amplitude control of the structure of FIG. 3. It can be designed as to require "N" signals in sequence which produces safety characteristics hitherto believed impossible in this art.

In FIGURE 5 there is shown another variation in accordance with this invention which variation uses both And and Inhibit (And Not) elements of computor circuitry to achieve a sequential arming procedure. Each of the cores 80, 81 and 82 are of the core material having the characteristics set forth in FIG. 1. The terminals of the output circuit actuate the arming device 24. In this particular modification it is necessary that the current flow i_1, i_2 both occur before i_3, which in turn must occur prior to that of i_4. Let us explore how this is obtained. Cores 80 and 81 are in the "zero" state initially and core 82 is in the "one" state. The direction of current flow of i_1 in control winding 83 sets the cores 80 and 81 in the "one" state. The induced current in output winding 85 of core 80 tends to polarize core 82 in the "one" state. Simultaneous with this the current in the output windings 86 of core 81 attempts to polarize core 82 by means of input winding 87 in the "zero" state so that there is a cancellation of the effects retaining core 82 in the "one" state. Current flow i_2 in the control winding 88 of core 81 polarizes the core 81 in the "zero" state. Current flow i_2 in the control winding 88 makes no change in cores 80 and 82. However core 81 is already in the "zero" state so that there will be no output in windings 86, but the current induced in windings 85 polarizes the core 82 to the "zero" state inducing a current in the output windings of core 82 arising out of this change of state which can be utilized to arm the detonator. Finally the impulse of current i_4 into windings 91 polarizes the core 82 to the "one" state and induces a current in output windings 92 which can detonate the explosive. Should the i_3 current flow before that of i_1 and i_2, or alternatively the i_2 before i_1 and i_3, as well as i_3 before i_2, the core 82 would not be suitably polarized so as to induce an output current pulse upon the flowing of current i_4. It is therefore seen that this circuit which uses the combination of And and Inhibit achieves circuitry sensitive to a sequence of events which can be controlled and prevent other than synthesized signals from arming and firing the projectile. It is apparent that my invention encompasses other computer circuitry similar in character to that set forth above and such circuitry can be so employed.

The utility of my invention should now be quite apparent. I have succeeded in producing an arming and firing means for projectiles which does not suffer the disadvantages of the prior fuze art. Particularly the disadvantage of transit or undefined phenomena arming the explosive train has been completely avoided. It also has the further advantage that the system is insensitive to nuclear radiation, which radiation levels become quite high both for missiles propelled into outer space and nuclear weapons. A still further advantage is the compactness of the fuzing and arming mechanism of the invention, particularly when printed circuit techniques are applied allowing it to be utilized in small projectiles. A further advantage is the rugged character of my fusing structure over types known to the art. Although I have discussed the fusing mechanism relative to projectiles it is applicable to mines and other types of ammunition. Particularly in both land and water mines it is desired to fuze the explosive so that after an event or sequence of events (pre-determined) the charge can be exploded. The pre-determined events can be of any definable nature which as already shown can include acceleration, change of magnetic field and reception of an electro magnetic radiation signal. The means responsive to the event causes current to flow in the appropriate windings of the magnetic gating element and may be of innumerable forms of which electro magnetic radiation receivers, photo and nuclear sensitive devices, telemetering equipments, accelerometer and other mechanically sensitive electrical generators, devices sensitive to magnetic flux change and other types of comparable transducers are representative.

As many apparently widely different embodiments of this invention may be made without departing from the spirit and scope thereof, it is to be understood that the invention is not limited to the specific embodiments hereof, except as defined in the appended claims.

I claim:

1. A fusing or arming mechanism for explosive containing projectiles comprising a first, second, and third core of a ferro magnetic material, said material having the property of a generally rectangular hysteresis curve, a first control winding on said first core and a second control winding on said second core, said first and second control windings being connected in series, an additional control winding on said second core, a first output winding on said first core, a second output winding on said second core, a third control winding on said third core, first conducting means connecting said first output winding with said third control winding, a fourth control winding on said third core, second conducting means connecting the second output winding with the fourth control winding, a separate input winding on said third core and a separate reverse output winding on said third core, two responsive circuits connected to said output winding, a diode in each of said responsive circuits, the first of said circuits including a switching motor and an explosive motor, the second of said circuits including a switch and a detonator, said switch being closed by said switching motor, said detonator being moved by said explosive motor, so constructed and arranged that a current flow in said first control winding causes a change in the polarization in said third core, and producing a current in the output winding actuating said motors in said first circuit and current producing means connected to said separate input winding to produce a polarization change effected by said first control winding to fire said detonator.

2. A fusing and arming mechanism for explosive-containing projectiles comprising a core of ferro-magnetic material having a generally rectangular hysteresis curve and being subject to flux change, said core having a plurality of individual windings for producing flux change in said core, a first acceleration responsive control winding on said core, a second flux control winding on said core, said second control winding being connected to a winding disposed about a permanently polarized magnet, a third input control winding and an output winding on said core, two responsive circuits connected to said output winding, a diode in each of said responsive circuits, first of said circuits including a switching motor and an explosive motor, second of said circuits including a switch

and a detonator, said switch being closed by said switching motor, said detonator being moved by said explosive motor, so contructed and arranged that a current flow in the second flux control winding induced by said polarized magnet causes a change in the polarization in said core, said acceleration responsive control winding carrying a current upon acceleration and inducing a negative magnetization in said core, said negative magnetization causing a change in polarization of the core conforming to that caused by said second control winding and producing a current in the output winding actuating said motors in said first circuit and an impact switch and current producing means connected to said third control winding to produce a polarization change in said core and opposite

to the polarization change effected by said first and second control windings to fire said detonator.

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