Sept. 5, 1944. H. J. NICHOLS 2,357,759

FUSE

Filed Jan. 27, 1941

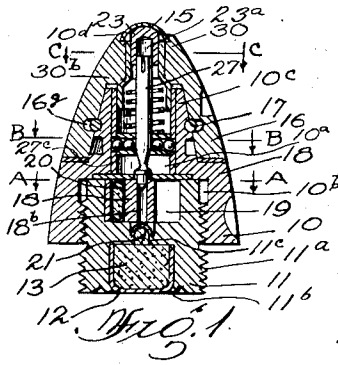

Fig. 1.

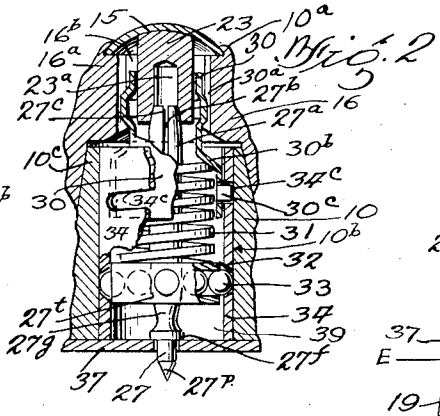

Fig. 2.

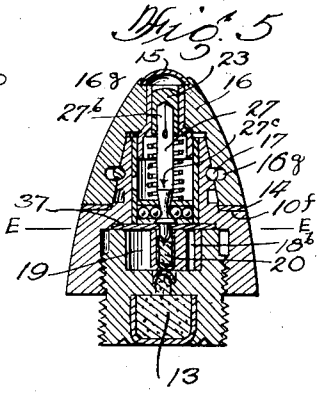

Fig. 5.

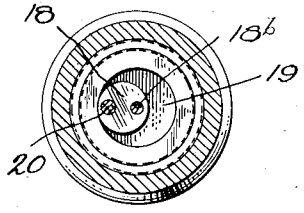

Fig. 1A.

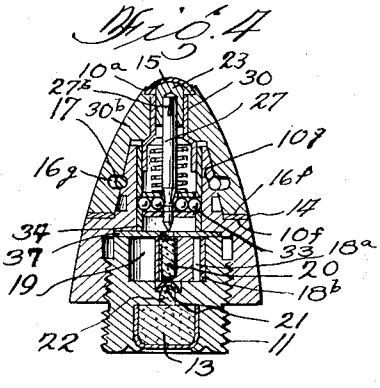

Fig. 4.

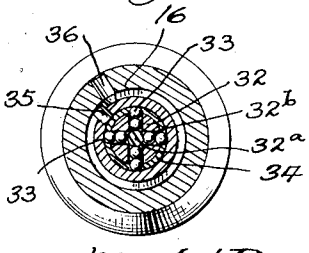

Fig. 1B.

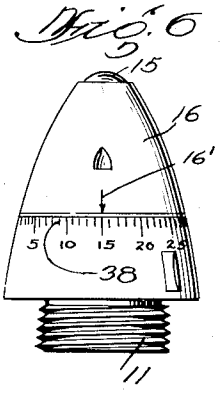

Fig. 6.

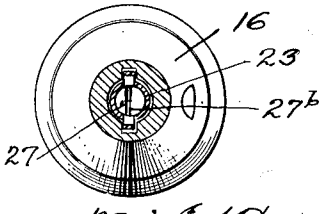

Fig. 1C.

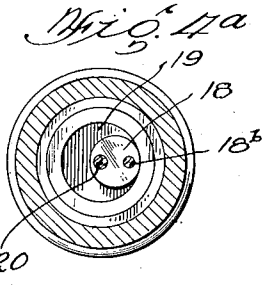

Fig. 4a.

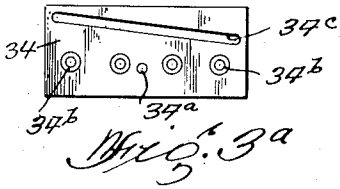

Fig. 3a.

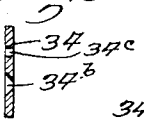

Fig. 3b.

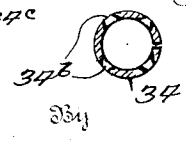

Fig. 3c.

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FUSE

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Application January 27, 1941, Serial No. 376,232

10 Claims. (Cl. 102—71)

This invention relates to a combination mechanical time-impact fuse for rotative projectiles. It is especially designed for anti-aircraft projectiles and the like and it will be described with relation to such application, altho it is to be understood that without material modification many features are equally applicable for other uses.

In my prior United States patent application Ser. No. 313,789 filed January 13, 1940, I disclosed a detonating fuse for small anti-aircraft projectiles characterized by its small size, safety features, quick impact action, and by a timed, self-destroying feature. The present invention retains the features and advantages of the prior invention, and in addition provides means for variably setting the timing of the burst of the projectile with reference to the gun. This last named feature is obtained without an increase in size, and by the addition of a few simple parts and the modification of certain parts in the prior fuse.

It is well known in ordnance circles that for many years the trend in time fuses has been towards the type employing mechanical time-setting mechanism, known generally as mechanical time fuses. This type has tended to replace powder-train time fuses, and has been devised in various forms, the most common form being that employing clock-work mechanism to provide the timing feature. While such time fuses have been used successfully in the larger sizes of anti-aircraft projectiles, so far as known no design has been evolved which will withstand the shock of firing in a projectile as small as that of a 37 mm. anti-aircraft gun as here proposed. For it is known, of course, that the firing shock is roughly inversely proportional to the diameter of the bore of the gun.

Furthermore, mechanical time fuses of the clock-work type are relatively expensive, since they involve numerous small parts which can be produced only on machine tools similar to those employed for making small clocks and watches.

It is therefore one of the main objects of the present invention to provide a settable time-impact fuse which is small, rugged, and inexpensive, yet which meets in a highly efficient, reliable and practical manner the numerous requirements for fuses of this class.

Another object is to provide simple and practical arming means which renders the fuse entirely safe in handling, storage, and firing in a gun.

Another object is to provide a timing mechanism for fuses which is simple and reliable and which will not be damaged or deranged by firing in small, high-power guns.

Another object is to provide a timing mechanism whose accuracy will not be materially affected by centrifugal force, temperature, and variations in atmospheric pressure when fired at different angles of elevation.

Another object is to provide simple and effective "bore-safe" and "muzzle-safe" features.

Another object is to provide a settable exploding mechanism for detonating anti-aircraft projectiles whose basis of measurement is substantially linearly proportional with respect to time.

Another object is to provide simple setting arrangements which enable a simple, evenly spaced time-scale to be employed.

Another object is to provide a setting mechanism which can be adjusted without complication merely by rotating the fuse nosepiece to the proper angular position with respect to the fuse body, and which can be re-set to a lower value merely by rotating the cap piece in the reverse direction.

Other objects will be in part obvious and in part hereinafter pointed out in connection with the following analysis of the invention.

This invention accordingly consists in the features of construction, combination of parts, and the unique relation of its members and in the relative proportioning and disposition thereof to obtain a highly efficient mechanism, all as more completely outlined herein.

To enable others skilled in the art fully to comprehend the underlying features of this invention, that they may embody the same in practical devices of various modified forms, as contemplated by the invention, a drawing showing a preferred embodiment of the invention forms a part of this disclosure, and in such drawing like characters of reference denote corresponding parts thruout the several views, in which—

Fig. 1 shows in longitudinal cross section a point-impact, timed detonating fuse illustrating one embodiment of the invention, the mechanism being shown unarmed or normal, safe condition.

Figs. 1A, and 1B, and 1C are transverse sections of the fuse shown in Fig. 1 the sections being taken on lines A—A, B—B, and C—C as indicated on Fig. 1, these views illustrating the normal position of the rotor, the cross-section of the bolt of the self-firing mechanism, and the cross-section of the upper portion of the setting sleeve respectively.

Fig. 2 shows in partly cut-away section the

striker arming and the self-firing mechanisms enlarged in detail.

Figs. 3*a*, 3*b*, and 3*c* show details of the cam sleeve forming part of the time-setting mechanism, in flat, cross-section and finished section respectively.

Fig. 4 is a view similar to Fig. 1, but showing the fuse in armed position.

Fig. 4A shows the armed position of the rotor in Fig. 4.

Fig. 5 is a view similar to Fig. 1 and Fig. 4, but shows the fuse mechanism in the fired position at self-firing.

Fig. 6 shows a detail of the index-point and time-scale for setting the fuse.

Referring now to the drawing, and particularly to Fig. 1, the main structure of the fuse is the casing comprising the body **10** and the cap **16** rotatably mounted thereon. The body **10** is provided with a forward, smooth, cylindrical chamber and a rearward cavity **10b**, the latter tapped to receive a container **11** screwed therein. Container **11** is provided with a threaded external portion to fit cavity **10***b* and with external screw threads **11***a* at the base portion for assembly to the projectile (not shown). Container **11** is also adapted to receive a booster cup **12**, the latter being filled with a compressed booster charge **13** of tetryl or the like. The booster cup is securely held in place by a spun-over lip **11***b* formed from the rim of container **11**, or otherwise as desired. Container **11** is further provided with a cylindrical, smooth chamber **19**, called the rotor chamber, adapted to receive a rotor **18** in which a detonator **20** is mounted. Extending from the booster cavity to the rotor chamber is a minor axial hole **11**c counterbored at the upepr end to receive the cord protector cup **21**. The interior of the cup and the hole **11**c are filled with tightly compressed tetryl or the like to form a cord for transmitting the detonating wave from the detonator **20** to the booster charge **13**. Detonator **20** comprises a thin, drawn copper shell filled with highly compressed detonating material, such as fulminate of mercury or the like, sealed and cemented in place in well known manner.

Rotor **18** is of short cylindrical form and is considerably smaller in diameter than the rotor chamber **19** in which it lies flat and eccentrically. The rotor has an off-center round hole **18***a* to receive detonator **20**, located so that the detonator can be moved into concentric relation to the fuse axis at arming, as from Fig. 1A to Fig. 4A. The rotor is also provided with a second smaller off-center hole **18***b* adapted to receive the point **27***p*, Fig. 2, of firing pin **27**, this hole being located in the rotor so that when assembled in unarmed position the rotor is permitted to swing freely around firing pin **27** as a pivot, but the detonator **20** is not permitted to approach the detonating cord **22**. Sufficient space is provided so that in event of premature explosion of the detonator, the explosion will not be transmitted to the booster charge.

Referring again to Figs. 1 and 1B, the fuse body **10** is also provided with a tapered stem **10**C adapted to support cap **16** rotatably mounted thereon by a snap-ring **17**, engaging annular grooves **10***g* and **16***g*. The bore of cap **16** is step counterbored to provide a working chamber **16***b* for setting sleeve **30**, and a coned cavity to fit the contour of stem **10**C. A soft gasket **14** assembled between a shoulder **10***f* on body **10** and the rim **16***f* of cap **16** Fig. 4 seals the fuse interior against entrance of moisture. A domed sealing disc **15** spun under a lip **10***d* similarly closes the opening at the point of cap **16**.

Referring now to the setback arming device shown in detail in Fig. 2, the firing pin **27** lies along the axis of the fuse from the point to support disc **37**, and comprises a cylindrical shank **27***a* into which a slot **27***b*, a taper **27***t*, a groove **27***g*, a flange **27***f* and a point **27***p* are cut (see Fig. 2). Assembled ahead of the firing pin is an impact member or striker **23** having an internal bore **23***a* somewhat smaller in diameter than that of the firing pin. The bore **23***a* is slightly tapered at the mouth, and the upper end of the firing pin is rounded at the corner to more easily enter this opening. The construction is such that at assembly the firing pin is readily entered into the mouth of the striker to the required limited extent, but that a relatively powerful driving force is required to push the striker completely down over the firing pin. It will be readily seen that by varying the fit of the firing pin shank with respect to the striker bore, and by varying the width and depth of the slot **27***b*, the driving force may be adjusted within wide limits to suit the arming requirements of different models of this fuse.

Referring now to Figs. 1 and 2 which show the details of the self-firing device and the time-setting mechanism therefor, the main elements of the exploder mechanism comprise setting sleeve **30**, exploder spring **31**, ball-cage **32**, balls **33**, and liner **34**. Sleeve **30** is a thin shouldered metal tube of two diameters, provided with two external splines **30***a* adapted to slide in internal longitudinal channels **16***a* in cap **16**, and with a lug **30***c* to co-act with a sloping cam slot **34***c* in liner **34**. (See Figs. 2 and 3*a*.) Split-liner **34** is preferably formed of a rolled-up strip, Fig. 3*c*, perforated in the flat with cam-slot **34***c* and four counter-sunk holes **34***b* (adapted to receive the outer rank of balls **33**) and register hole **34***a*, and then formed into a cylindrical liner. (See Fig. 3*c*.) Ball-cage **32** is of squat cylindrical form, having an axial hole **32***a* Fig. 1*b* to receive the shank of the firing pin **27**, and two cross-diameter holes **32***b* to receive eight small steel balls **33**, called the locking balls. (See Fig. 1B.) The exploder spring **31** is a helical compression spring assembled between the ball-cage **32** and the internal shoulder **30***b* of sleeve **30**. The compression force on this spring is regulated by the screw action of sleeve **30** when rotated in liner **34** to set the timing of the explosion. Liner **34** is of such size externally as to fit tightly in the bore of the body **10**, but internally it is slightly larger than the diameter of ball-cage **32**. The locking balls **33**, however, normally retain the ball-cage in the position shown in Fig. 2, so that the ball-cage assembly acts like a bolt in a lock.

The assembly of the self-firing device is effected as follows: The setting sleeve **30** is inserted in the split liner **34** by slightly expanding the latter to enable lug **30***c* to snap into slot **34***c*, Fig. 2. Then the liner is pressed into the bore **10***b* of body **10** so that the register hole **34***a* registers with the small end of stop pin **35**, and the latter is pushed home. (See Fig. 1B.) Next exploder spring **31** is inserted in place, the required number of balls are placed in the ball-cage **32**, and the latter is slipped over the firing pin **27** at the groove **27***g* and into the bore of liner **34**. When the balls are aligned with the holes **34***b* in the liner walls, the firing pin can drop down so that the tapered portion **27***t* wedges the balls **33** into the holes **34***b*, locking the assembly together as shown in Fig. 2. The

cap 23 is then dropped into place over the end of firing pin 27. Gasket 14 is set in position around the stem 10c, Fig. 1, snap-ring 17 is assembled into groove 16g of cap 16, which latter can then be pushed into position over the stem, and when the snap-ring comes even with groove 10g, the cap is locked against displacement. Stop pin 36 is then placed in a hole in cap 16, Fig. 1B, and secured therein by peening the edge of the hole. Then, as indicated in Fig. 1B, cap 16 can be rotated almost 360° (being limited by the two stop pins 35 and 36), and in so doing channels 16c engage splines 30a Fig. 2 to rotate sleeve 30, whereupon lug 30c riding in cam slot 34c moves sleeve 30 longitudinally in the bore of liner 34. Thus internal shoulder 30b varies the compression of exploder spring 31, thereby to predetermine the time of flight at which self-firing occurs.

To complete the assembly of the fuse the following procedure may be followed. By inverting the body from the position shown in Fig. 1, a thin but strong metal washer, termed the support-disc 37, and having an axial hole of such size as to receive the point 27p of firing pin 27, is dropped into place over the firing pin. Rotor 18 is then mounted on disc 37 while inverted so that the firing pin point enters hole 18b. Then container 11 is screwed tightly into place in the body 10, care being taken that rotor 18 enters freely into rotor chamber 19.

Referring now to Figs. 2 and 6, the operation of the fuse is as follows: To set the fuse, rotate the cap 16 relative to the body 10 until the index point 16' comes opposite the desired mark on the time scale 38, the fuse being shown in Fig. 6 as set at 15 seconds. On firing, due to the set-back force, striker 23 slips over the head of the firing pin as shown in Fig. 5. Due to the same force, firing pin 27 remains with its point 27p in pivot hole 18b, as shown in Figs. 1 and 1A, preventing the rotor from turning so as to bring the detonator 20 into alignment with the fuse axis. Hence should detonator 20 be exploded by the shock of set-back, no harm would result beyond making the fuse a "dud."

Consider now the action of rotor 18 when the projectile is in the bore of the gun. The set-back force to the rear will greatly exceed the tangential torque-force due to the angular acceleration of the projectile, hence the rotor will remain pressed against the base of the rotor chamber and will take up the rotation of the projectile without slipping. But should the acceleration be reversed in direction due to some obstruction in the gun bore, the rotor would tend to be thrown forward. However, the firing pin would momentarily prevent the detonator being rolled out of a safety position, and thereafter an interval would elapse before the detonator moved into armed position. It is evident without detailed analysis that the detonator will be prevented from moving to the armed position while the projectile is in the bore of the gun, and for a brief interval thereafter, assuring "bore-safe" and "muzzle-safe" action.

After the projectile leaves the muzzle of the gun, the firing pin 27 will creep forward, moving to the forward position shown in Fig. 4, due to relative acceleration produced by the air-drag on the projectile. Because of the static unbalance produced by unequal holes 18a and 18b, rotor 18 is in unstable equilibrium, and when set free by the firing pin, it will start rolling around in the rim of the rotor chamber. However, the tendency to roll is quickly curbed due to the centrifugal component, and the rotor will stop in stable equilibrium with detonator 20 at the axis as shown in Fig. 4A, in which position detonator 20 is in alignment with the cord 22 and firing pin 27, and the fuse is completely armed.

On striking the target, the head of the projectile will encounter substantial resistance, and the thin domed sealing disc 15 and striker 23 will be driven inwardly, driving the firing pin into the detonator 20, instantly detonating the latter, the booster charge 13, and the projectile burster charge not shown. It is known that under the conditions here described detonation can proceed so rapidly that a projectile having a suitable high-explosive charge is fragmented within a few inches of encountering the target.

But in the event the projectile misses the target, or it is desired to time the burst of the projectile short of the target to obtain the so-called shrapnel effect, the fuse proceeds to detonate itself in the following manner: At assembly of the fuse as shown in Fig. 2 the shank of the firing pin wedges the locking balls 33 in the outward position, so that the outer balls engage firmly in the holes 34b in liner 34, locking the ball-cage 32 in the position shown in Fig. 4. Hence, the ball-cage normally sustains the thrust of exploder spring 31, and at firing the set-back of the spring, the ball-cage, and balls 33. After firing in a gun and during flight, the centrifugal force on the balls due to the spin of the projectile causes the balls to exert substantial radial force tending to prevent their displacement inwardly as would be required to permit the balls and ball-cage 32 to pass completely into the cavity 39 in liner 34. Altho in the armed position of the firing pin the groove 27g, Fig. 2, is moved opposite the level of balls 33, so long as the locking component due to the centrifugal force on the balls exceeds the thrust component due to the exploder spring the ball-cage will remain in the position shown. But as the spin of the projectile progressively decreases in flight from a maximum at the muzzle of the gun, the centrifugal locking force due to the balls likewise diminishes, while the thrust force of the exploder spring remains constant. Hence at some range the locking margin will disappear, and the balls will move inwardly into groove 27g, and ball-cage 32 will be snapped back by exploder spring 31. As it does so the balls re-engage the firing pin, and due to the flange 27f, seize or clutch the firing pin at the groove 27g. The force of the exploder spring is thus applied to drive the firing pin into the detonator to explode same (see Fig. 5).

It is evident that the principal factors governing the locking action of the balls are the number and size of the balls, the centrifugal force on the balls (directly related to the spin), the thrust of the exploder spring, and the slope on the lower rim of the holes 34b in liner 34. By means of fuse spinning apparatus, and by proper design of the above factors, the rate of spin at which firing will take place can be predetermined and related to the time-of-flight to meet the requirements of any particular application. By reference to range tables, the relation between time-of-flight and range can be predetermined according to the established practices of gunnery. The exploder spring 31 can then be designed so that its range of compression due to the sleeve 30 will match the desired variation in timing.

It is to be noted that the decline of spin approximates a linear function of time since the loss of linear velocity due to work done against

gravity when firing at high angles, as in anti-aircraft defense, does not materially effect the rate of spin. While, as in the case of all types of time fuses, some test firings will doubtless be necessary to correlate accurately the fuse setting with actual ranges, such tests do not present unusual dfficulties, but are in fact routine matters.

By means of the fuse here described, a single type of anti-aircraft ammunition serves both for long-range firing at high-flying planes where high explosive shrapnel is considered most effective, and at short range firing against dive-bombers and attack planes where direct hits are sought for. In the latter case optimum results are secured from a senstive, instantaneous impact fuse as here provided, and when used in shells for aircraft cannon, the fuse here described can be preset at an optimum range, as for example just beyond the range of opposing machine guns, where the shrapnel effect increases the rate of hitting, whereas at close-in ranges, direct impact action is most effective. It will be evident to those skilled in the art that the fuse of the invention offers a combination of advantages not heretofore obtainable from a single type of fuse.

Without further analysis the foregoing will so fully reveal the gist of this invention that others can, by applying current knowledge, readily adapt it for various applications without omitting certain features that, from the standpoint of the prior art, fairly constitute essential characteristics of the generic or specific aspects of the invention, and therefore such adaptations should and are intended to be comprehended within the meaning and range of equivalency of the following claims.

I claim:

1. In a settable combination time or impact detonating fuse for rotative projectiles, in combination, a fuse body, a container member assembled in said body and carrying a booster charge at the rear end thereof, a normally relatively rotatable cap assembled to said body at the forward end thereof, an impact element including a firing pin slidably mounted inside said body and cap, means adapted to be telescoped by set-back force for arming said impact element, a rotor adapted for actuation by centrifugal force as the fuse is in flight mounted in said container member and carrying a detonator, means including said firing pin for normally retaining said rotor with the detonator in unarmed position, means for releasing said rotor when the fuse is fired in a gun to permit subsequent rotation of said detonator into armed position in line with said firing pin and said booster charge, and centrifugal timing means settable by said rotatable cap for timing the exploding action of said firing pin with said detonator at a pre-selected time after firing in a gun.

2. In a combination fuse of the time or impact class for rotative projectiles, in combination, a fuse body, a booster charge carried thereby, a normally relatively rotatable cap assembled to said body, an impact firing pin mounted for axial movement in said body, set-back arming means therefor, a detonator in a rotor mounted between said firing pin and said booster, centrifugally actuated arming means integral with said rotor for rotating said detonator into armed position, removable means including said firing pin for maintaining said detonator in unarmed position, and means for causing exploding action of said firing pin with said detonator at a settable time after from firing in a gun, including means adjusted by said rotatable cap.

3. In a combination time-impact detonating fuse for rotative projectiles, in combination, a body member, a normally relatively rotatable cap member mounted thereon, impact firing means mounted for axial movement in said body member, set-back actuated arming means therefor, a centrifugally actuated rotor carrying a detonator, arming means therefor including said firing means, and settable means for causing said firing means to explode said detonator after firing in a gun, including timing means settable by said relatively rotatable cap member.

4. In a combination settable time or impact detonating fuse for rotative projectiles, impact firing means including a firing pin and set-back actuated arming means therefor, a detonator carried in a rotor normally restrained by said firing pin from rotating the detonator into armed position, centrifugally actuated means integral with said rotor for turning said detonator into armed position after firing in a gun and release by said firing pin, and settable centrifugal timing means for exploding said detonator including said impact firing pin, a body part of the fuse and a rotatable part mounted thereon, a cylindrical shell within said parts, a compression spring within said shell, and mechanism controlled by the relative rotation of the aforesaid parts for varying the compression of said spring whereby the timing varies correspondingly.

5. In a combination time or impact fuse for rotative projectiles, a body and a rotatable cap mounted thereon, exploding mechanism including an impact firing element housed in said body and cap and a detonator carried by a centrifugally actuated rotor mounted in a cavity in said body and normally held to maintain the detonator in safe position, means for rotating said detonator into armed position after firing in a gun, and settable centrifugal timing means for causing exploding action of said element with detonator after a pre-set time interval from firing in a gun including said rotatable cap and a compressed exploder spring the compression of which is varied in proportion to the rotation of said cap relative to the body, and a scale and indicator carried by said body and cap for visually indicating the pre-set time interval.

6. In a combination settable time-impact fuse for rotative projectiles, a body, a rotatable setting member for pre-setting the time interval from firing of the projectile in a gun to explosion of the detonator mounted on said body, exploding and arming means including an impact firing pin mounted for axial movement in said body, and a detonator mounted in a centrifugal rotor in said body, removable means for maintaining said detonator in normal safe position, arming means for rotating said rotor to turn the detonator to armed position, and means including a regulatable compression spring and a centrifugal clutch for causing said firing pin to explode said detonator at the pre-set time interval from firing in a gun.

7. A device as set forth in claim 6 in which said centrifugal clutch comprises a ball cage and a plurality of balls carried thereby urged outwardly by centrifugal force in flight to maintain said ball cage in position until said centrifugal force decreases a predetermined amount regulated by said compression spring.

8. In combination as set forth in claim 6, in which the arming means for said detonator in-

cludes safety means to maintain the detonator in safe condition until the fuse has left the bore of the gun and centrifugal means integral with the rotor to move the detonator to armed position immediately thereafter.

9. In a combination settable time-impact fuse for rotative projectiles for rifled guns, in combination, a casing, and settable exploding mechanism therein including an impact firing element, arming means therefor actuated by set-back in the gun, a detonator safety arming means carrying said detonator, including a rotor held in normal safe position by said firing element and adapted to rotate said detonator into position to be engaged by said firing element after leaving the muzzle of the gun, and settable centrifugal means unlocked by forward movement of said firing element for exploding said detonator at a pre-set time interval after firing.

10. In a combination as set forth in claim 9, in which the safety arming means comprises a cylindrical member normally holding the detonator carried thereby out of alignment with said impact firing element but adapted to rotate said detonator into line with said impact element under the centrifugal action of the rotating fuse in flight, and the centrifugal means consists of a ball clutch comprising a plurality of balls carried in ball cage, a stationary ball race, a compression spring seated on said ball cage and means for variably compressing said spring.

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