CONFIDENTIAL

OP 1480

(FIRST REVISION)

VT FUZES

FOR PROJECTILES
AND SPIN-STABILIZED ROCKETS

A BUREAU OF ORDNANCE PUBLICATION

15 MAY 1946

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DEPARTMENT OF THE NAVY
BUREAU OF ORDNANCE

15 MAY 1946

This publication is CONFIDENTIAL and shall be safeguarded in accordance with the security provisions of U. S. Navy Regulations, 1920, Article 76

NAVY DEPARTMENT
BUREAU OF ORDNANCE
WASHINGTON 25, D. C.

15 May 1946

CONFIDENTIAL

ORDNANCE PAMPHLET 1480 (FIRST REVISION)

VT FUZES FOR PROJECTILES AND SPIN-STABILIZED ROCKETS

1. Ordnance Pamphlet 1480 (1st Rev.) describes U. S. Navy Radio Proximity (VT) fuzes for projectiles and spin-stabilized rockets, their operation, and characteristics and contains pertinent information on their usage.

2. This pamphlet supersedes Ordnance Pamphlets 1480 (Preliminary) and 1480A (Preliminary), both of which are to be destroyed by burning.

3. This publication is CONFIDENTIAL and shall be safeguarded in accordance with the security provisions of U. S. Navy Regulations, 1920, Article 76.

G. F. Hussey, Jr.,
Vice Admiral, U. S. Navy,
Chief of the Bureau of Ordnance.

M. F. Schoeffel

Acting.

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Chapter 1

INTRODUCTION

Purpose

The purpose of this OP is to acquaint officers and necessary personnel with radio proximity VT fuzes for projectiles and spin-stabilized rockets. It covers the operation, the performance characteristics, the projectiles and rockets with which used, and the theory of operation of these fuzes.

Definition

The various types of proximity or influence fuzes for gun projectiles, howitzer projectiles, mortar projectiles, rockets, bombs, and other missiles are designated by all U. S. Services as VT fuzes. The term VT has no significance or meaning as an abbreviation, but was devised for general usage in shipment orders, stock cards, loading lists, etc., when security requirements during the war necessitated this.

Description

Navy VT projectile fuzes are nose fuzes, cylindrically shaped, with an ogive nose which usually follows the contour of the projectile. Their size necessitated certain changes in fuzed ammunition. The fuze cavity in the explosive filler of the projectile had to be made much larger to accommodate VT fuzes. The base detonating fuze was eliminated from the projectile because (1) the radio proximity fuze would not perform normally in the presence of tracer gases, (2) there was no need in antiaircraft fire for a base detonating fuze, (3) the absence of a base detonating fuze reduced the hazard to surface craft and shore installations from A. A. projectiles reaching the ends of their trajectories, (4) more space was left available for explosive filler. However, the VT fuzed projectiles for the 6″/47 gun do have a base detonating fuze without tracer because of their probable use in shore bombardment.

All Navy projectiles assembled with VT fuzes are stenciled on two sides (180° apart) with the letters VT, ¾″ high in black color just before the rear edge of the paint indicating the bursting charge.

Operation

VT fuzes of the U. S. Navy are of the electromagnetic type known as radio proximity fuzes and are actuated by combined proximity and rate of approach to any target which gives a proper reflection. This includes metal objects, water, earth, etc. Operation is the same at day or night. The actual detonation of the projectile is accomplished in the following way: A VT fuzed projectile radiates a continuous radio signal which is reflected from targets of the type mentioned. When the reflected signal from the target reaches an appropriate value, a condenser is allowed to discharge through an electrical detonator called a squib. The blast from this squib operates a standard auxiliary detonating fuze, which in turn detonates the main charge of the projectile. No setting is necessary or possible with current type of VT fuzes. They will detonate automatically if the projectile passes sufficiently close to the target.

Safety

Special effort has been given to providing safety features in VT fuzes. As a result, they are perhaps the safest fuzes in use by the U. S. Navy in regard to handling safety, safety in the bore, and freedom from muzzle bursts. VT fuzes are not immune from derangement if the projectiles are handled or loaded roughly so as to strike the fuzes on hard surfaces. However, dangerous conditions are improbable as a result of such treatment; rather, abnormal operation or duds may result.

Remarks

Because of the need for a proximity fuze and because of the effectiveness of even the early designs, the VT fuze was placed in service before it was fully developed. The further development and the information gained through service use resulted in improvements that were incorporated in the fuzes. This accounts for the great number of marks and mods of fuzes that have been produced and issued. As development approaches perfection, there should be fewer models and changes.

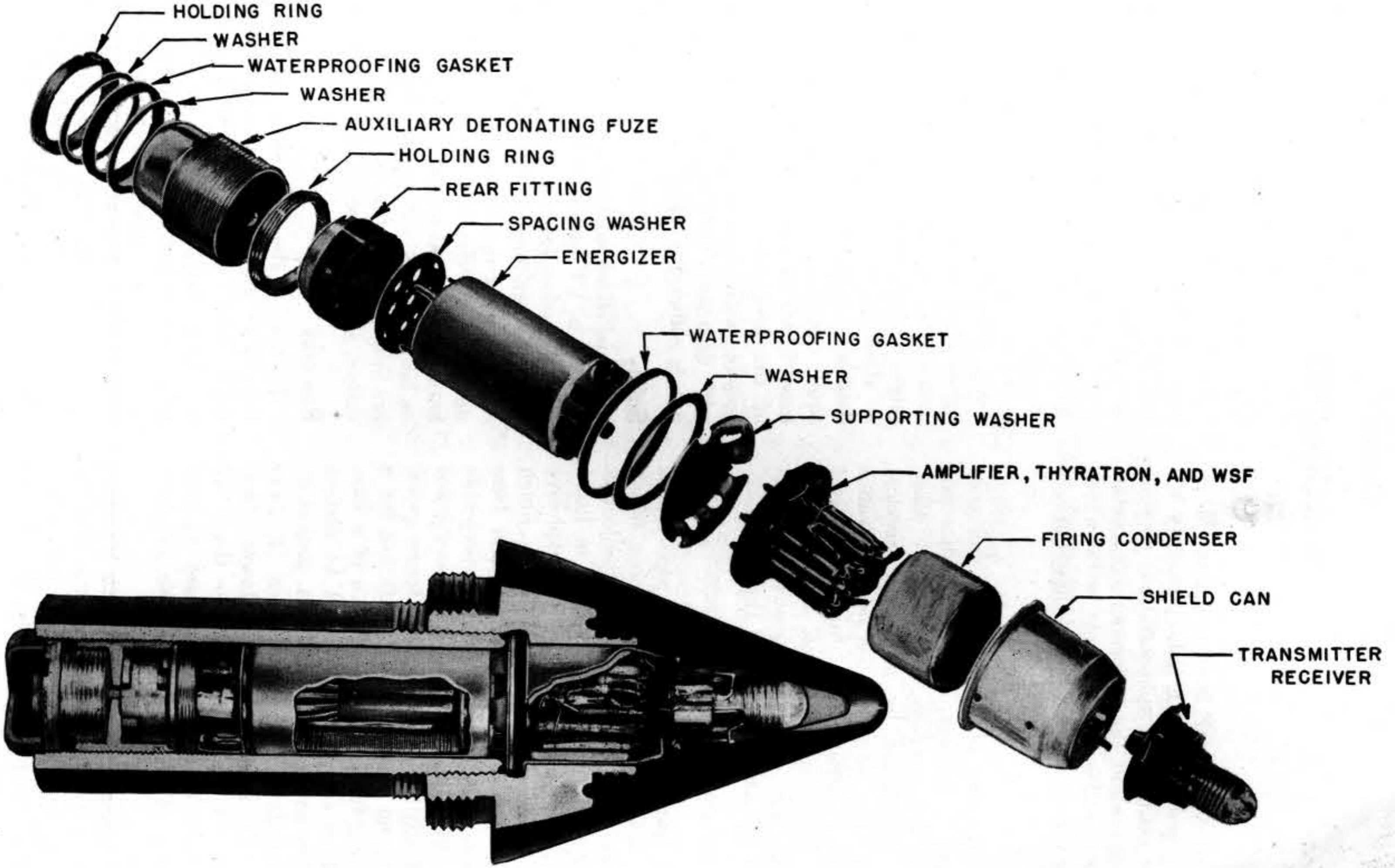


Figure 1. Cutaway and exploded view of a typical VT fuze (VT Fuze Mk 53 Mod 5).

Chapter 2

DESCRIPTION

Introduction

The VT fuze is composed of the following six main subassemblies or groups:

1. The fuze body, or container
2. Transmitter-receiver group, or oscillator group
3. Amplifier, thyratron, and wave-suppression feature (WSF) group
4. Reserve energizer
5. Rear fitting
6. Auxiliary detonating fuze.

Since space is limited, parts are located to achieve maximum space efficiency consistent with function. As a result, the firing circuit function is accomplished by components of the rear fitting and of the amplifier, thyratron, and WSF group.

Fuze Body

The fuze body consists of a plastic nose ogive molded integral to a steel base ring, and a steel body cylinder with external left-hand threads at one end and internal left-hand threads at the other end. The nose base ring is threaded externally to fit the threads in the projectile nose and internally to receive the external threads of the body cylinder.

Transmitter-Receiver

The transmitter-receiver consists of a one-tube oscillating detector and an antenna. The antenna is either a conical metal cap molded into the plastic nose tip or a wire loop within the nose and coupled to the projectile which acts as the radiating antenna. The triode radio tube is set in a rubber socket for protection from shock and is mounted within a plastic form around which the transmitter-receiver coil is wound. The component parts are assembled in a plastic molding which is mounted on the shield can. The electrical leads connect to the antenna and the electrical circuit of the fuze. A ground is obtained for the electrical circuit through the shield can.

When the energizer is activated, the transmitter radiates a continuous radio wave into the space surrounding the fuze.

The transmitter-receiver is capable at the same time of receiving the radio waves which are reflected from a target. As the fuze approaches a target, the intensity of the reflected wave increases, producing what is known as a target signal.

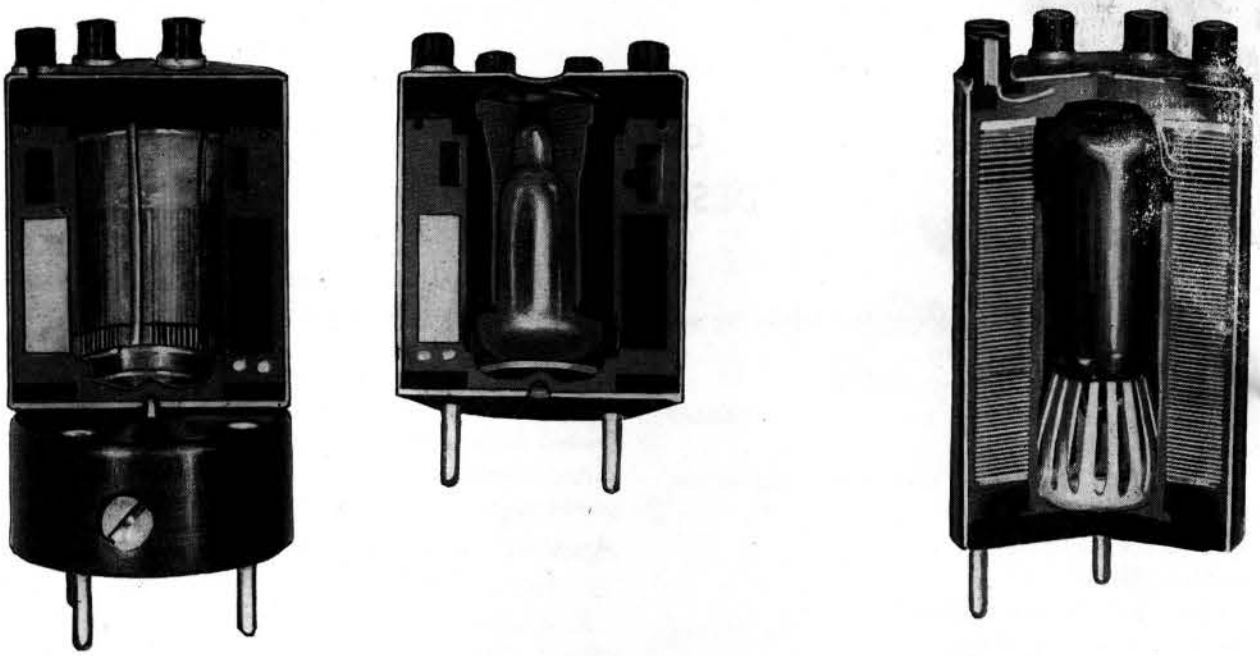
Amplifier, Thyratron, and Wave-Suppression-Feature (WSF) Group

The parts of the amplifier, thyratron and WSF group, with the tubes in rubber sockets, are mounted on a plastic molding. They are contained within the shield can, with the annular firing condenser encircling the parts. Electrical leads connect with the transmitter-receiver and contact pins in the plastic base.

Amplifier. The amplifier consists of two miniature pentode tubes with their associated resistors and condensers. Its function is to increase the amplitude of the target signal appearing at the output of the oscillator detector until it is capable of operating the firing circuit. Without amplification, the target signal, even on close proximity to the target, is of too low magnitude to perform useful service.

Wave-Suppression Feature. The wave-suppression circuit is composed of a diode tube and various resistors and blocking or filter condensers. It decreases the sensitivity of the amplifier in the presence of steady signals. Thus it renders the fuze insensitive to the relatively steady signals reflected from waves when the projectile is fired on a low trajectory. This tends to prevent the fuze from being operated by the reflected signals from waves.

Firing Condenser. The firing condenser is an annular electrical condenser in the firing circuit. It provides a means of storing an electrical charge, received from the energizer, which can be rapidly expended, when called upon, to fire the squib.



SHORT ENERGIZER MK 4 MOD 2
(LEFT HALF SECTION PLUGGED INTO
SPIN BREAKER MK I MOD 0)

LONG ENERGIZER
MK 5 MOD 2

Figure 2. Sectional views of reserve energizers.

Thyratron. The thyratron is a triode radio tube with a small amount of argon gas in the bulb. It acts as an electronic switch to discharge the firing condenser through the squib when the projectile is near a target. When the projectile nears a target, the target signal received by the thyratron from the amplifier becomes of sufficient magnitude to lower the thyratron grid bias and allow the condenser to discharge through the squib. The squib is exploded by the surge of current.

Reserve Energizer

The reserve energizer is located in the fuze body cylinder, with its contact clips receiving the contact pins of the transmitter-receiver. It is the source of electric power for operation of the fuze. It is composed of three compact wet-type batteries; the "A" battery, "B" battery, and "C" battery. The electrolyte for the batteries is contained in a glass ampoule mounted in a soft plastic cup in the central cavity of the energizer. The ampoule rests on the breaker which fits into the bottom of the plastic cup. The plates of a long-type energizer such as Energizer Mk 5 Mod 2 (fig. 2) are made up of flat zinc washers, coated on one side with carbon and assembled in a stack surrounding the ampoule. They are separated from each other by means of insulating washers at their inner and outer rim. The whole assembly is contained in a metal can lined with plastic. Holes in the zinc washers permit distribution of the electrolyte when the ampoule is broken.

When the electrolyte is distributed, each cell develops a small voltage. The "A," "B," and "C" batteries are composed of the correct number of cells connected in series or parallel to produce the required voltage and current for each. The leads from each battery are connected to the proper contact clips on the energizer cover. Other wires pass directly through the energizer from the contacts on the cover to those on the bottom, and serve to connect the squib and safety switches in the rear fitting to the rest of the electrical circuit.

A short energizer was developed for use in the small compact fuzes used in the 3″/50 projectile, and for use in the spin rocket fuze where employment of a spin breaker was necessary.

In the short energizer, shown in figure 2, the battery plates are smaller and of different material, and are arranged in banks parallel to the longitudinal axis of the energizer. The fundamental operation of this energizer is identical to the longer model.

Spin Breaker. In the 5″ spin-stabilized rocket, low acceleration does not produce set-back forces of sufficient magnitude to break the electrolyte ampoule of the energizer in the Fuze Mk 173. A spin breaker, located adjacent to, and below the energizer, is used for this purpose.

Figure 2 illustrates how the spin breaker is plugged into the bottom of the energizer. Drawings illustrating how the spin breaker operates are shown in figure 3. The numbered arrows in the drawings denote the action and sequence of operations. The breaker consists of a metal body and cover plate; a stationary firing pin threaded into the side of the body; a plunger and plunger cup threaded into the top of the body; and levers, triggers, and a spring-loaded primer contained in the body. Operation of the spin breaker is as follows: The breaker is assembled with the interlocking levers held toward the axis by steel springs. They are so oriented that centrifugal force overcoming the resistance of the springs causes them to swing outward (**1** and **2**) thus unlocking the auxiliary trigger (**3**) and freeing the trigger. The trigger then rotates (**4**) from pressure of the compressed firing spring, allowing the primer in the primer carrier to be forced onto the firing pin by its compressed spring (**5**). The primer fires when it strikes the firing pin. The ampoule is broken when the plunger is forced through the bottom of the energizer by the explosion of the primer. The plunger is held in the retracted position, until the primer is fired, by a slight shoulder on the plunger that bears on the rim of the hole through the top of the plunger cup. The pressure from the exploding primer breaks down this shoulder and forces the plunger through the small hole (**6**).

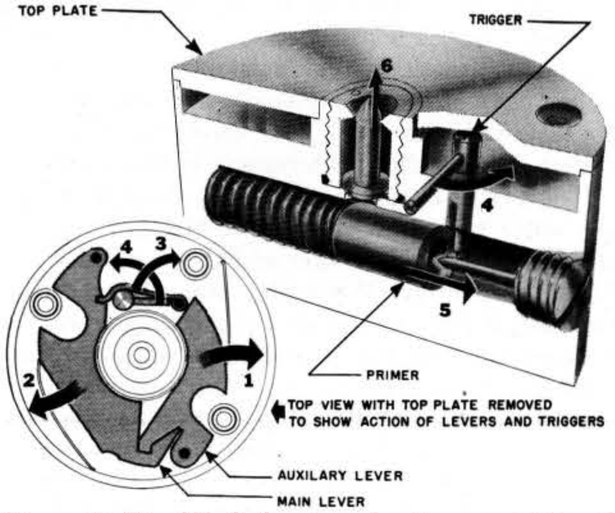


Figure 3. Simplified drawing showing operation of Spin Breaker Mk 1 Mod 0.

The spin breaker operates with a rotational speed of between 1500 and 2100 r. p. m.

In order to complete the electrical circuit to the rear fitting, which contains the squib and safety switches, wires lead directly through the breaker body from connector clips at the top to connector pins at the bottom. When the spin breaker is used, the rear fitting then plugs into the spin breaker instead of directly into the bottom of the energizer.

Dry Energizers. All current models of Navy VT fuzes contain wet-type reserve energizers. However, the first models, now obsolete, received their electrical energy from a dry energizer. The energizer was not connected to the electrical circuit until certain set-back switches were closed when the projectile was fired. Dry energizers deteriorated rapidly, having a shelf life of only about six months.

Rear Fitting

The rear fitting consists of a plastic body housing the reed spin and mercury switches, and the squib. These parts are potted in wax for shock protection. The cover is a fabric-base phenolic disc attached by metal pins into the plastic body. A metal disc with a hole through the center for the squib to blow through is attached to the bottom by steel pins. Electrical connections are from contact clips at the top to the squib and switches. A ground connection is made through one of the steel pins to the bottom disc.

Squib. The squib or cannon primer consists of a small container of explosive with an embedded filament of fine wire attached to electric leads. When a surge of electrical current passes through it, the filament is heated to a very high temperature and ignites the explosive.

Reed Switch. The reed switch is electrically connected across the firing condenser to prevent the condenser from receiving a charge if the energizer becomes activated from accidental breakage of the electrolyte ampoule by dropping or rough handling.

Figure 4 is a sectional drawing of the reed switch. The switch consists of a metal cup with an adjustable contact stud threaded through the lower side and a metal reed inserted through an insulator in the top of the cup. The reed serves as one terminal of the switch, and the adjustable contact stud serves as the other terminal. The spring action of the metal reed holds it in contact with the stud, making a closed circuit. The switch is mounted so that, when the projectile is fired, centrifugal force overcomes the resistance of the reed, causing it to swing out from the contact stud, thus breaking the short circuit across the firing condenser immediately upon firing.

Mercury Switch. The mercury switch, when closed, completes a short circuit across the squib. It is a safety feature of the fuze designed to prevent a charge from passing through the squib in case the condenser accidentally received and released a charge.

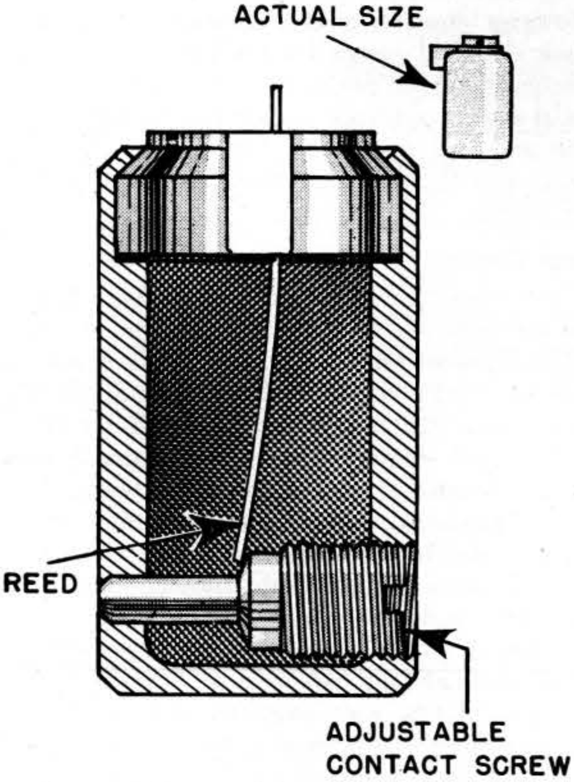


Figure 4. Sectional drawing of reed switch.

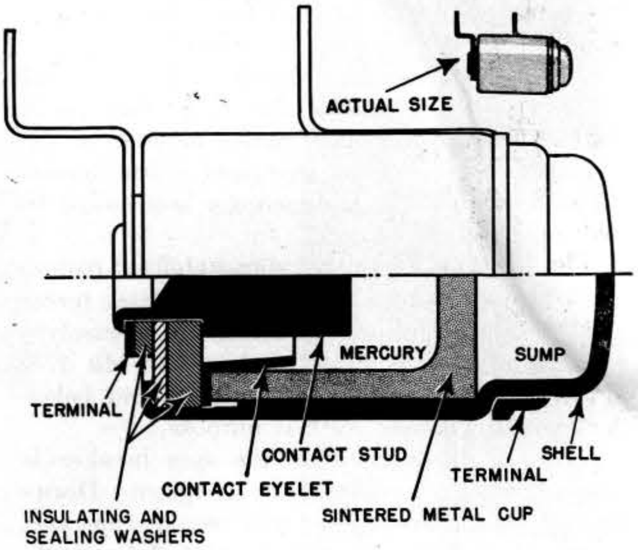


Figure 5. Sectional drawing of mercury switch.

A drawing of the mercury switch is shown in figure 5. The principal parts are the metal body, a sintered metal cup, a metal contact stud, and a globule of mercury. The contact stud is extended through the top of the body into the inner chamber of the switch formed by the sintered metal cup. It is insulated from the body and makes one of the terminals of the switch. A brass eyelet which fits over the rim of the sintered cup makes pressure contact with the body and forms the other terminal of the switch. When assembled, the globule of mercury is in the sintered metal cup and in contact with the stud, thus acting to close the circuit through the two terminals of the switch.

The switch is mounted between the center and the outer periphery of the rear fitting, with the mercury toward the center and the sump farthest from the center. When the projectile is fired, centrifugal force acting on the mercury causes it to pass through the porous sintered metal cup into the outer chamber or sump, thus removing the short-circuit it had imposed across the terminals of the squib. Continued pressure for a short time from centrifugal force is necessary to cause the mercury to pass through the sintered metal cup.

Certain current fuzes, particularly some Mods of Mk 58, contain mercury switches which have a copper cup with a hole in the bottom covered with a paper disc in place of the sintered metal cup. Operation is as described above. The Fuzes Mk 47, Mk 53, and Mk 59 have two mercury switches wired in parallel across the terminals of the squib for additional safety.

Clock Works. Dry-energizer fuzes, now obsolete, contained a safety feature operated by a mechanical clockwork similar to the Time Fuze Mk 18. It ran for 0.4 to 0.6 seconds after leaving the gun, at which time it removed a mechanical gate from the canal between the auxiliary detonating fuze and the electrical squib. An electrical short circuit across the firing squib was broken only when the clockwork operated.

The simpler-to-manufacture mercury switches supplant the clockwork in current fuzes; however they are not as positive or precise in their action.

Auxiliary Detonating Fuze

The auxiliary detonating fuzes used in VT fuzes are standard. A complete description of them can be found in OP 1212, Projectile Fuzes.

The auxiliary fuze is assembled in the safe condition and is armed by centrifugal force.

It is fired by the squib and in turn sets off the main charge of the projectile.

Assembly and Waterproofing

The transmitter-receiver group and the amplifier, thyratron, and WSF group are assembled inside the fuze nose and secured by steel pins through the plastic base and rim of the shield can into a shoulder of the steel nose base ring. The press fit of these steel pins with the shield can completes the electrical ground to the fuze body and to the projectile when the fuze is threaded into the projectile nose. Molten wax is poured into the nose to fill the void space. The wax solidifies and protects the units against the shock of handling and firing.

The reserve energizer is plugged into the base of the amplifier, thyratron, and WSF group with a supporting washer interposed between them. A flat metal washer and rubber water-proofing gasket fit onto the flange of the supporting washer, so that when the body cylinder is screwed into the nose base ring the rubber gasket is compressed to form a waterproof seal.

The rear fitting is plugged into the base of the energizer, with a rubber spacing washer inserted between them. In assembly, pressure is applied to the rear fitting, and the holding ring is threaded into the body cylinder until it engages the base of the rear fitting. Pressure is then removed, and the holding ring is staked into position. The holding ring also completes the electrical ground from the base of the rear fitting to the fuze body.

The auxiliary detonating fuze threads into the lower end of the body cylinder. Waterproofing is accomplished by means of a rubber waterproofing gasket sandwiched between two thin metal washers and held in compression between the fuze body cylinder and the lower part of the auxiliary detonating fuze by a threaded holding ring.

Chapter 3

OPERATION

When assembled, the reserve energizer is inert and does not supply energy to the electric circuits of the fuze. The reed switch is closed, thus placing a short circuit across the firing condenser. The mercury switches are closed, placing one or two short circuits across the firing squib. The auxiliary detonating fuze is also in the unarmed condition. The fuze remains in this condition during transportation and storage and until the projectile in which it is assembled is fired from a gun.

When the projectile is fired from a gun, the ampoule in the reserve energizer is shattered on the breaker as a result of set-back forces, and the electrolyte is freed. Centrifugal force distributes the electrolyte to the battery cells, and the reserve energizer becomes active. Centrifugal force acting on the reed of the reed switch causes it to open immediately upon firing, thus removing the short circuit it had imposed across the firing condenser. Centrifugal force causes the mercury in the mercury switch to be forced from its inner chamber through the sintered metal cup into the outer chamber of the switch, thus removing the electrical short circuit it had imposed across the squib. A short predetermined time is required for this action.

The auxiliary detonating fuze is also armed by centrifugal force. Centrifugal force throws the rotor detents outward, freeing the rotors. After set-back forces are expended, centrifugal force causes the rotors to rotate into the armed position, so that their explosive charges are in line with each other.

After the energizer is activated, it becomes a source of power for the electrical part of the fuze; the firing condenser begins to receive a charge, and the transmitter starts to radiate a radio signal.

When the firing condenser is charged, the mercury switches open, and the auxiliary detonating fuze is armed, the fuze is fully armed. The elapsed time varies from 0.3 seconds to 0.9 seconds in projectile fuzes and from 4 seconds to 12 seconds in spin-stabilized rocket fuzes.

The radio signals that are radiated by the fuze are reflected from such targets as metal objects, water, earth, etc. The engine and control cables of wooden airplanes will also reflect signals. When the projectile comes into close proximity to the target, the reflected signal from the target reaches the required amplitude and allows the thyratron to fire, thereby discharging the firing condenser through the squib. The blast from the squib operates the auxiliary detonating fuze, which in turn initiates the detonation of the projectile.

In early model VT fuzes with dry energizers, now obsolete, operation was somewhat different from present wet-energizer fuzes. Instead of the mercury switches, the fuzes contained a mechanical clockwork similar to Time Fuze Mk 18, which ran for 0.4 to 0.6 second after leaving the gun, at which time it removed a mechanical gate from the canal between the auxiliary detonating fuze and the electrical squib. An electrical short circuit across the firing squib was broken only by operation of the clockwork. Set-back force, incident to firing, closed set-back switches which connected the dry energizer, which was the source of power, to the electrical circuit. Operation after arming was the same as that in the wet-energizer fuzes.

In the VT fuze for spin-stabilized rockets, set-back force is not depended upon to break the electrolyte ampoule, because the force is far less in a rocket than in a projectile fired from a gun. The ampoule is broken by means of a spin breaker, described in Chapter 2.

Chapter 4

VT FUZES FOR PROJECTILES

MK 32 MODS 0–10, 14, 16–18, 20, 30, 40

(Obsolete)

General Data

Projectiles Used In. 5″/38, 5″/25, 5″/51 A. A. Common. All mods except Mod 30 could be used in the 5″/51 gun at 2600 f/s initial velocity reduced charge only. Mod 30 could not be used in the 5″/51 rounds.

Markings

Mk 32 Mod____________

Model ____________ Lot ____________ (and date of designation)

Over-All Dimensions and Weight

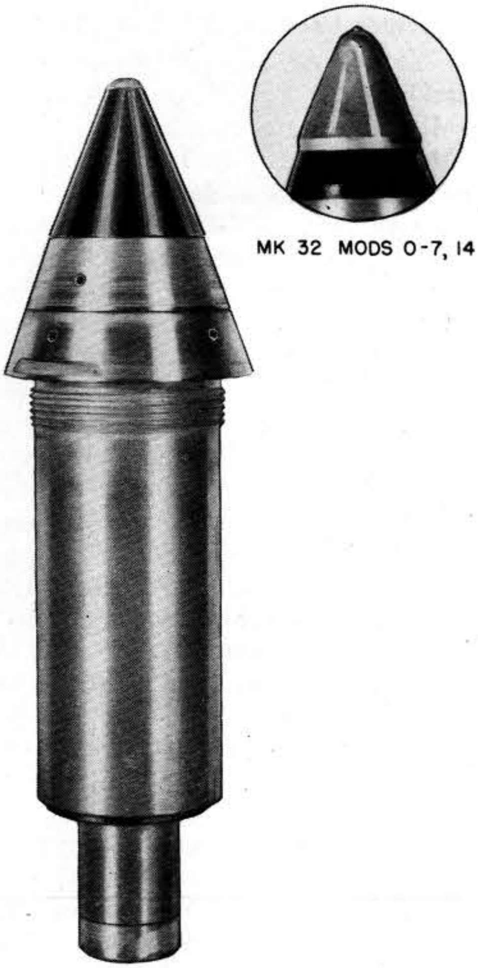
Length	12 in. (approx.)
Diameter at base of ogive	3.3 in. (approx.)
Threaded length	0.6 in. (approx.)
Threads	2.65 in. 10 R. H.
Weight	6.81 lb.

Material. Steel base ring; black lucite plastic nose ogive; aluminum nose cap or metal button tip; steel body cylinder.

Arming Range	Mods 0–20, 40–700 yd. Mod 30–1100 yd.
Type of Energizer	Mods 0–20, 40—Dry Mod 30—Reserve
Wave-Suppression Feature	Mod 40 only
Self-Destructive Feature	None
Auxiliary Detonating Fuze	Mk 54 (replacing the Mks 17 and 46)
Compression-Type Waterproofing	No

Description

This fuze was designed to initiate detonation of the round at the most advantageous point upon approach to a target when passing within the maximum influence radius of about 50 feet. Burst heights above water for all mods without the wave-suppression feature were high at most ranges, averaging 130 feet at 12,200 yards in the 5″/38, with burst heights varying widely between rounds. At shorter ranges, burst heights over water averaged lower; but a wide dispersion in burst heights did occur. Those fuzes without the wave-suppression feature were especially af-



MK 32 MODS 0-7, 14

MK 32 MODS 8,10,16,18,20,30,40

Figure 6. VT Fuze Mk 32

fected by water surface conditions. Because of the wave-suppression feature, the burst heights above water of the Mod 40 varied between 10 and 50 feet. The Mod 40 had normal sensitivity above about 200 feet from the water, but had automatically reduced sensitivity below that level because of the wave-suppression feature.

Employment

This fuze was used for antiaircraft fire from 600 yards minimum range (1100 yards for Mod 30) to the extreme range of the gun. The minimum range for employment was less than the arming range given above. The arming range given was the distance at which 90% of the operable rounds would be armed. At the shorter minimum range given for employment, 90% would not be armed; but a sufficient percentage of fuze were armed to make the fire effective at 100 yards less than the arming range given. The Mod 40, with WSF, was recommended for any gun elevation and could be used effectively against torpedo bomber attack and PT boat attack.

These fuzes are no longer in production or use. They have been replaced by the VT Fuze Mk 53.

MK 40 MODS 0–5, 7

(Obsolete)

General Data

Projectiles Used In. 5″/25, 5″/38 A. A. Common.

Markings

Mk 40 Mod ______________

Model ____________ Lot ____________

Over-All Dimensions and Weight

Length	12 in. (approx.)
Diameter at base of ogive	3.3 in. (approx.)
Threaded length	0.5 in. (approx.)
Threads	2.65 in. 10 R. H.
Weight	6.81 lb.

Material. Steel base ring; black lucite plastic nose ogive; metal button tip; steel body cylinder; except Mod 7, which has green ethyl cellulose plastic nose ogive without button tip.

Arming Range	700 to 900 yd. for different Mods
Type of Energizer	Reserve
Wave-Suppression Feature	Present
Self-Destructive Feature	None
Auxiliary Detonating Fuze	Mk 54 (replacing Mks 17 and 46)
Compression-Type Waterproofing	No

Description

This fuze had a maximum influence radius of about 70 feet. Against aircraft below 200 feet altitude, operating radius was reduced, depending on the height of the trajectory and the height of the waves, because of the wave-suppression feature. Burst height over land or water varied between 10 and 30 feet.

MK 40 MOD 0-5

MK 40 MOD 7

Figure 7. VT Fuze Mk 40.

Employment

This fuze was recommended for antiaircraft fire from a minimum range of 700 yards to the extreme range of the gun. The wave-suppression feature made this fuze effective against low-flying aircraft and surface targets. It could be used effectively for barrage of land targets where a burst height of 10–30 feet was effective against personnel and lightly protected equipment and installations.

Remarks

The fuze is no longer in production or use. It has been replaced by the VT Fuze Mk 53.

MK 45 MODS 11 AND 12

(Obsolete)

General Data

Projectile Used In .... 3″/50 A. A.

Markings

Mk 45 Mod ____________

Model ____________ Lot ____________

Over-All Dimensions and Weight of Mk 45 Mod 12

Length .... 7.7 in. (approx.)

Diameter at base of ogive .. 2.4 in. (approx.)

Threaded length .... 1.0 in. (approx.)

Threads .... 2.00 in. 12 R. H

Weight .... 2.40 lb.

Material. Green ethyl cellulose plastic nose ogive molded integral to steel base ring; perforated steel nose cap molded into the inside forward end of plastic ogive; steel body cylinder.

Arming Range .... 600 yd.

Type of Energizer .... Reserve

Wave-Suppression Feature .... None

Self-Destructive Feature .... None

Auxiliary Detonating Fuze .... Mk 44

Compression-Type Waterproofing .... No

Description

This fuze has a maximum influence radius of about 50 feet. Burst heights over water at long range will average around 75 feet, with wide variations in burst heights occurring as a result of wave effect and variations in sensitivity between individual fuzes. Burst heights over water at shorter ranges will generally average to lower levels.

Employment

This fuze is used for antiaircraft fire from a minimum range of 500 yards to the extreme range of the gun.

Remarks

The Mk 45 Mod 11, with longer base, was declared unserviceable and recalled, to be replaced by the Mk 45 Mod 12. The Mk 45 Mod 12 was later replaced by the VT Fuze Mk 58. Mod 11 and Mod 12 are not physically interchangeable. VT Fuzes Mk 45 are constructed with only one mercury switch.

MK 45 MOD II

MK 45 MOD I2

Figure 8. VT Fuze Mk 45.

MK 47 MOD 0

General Data

Projectiles Used In. 6″/47 H. C. Mk 34

Markings

Mk 47 Mod 0
Model ____________ Lot ____________

Over-All Dimensions and Weight

Length	9.0 in. (approx.)
Diameter at base of ogive	3.3 in. (approx.)
Threaded length	0.5 in.
Threads	2.65 in. 10 R.H.
Weight	4.91 lb.

Material. Green ethyl cellulose plastic nose ogive molded integral to steel base ring; perforated steel nose cap molded into the inside forward end of plastic ogive; metal button tip; steel body cylinder.

Arming Range	800 yd.
Type of Energizer	Reserve
Wave-Suppression Feature	Present
Self-Destructive Feature	None
Auxiliary Detonating Fuze	Mk 44
Compression-Type Waterproofing	Yes

Description

This fuze was designed for the Projectile Mk 34 (H. C. round) for the 6″/47 gun. It is not usable in the Projectile Mk 39 for 6″/47 Double Purpose guns. It has a maximum influence radius of about 75 feet. Burst heights over water or land vary from 10 to 50 feet.

Employment

This fuze was designed primarily for use against aircraft at all altitudes and at all ranges over a 700-yard minimum. It may also be used effectively against personnel and light shore installations. Because of the probability of its use for shore bombardment, the projectile contains a base detonating fuze with the tracer plugged.

Remarks

Fuzes Mk 47 Mod 0 have the improved compression-type waterproofing. It consists of an annular rubber gasket held in compression between the VT fuze body cylinder and the lower part of the Auxiliary Detonating Fuze Mk 44 by means of a threaded steel holding ring.

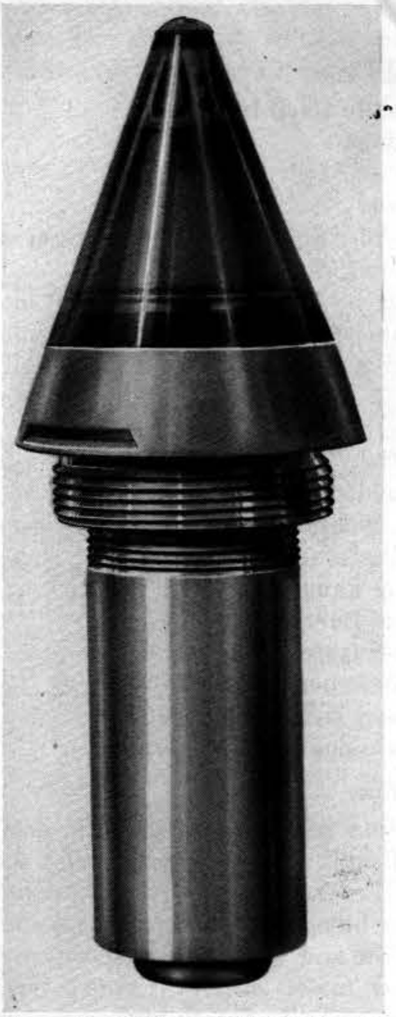


Figure 9. VT Fuze Mk 47 Mod 0.

MK 53 MODS 0–2
(Obsolete)

General Data

Projectiles Used In. 5″/25, 5″/38, 5″/51 A. A. Common. Mk 53 Mod 0 recommended for use in 5″/51 guns at reduced charge of 2600 f/s. Other mods may be fired at full charge.

Markings

Mk 53 Mod ____________

Model ____________ Lot ____________

Over-All Dimensions and Weight

Length	9.0 in. (approx.)
Diameter at base of ogive	3.3 in. (approx.)
Threaded length	0.5 in. (approx.)
Threads	2.65 in. 10 R. H.
Weight	4.79 lb.

Material. Green ethyl cellulose plastic nose ogive molded integral to steel base ring; steel body cylinder; Mod 0 has perforated steel nose cap molded into the inside forward end of plastic nose and metal button tip.

Arming Range	800 yd.
Type of Energizer	Reserve
Wave-Suppression Feature	Present
Self-Destructive Feature	None
Auxiliary Detonating Fuze	Mk 44
Compression-Type Waterproofing	No

Description

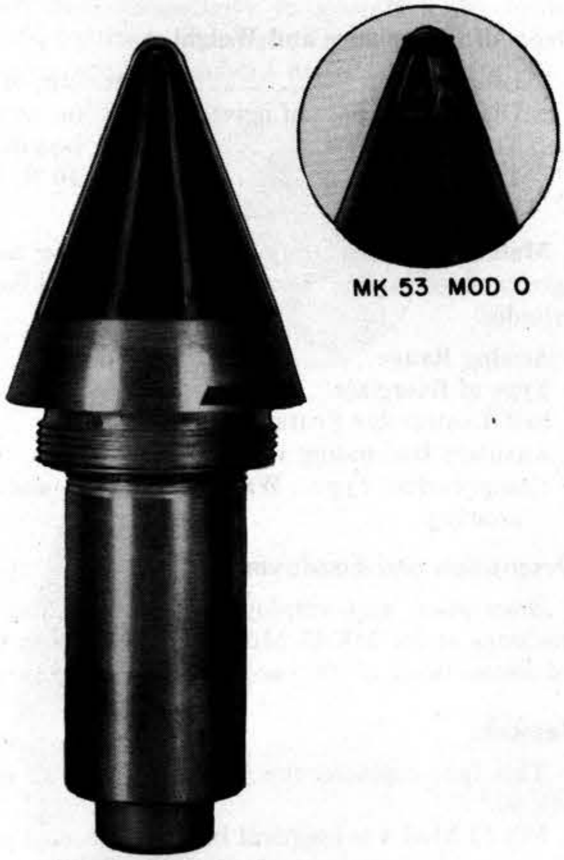
This fuze has a maximum influence radius of about 75 feet. Against aircraft below 200 feet altitude, operating radius is reduced, depending on the height of the trajectory and the height of the waves, because of the wave-suppression feature. Burst height over land or water will vary between 10 and 50 feet.

Employment

This fuze is used for antiaircraft fire from a minimum range of 700 yards to the maximum range of the gun at all elevations. It is also effective against personnel and light equipment in shore bombardment where an aerial burst will produce fragmentation damage.

Remarks

This fuze replaced the VT Fuzes Mk 32 and Mk 40.



MK 53 MOD 0

MK 53 MODS 1&4

Figure 10. VT Fuze Mk 53 Mods 0–4.

MK 53 MODS 3–6

(Mods 3 and 4—Obsolescent)

General Data

Projectiles Used In. 5″/25, 5″/38, 5″/51 A. A. Common. Mk 53 all Mods except Mod 0 are recommended for use in 5″/51 guns at full charge.

Markings

Mk 53 Mod ____________
Model ____________ Lot ____________

Over-All Dimensions and Weight

Length	9.0 in. (approx.)
Diameter at base of ogive	3.3 in. (approx.)
Threaded length	0.5 in. (approx.)
Threads	2.65 in. 10 R. H.
Weight	4.91 lb.

Material.—Green ethyl cellulose plastic nose ogive molded integral to steel base ring; steel body cylinder.

Arming Range	500 yd.
Type of Energizer	Reserve
Self-Destructive Feature	None
Auxiliary Detonating Fuze	Mk 44
Compression-Type Waterproofing.	Mods 5 and 6 only

Description and Employment

Description and employment of this fuze is the same as for Mk 53 Mods 0–2 except that the minimum range is 400 yards instead of 700 yards.

Remarks

This fuze replaced the VT Fuzes Mk 32 and Mk 40.

Mk 53 Mod 4 is identical in all operational and physical characteristics to the Mk 53 Mod 3, except that it operates at a different frequency than the Mod 3. This change in frequency was made as a countermeasure protection.

Mk 53 Mod 5 is identical to Mod 4 except that the body cylinder of the fuze is 0.316 inch longer in order to accommodate the compression type of waterproofing between the body of the VT fuze and the auxiliary detonating fuze. The length of the projectile cavity to the lower face of the auxiliary detonating fuze remains the same as in previous mods; but because of the long body cylinder the distance to the shoulder of the cavity is increased; hence, Mod 5 will not fit any previous projectile cavity.

Mk 53 Mod 6 is identical to Mod 5 in operational and physical characteristics, except that it operates at a different frequency (same as Mod 3). Mod 6 is physically interchangeable with Mod 5, but not with any previous mod.

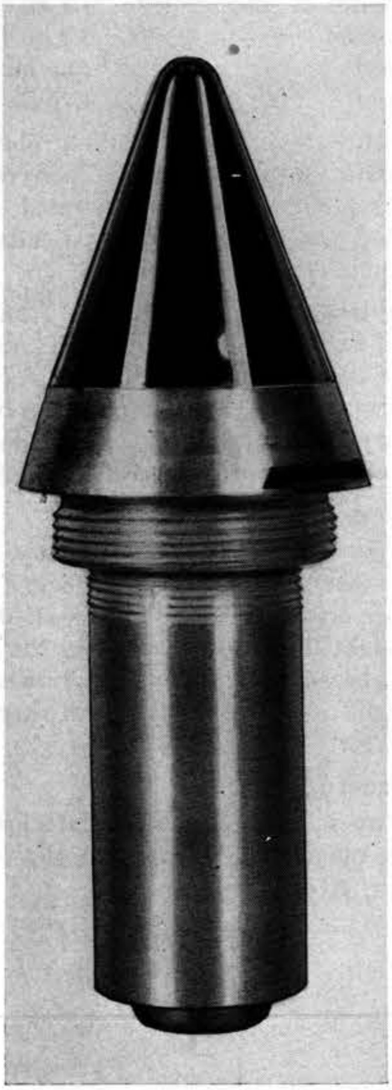


Figure 11. VT Fuze Mk 53 Mods 5 and 6.

MK 58 MODS 0–4

(Mods 0, 1, 2—Obsolete)

General Data

Projectiles Used In---------- 3″/50 A. A.

Markings

Mk 58 Mod ____________

Model ____________ Lot ____________

Over-All Dimensions and Weight

Length	7.8 in. (approx.)
Diameter at base of ogive	2.4 in. (approx.)
Threaded length	1.0 in. (approx.)
Threads	2.00 in. 12 R. H.
Weight	2.40 lb.

Material. Green ethyl cellulose plastic nose ogive molded integral to steel base ring; steel body cylinder; steel cap molded inside forward end of plastic ogive; in addition, Mod 1 has a metal button tip.

Arming Range	600 yd.
Type of Energizer	Reserve
Wave-Suppression Feature	Present
Self-Destructive Feature	None
Auxiliary Detonating Fuze	Mk 44
Compression-Type Waterproofing.	Mods 3 and 4 only

Description

The maximum influence radius of this fuze varies between 40 and 100 feet for different lots and mods. Sensitivity to aircraft flying below 200 feet altitude is reduced by the wave-suppression feature; the amount of reduction depending

MK 58 MOD 0

MK 58 MOD 1

MK 58 MOD 2

MK 58 MODS 3 & 4

Figure 12. VT Fuze Mk 58.

on the height of the trajectory and the condition of the waves. Burst heights over land and water average between 5 and 15 feet.

Employment

This fuze is used for antiaircraft fire at ranges from 500 yards to the extreme range of the gun at all elevations. It is useful against low-flying airplanes, small surface craft, and in land barrage against personnel, light equipment, and installations.

Remarks

The VT Fuze Mk 58 has replaced the VT Fuze Mk 45. Mk 58 Mods 0–2 have short body cylinders without compression-type waterproofing. They operate at different frequencies. Mods 0–2 are physically interchangeable with Mk 45 Mod 12 but not with Mk 45 Mod 11.

Mk 58 Mods 3 and 4 have long body cylinders with compression-type waterproofing. Mods 3 and 4 are not physically interchangeable with previous mods, nor with Mk 45 Mods 11 and 12.

The Mod 3 operates at the same frequency as the Mod 2. The Mod 4 operates at the same frequency as the Mod 1.

All mods of Mk 58 have similar operational characteristics.

MK 59 MOD 0

General Data

Projectiles Used In	5″/54 H. C.

Markings

Mk 59 Mod 0

Model ____________ Lot ____________

Over-All Dimensions and Weight

Length	9.8 in. (approx.)
Diameter at base of ogive	2.7 in. (approx.)
Threaded length	0.5 in. (approx.)
Threads	2.35 in. 10 R. H.
Weight	4.05 lb.

Material. Green ethyl cellulose plastic nose ogive molded integral to steel base ring; steel body cylinder

Arming Range	600 yd.
Type of Energizer	Reserve
Wave-Supppression Feature	Present
Self-Destructive Feature	None
Auxiliary Detonating Fuze	Mk 44
Compression-Type Waterproofing	Yes

Description

This fuze was designed for use in the H. C. round for the 5″/54 guns.

Employment

This fuze is for use against aircraft from a minimum range of 500 yards to the extreme range of the gun at all elevations. It is effective against low-flying airplanes and small surface craft, and for land barrage against personnel, light equipment, and installations.

Remarks

All VT Fuzes Mk 59 have the improved compression-type waterproofing.

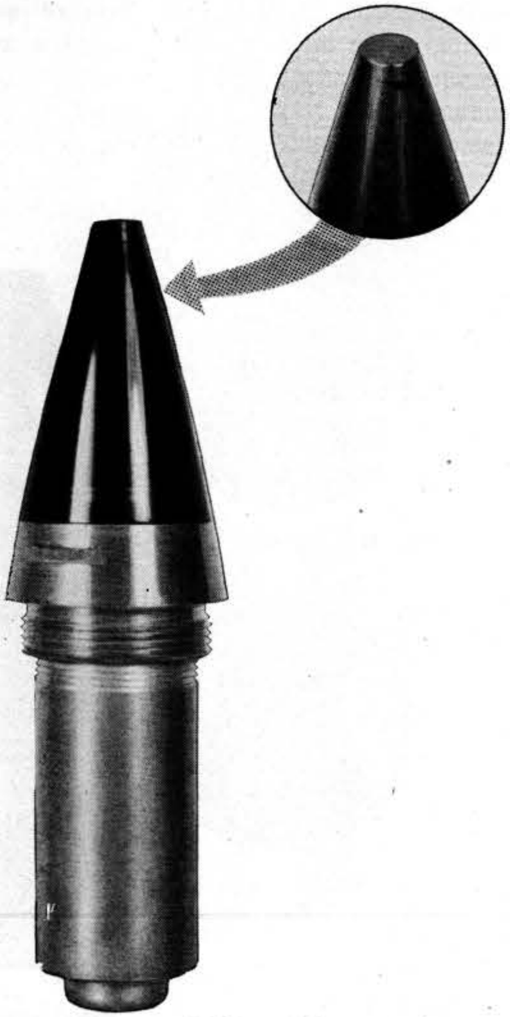


Figure 13. VT Fuze Mk 59 Mod 0.

Chapter 5

VT FUZES FOR SPIN-STABILIZED ROCKETS

MK 173 MODS 0, 2, AND 4

General Data

Rockets Used In. 5.0-in. Surface High Capacity Spin-Stabilized Rocket (5.0-in. Rocket Head Mk 10 and Mods; 5.0-in. Rocket Motor Mk 4 and Mods).

Marking

Mk 173 Mod ____________

Model ____________ Lot ____________

Over-All Dimensions and Weight

Length	8.5 in. (approx.)
Diameter at base of ogive	2.4 in. (approx.)
Threaded length	1.0 in. (approx.)
Threads	2.00 in. 12 R. H.
Weight	2.52 lb.

Material. Green ethyl cellulose plastic nose ogive molded integral to steel base ring; nose cap molded into the inside forward end of plastic ogive; steel body cylinder.

Arming Range. The arming range is 1800 to 3300 yards, with 50% of operable rounds armed by 2500 and 90% armed by 3300 yards. These arming distances are based on standard conditions of 70° F. propellant temperatures. Tests indicate that the arming time will be slightly earlier when the rounds are at temperatures above 70° F. during launching, and later at temperatures below 70° F.

Type of Energizer	Reserve
Wave-Suppression Feature	Mod 4 only
(For more uniform burst heights at various angles of fall.)	
Self-Destructive Feature	None
(Future mods may employ an impact detonating element.)	
Auxiliary Detonating Fuze	Mk 44
Compression-Type Waterproofing	Mods 2 and 4 only

Description

The operation of the VT Fuze Mk 173 is very similar to VT projectile fuzes. The differences are in the internal construction, particularly the amplifier circuit; and therefore other marks of VT fuzes are not interchangeable with the Mk 173. Neither are VT Fuzes Mk 173 interchangeable with other mechanical-type fuzes, because of the fuze cavity size. Another difference between the Mk 173 and other VT projectile fuzes is the means provided for breakage of the electrolyte ampoule in the energizer. In the Mk 173 the ampoule is broken by a spin breaker. See Chapter 2, page 3. The distribution of the electrolyte to the cell plates is caused by centrifugal force as in wet-energizer VT projectile fuzes.

Employment

The VT Fuze Mk 173 is for use in ground-to-ground or ship-to-shore bombardment against personnel, light armament, and equipment. VT Fuzes Mk 173 are not satisfactory for use against aircraft, because of their long arming time. Such use is not recommended.

Range characteristics and ballistics for the 5.0-in. rocket (5.0-in. Rocket Head Mk 10 and Mods; 5.0-in. Rocket Motor Mk 4 and Mods) using VT fuzes are similar to rounds with point detonating fuzes such as the Mk 30. A summary of characteristics, with limitations at propellant temperatures of 70° F., is as follows:

Angle of Elevation	Range	% Normal Operation of VT Fuzes
Minimum 15°	2500	50
20°	3300	65
45°	4800	80

It will be noted that at ranges less than 3300 yards, VT fuzed rounds become slightly less effective. This is due to after-burning of the propellant grain, which prevents complete arming of the VT fuze. This characteristic is less evident at propellant temperatures above 70° F., because faster burning takes place. This characteristic is more pronounced at lower temperatures. The height above ground at which this fuze will operate varies from 15 to 75 feet, while over water the burst heights will generally be a little higher. The average height of burst is about 40 feet from the ground or water surface. Fuzes may function if the trajectories pass within 400 feet of hill tops, ridges, or tree tops. For high-angle approach to dense foliage, bursts will occur around tree-top level, with bursts occurrring higher for lower approach angles.

In salvo fire from Reel Feed Automatic Launchers Mk 51, the premature score may increase to 30%, with a four-foot lateral spacing between simultaneously firing launchers. With a lateral spacing of fifteen feet and a longitudinal spacing (along line of fire) of twelve and one-half feet for the Launcher Mk 51, the normal incidence of about 15% prematures for rapid salvo fire has been obtained in tests. No salvo effect tests have yet been performed with the Launcher Mk 102.

Safety

The VT fuze Mk 173 is armed only by the spin (approximately 80 r. p. s. required to arm) of the rocket after launching. This fuze contains the standard Auxiliary Detonating Fuze Mk 44, which is also armed by spin of the rocket.

MK 173 MOD 0

MK 173 MODS 2, 4

Figure 14. VT Fuze Mk 173.

When a rocket round misfires in the launcher, the entire round shall be disposed of in accordance with instructions in OP 1260.

When a rocket round is not fired, the round shall be removed in accordance with instructions in OP 1260. The VT fuze shall not be removed from the rocket for stowage. Unused rounds shall be carefully restowed to afford maximum protection from heat, moisture, and salt spray.

Personnel shall take cover during rocket firing of VT fuzed rounds, because of possible premature bursts of rounds at about 300 yards from the launcher. The fragment back spray from such a burst may be dangerous. Safety features should prevent bursts from occurring closer than 300 yards to the launcher.

Safety precautions regarding rocket motors, etc., are given in OP 1260.

Remarks

The Mk 173 Mod 0 does not have the wave-suppression feature or compression-type waterproofing. Mod 2, which is not expected to be issued, has compression-type waterproofing, but does not have the wave-suppression feature. Mod 4 has both the wave-suppression feature and compression-type waterproofing. Because of the longer body cylinder necessary for compression-type waterproofing, Mods 2 and 4 are not physically interchangeable with the Mod 0. All Mods employ essentially the same frequency. At the present time only the Mod 0 has been issued.

Chapter 6

OPERATIONAL USE

Introduction

U. S. Navy VT fuzes are designed primarily for use in antiaircraft fire to produce automatic detonation of the projectile in close proximity and proper relation to the target, so that the maximum amount of damage will be inflicted on the airplane and its operating personnel by the fragments from the bursting projectile. Extensive tests and combat use of Army VT fuzes designed primarily for howitzer use established the devastating effect of proximity fuze air bursts on light equipment and especially on exposed and entrenched personnel. VT fire also can be very effective against certain types of shipping.

Antiaircraft

Limitations. Certain features and conditions limit, to a degree, effectiveness of VT fuzes in antiaircraft fire. A distance of travel along the trajectory, called the arming range, is required for the fuze to become fully armed. In the various fuzes this distance ranges from 500 to 1500 yards (1800 to 3300 yards for Mk 173) and is required for safety reasons. The fuze, being unarmed, will not operate against targets within the arming-range distance.

During firing on a flat trajectory against low-flying planes, the sensitivity of the fuzes is decreased by the wave-suppression feature. This means that the projectile must pass nearer the target in order for the VT fuze to cause detonation. In effect, the size of the target is reduced, and fewer bursts will be obtained with the same accuracy of fire.

It should be remembered that at full sensitivity it is possible to obtain bursts at miss distances too great to yield any significant probability of useful effect on the target. Loss of these bursts does not necessarily imply a loss in damage done to the target.

In salvo fire the premature bursting of one projectile will occasionally actuate a closely adjacent VT fuzed projectile. The result is a somewhat increased percentage of prematures in salvo fire. Numerous tests have demonstrated that this effect is seldom serious. However, uniformly better performance occurs in rapid, continuous, or ripple salvo fire. This type of fire is recommended in all applications, including shore bombardment.

Rain storms, electrical disturbances in the atmosphere, fog, and heavy smoke also affect VT fuzes to a slight degree, and somewhat poorer performance can be anticipated when such conditions are encountered. Present VT fuzes operate in the temperature range 10°F. to 120°F. Operation is best at moderate temperatures (60°F. to 80°F.).

Tracers cannot be used with VT fuzes. When tracers are used, the fuzes are caused either to "premature" on arming or to remain electrically inoperative until the tracer burns out. This is caused by the ionized trail from the tracer flame. The same effect is present in rockets; hence the long arming time for rocket VT fuzes.

When VT fuzed ammunition is fired, falling projectiles present the danger of influence bursts in the midst of friendly ships, personnel, and equipment. A self-destructive element is being developed for VT fuzes; and, if it is incorporated in the fuzes, it will have considerable value in reducing this danger. This would permit more active and unrestricted fire against planes attacking a large task group or attacking shipping in the vicinity of friendly territory.

Effectiveness. Experience demonstrates that VT fuzes make heavy A. A. guns several times as effective as if time fuzes were used exclusively. Even a two-fold increase in effectiveness is, of course, equivalent to twice as many guns bearing on the target.

No special technique is required in firing VT fuzed projectiles at aircraft. Fire is directed at the target in the best manner possible with whatever fire-control equipment is available. No setting of VT fuzes is possible or necessary with current types of VT fuzes, and they are always "on" in range. They will detonate automatically [illegible] they come sufficiently close to the target. The radius of operation would be equal to the lethal distance in the ideal VT fuze.

The radius of operation against aircraft depends on various factors, among which are size of the airplane, aspect which the airplane presents to the approaching projectile, rate of approach, particularly type of fuze being used, etc. The average radius of operation of current VT fuzes is about 75 feet, varying somewhat with the factors mentioned above.

A good fire-control solution is especially well repaid in the case of VT fuzes. The nearer the projectile passes to the airplane, the higher will be the operability of the fuzes. Few twin-engine bombers will survive more than two or three influence bursts of five-inch projectiles within the optimum sensitivity pattern; and occasionally one is sufficient to produce immediate crash damage. The damage to an airplane and to its operating personnel of a three-inch burst is roughly one-third of that of a five-inch burst, similarly located.

Also, in the case of airplanes flying low to the water, the height of the target above water and the state of the sea affect the operating radius. The first fuzes issued were only partially effective against low-flying airplanes. All current Navy VT fuzes contain a wave-suppression feature (WSF), which discriminates between the influence effect of the rough surface of the sea and the influence effect of an airplane. The operating radius of WSF fuzes is automatically adjusted to a smaller value along low trajectories and upon approach to the sea. All WSF fuzes are fully effective against planes at high altitude, as well as reasonably effective against planes flying low over the water. Some bursts, close to but beyond the plane, and therefore ineffective, occur in the latter case.

Any evaluation of the ratio of VT fuzes to time fuzes used in antiaircraft fire should take into account the tactical situation, the number of guns in a group, and the total size of the battery which can be brought to bear.

Under average circumstances it is recommended that 50% to 75% of five-inch and three-inch rounds be VT fuzed. Time fuzed bursts in the general vicinity of the target have value in pointing out the target to other ships and to the automatic weapons, in deterring an attack and influencing its accuracy, and in permitting adjustment of a grossly inaccurate solution.

Individual ships will, of course, evaluate these various factors differently; but 50–75% VT fire is believed to be a good figure.

Under unusual conditions, such as in night action, a higher ratio of VT to time fuzes might be desirable, possibly up to 100% VT fuzes.

Navy ships, especially carriers, prefer 100% VT fire against diving targets, where the virtues of time fuzes have little or no application.

Theoretical advantage ratios of VT fire over time-fuzed fire have been arrived at from analyses of proving ground and other special firing. These theoretical advantage ratios are, in general, confirmed by analysis of combat reports. The table below shows this advantage in five-inch fire. Two typical fire-control situations are considered, (1) one-half the rounds pass through a circle, centered on the target, with radius of 100 feet, (2) one-half the rounds pass through a circle, centered on the target, with radius of 200 feet.

1.

Advantage Ratio	Percent Normal Fuzes
6	70
5	60
4	50

2.

Advantage Ratio	Percent Normal Fuzes
4	70
3	60
2.5	50

With smaller shooting errors, the advantage ratio is greater.

The difference between ballistics of VT fuzed and mechanical time fuzed ammunition is indistinguishable with practical fire control, and need not be considered.

Shore Bombardment

Limitations. Certain factors limit the use of VT fuzes for bombardment. Current VT fuzes are not operable at usual bombardment velocities, of

1200 f/s, but must be fired at full charge. Therefore, at ranges under 6000 yards, the trajectory is so flat that serious range error in burst occurs unless firing against obverse slopes. Above 6000 yards, this effect is not serious.

Clearance of crests on which friendly troops are located should exceed 500 feet to prevent the possibility of a burst over the crest.

Rough terrain, jungle, and swamps will cause some increase in the burst height.

Due regard must be given to the effect of random prematures along the trajectory when firing over boat lanes, friendly ships, and friendly troops. Most spontaneous prematures occur short of 3000 yards, and the danger from random prematures beyond this range is rather slight.

Effectiveness. Navy VT fuzes function at about the same height over flat land of any type as over the sea. Typical average heights of operation are 10 feet at 6000 yards range and 25 feet at 12,000 yards range.

VT fuze air bursts "follow" the terrain, and at ranges over 6000 yards the range dispersion of the bursts is only slightly greater than the fall of shot with A. A. Common ammunition.

Use Against Ships

The danger area which large ships present to VT fuzes is roughly twice that presented to impact fuzes. Air bursts over a ship can be expected to have an effect on light topside equipment and on exposed personnel on the weather decks, but light splinter shields are sufficient to stop most of the fragments. Common and A. A. Common ammunition with impact fuzing is much more effective in disabling and sinking ships.

Against motor torpedo boats, personnel barges, and other light craft, current VT fuzes with WSF are recommended for all ranges.

Targets for Antiaircraft Gunnery Practice with VT Fuzes

VT characteristics for various standard targets:

Target	Description	Average Influence Radius (Fuze Mk 53)	Remarks
Mk 7	Towed sleeve	-------	Unsatis.
Mk 15	Towed sleeve	20 ft	Unsatis.
Mk 17	High-speed conical towed sleeve	20 ft	Unsatis.
Mk 19	do	20 ft	Unsatis.
Mk 20	do	20 ft	Unsatis.
Mk 22	do	50 ft	Satis.
Mk 23	do	45 ft	Satis.
TD2C	Drone	40 ft	Satis.
TDC2	do	40 ft	Satis.
F6F	do	70 ft	Satis.
	Any metal covered glider or drone of size comparable to a fighter plane	70 ft	Satis.

Targets of small influence radius are considered unsatisfactory, since they present such a small target area to a VT fuze as to give no true indication of the results to be expected when firing against a full-scale plane.

Chapter 7

CHARACTERISTICS

Operability

Percent Operability. When new, and depending upon the particular model, Navy VT fuzes have a percent operability of from 65% to 90% normal. They generally are considered unsatisfactory when they fall below 50% normal operability. It should be noted that VT fuzes with 50% normal operability are more effective than normally set time fuzes with 100% operability, because of the inherently greater range dispersion of bursts with the latter. The VT fuze does not cause a normal burst unless a target is within its influence field. Thus, with VT fuzes there is a direct relationship between fire control and the number of bursts. The number of bursts obtained with mechanical time fuzes is independent of the accuracy of fire. As a result, the word "operability" requires some comment.

The performance of VT fuzes generally is measured in percent of units operating on a water surface at the end of a moderately long flight. Under such conditions, roughly 50% of the failures are prematures. Many of these are otherwise normal units which are triggered by some external or internal disturbances before the end of flight, and would have operated normally in the presence of a target prior to the point at which they prematured. Therefore, the number of fuzes normally operable varies with the distance of the target from the firing point. Since only a small portion of the projectiles fired at an enemy plane are at the extreme ranges of VT standard over-water tests, the operability of VT fuzes which come within damage range is almost always greater than quoted performance figures.

Premature Bursts. A premature is any burst caused by a VT fuze which is not the result of proximity to the target or some other radio wave reflecting surface. A large proportion of the prematures occur upon arming with the first surge of power, as with most electrical equipment.

Duds. A VT fuze which fails to function in the proximity of a target or other radio wave reflecting surface is known as a dud. Consideration must be given to the arming range and the extent of influence of the particular model before classifying as a dud a failure to burst in the vicinity of a target. Some duds will burst upon impact if there is a sufficient charge on the condenser and the projectile lands in such an attitude that the shock closes the reed switch. This allows the condenser to discharge through the reed switch and the squib. (See fig. 26 p. 37.)

Temperature. Present VT fuzes are operable over a temperature range of 10° F. to 120° F. Operation is best at moderate temperatures (60° F.–80° F.).

Damage. A blow damaging the nose may affect operability but will not render the fuze unsafe.

Serious Effects on Operability

TRACERS. Tracers cannot be used with VT fuzes. When VT fuzes are fired with missiles containing a tracer, the fuzes either premature on arming or remain electrically inoperative until the tracer burns out. (This is caused by the ionized trail from the tracer flame.)

COPPERING. Coppering of 3"/50 guns interferes with VT fuze operability. Decoppering by firing one or more illuminating projectiles after every 50 rounds is recommended.

HOT GUNS. Rounds which remain in a very hot gun over 40 seconds generally will result in duds. The heat will melt the potting compound and cause it to flow, thus almost destroying the resistance of the fuze to the shock of firing.

Moderate Effects on Operability

ATMOSPHERIC EFFECTS. VT fuzes fired during atmospheric electrostatic distrubances have an increased percentage of prematures. Prematures increase with the rate of precipitation during rain-fall and in the vicinity of rain clouds. VT fuzes will occasionally function when entering a cloud. Fog and smoke have a lesser effect, but do occasionally cause prematures. These effects are seldom very serious, however; and the ammunition remains effective during all ordinary atmospheric conditions. These statements apply to the present models. Older models were less sensitive and not affected by some of the above factors.

WINDOW. A very dense infection of window of the proper frequency causes VT fuzes to function. Huge quantities of window would be required effectively to protect a region of significant size.

AERIAL FLARES. VT fuzes will function on aerial flares if they pass within 20 feet; but extensive tests have shown that the ability of influence bursts, or in fact gunfire in general, to extinguish flares is very slight.

SALVO FIRE. In salvo fire the premature bursting of one projectile will occasionally actuate a closely adjacent VT fuzed missile. Numerous shipboard tests have demonstrated that this effect is seldom serious. However, uniformly better performance occurs in rapid, continuous or ripple salvo fire and this type of fire is recommended in all applications.

VERY NEW OR VERY OLD GUNS. In such guns there is a tendency toward a decreased percentage of normal bursts. In very new guns the decrease in performance is accredited to higher muzzle velocity, greater setback force, and increased spin. In a worn gun, bore enlargement at the origin results in undue shock and strain when the projectile hits the lands of the rifling.

No Effect on Operability

DEGAUSSING AND DEPERMING. No special precautions are necessary with respect to VT fuzes during a deperming operation or while the degaussing gear is energized.

SHIPBOARD RADIO AND RADAR. Present Navy equipment in these categories should have no effect on U. S. Navy VT fuzes.

Arming Range

Arming range is the distance along the trajectory that the missile must travel before the fuze is capable of operation in the presence of a target. It is especially important during antiaircraft use and in consideration of danger to surrounding personnel and gear. The arming range for the various Navy VT fuzes is given in Appendix B, page 39.

The missile cannot arm until several actions take place within the fuze. The time required for these actions determines the arming range and is influenced by a number of factors, which may be classified under two general headings:

1. Internal design features
2. External factors

Internal Design Features

ACTIVATING TIME OF BATTERY. The activating time of the reserve energizer is the time required for setback and centrifugal forces to break the ampoule and distribute the electrolyte, and for voltages to build up to maximum. At moderate temperatures full power is available within 0.1 seconds (for 3″/50 gun) to 0.25 seconds (for 5″/38 gun). This time interval varies inversely with the spin frequency of the missile, since distribution of the electrolyte is dependent upon the centrifugal force produced by the rotation of the projectile.

CONDENSER CHARGING TIME. The condenser charging time is the time necessary for the firing condenser to become charged through a fixed resistor and the mercury unshorter switch. A charge ample for firing the squib usually is available within 0.2 to 0.5 seconds (somewhat longer in Mk 173) after full power is received from the energizer. The rate of charging is determined by the characteristics of the circuit, which are designed to meet the tactical arming requirements of the particular model.

MERCURY SWITCH UNSHORTING TIME. The unshorting time for the mercury switch is the time necessary for the spin to force the mercury through the porous wall, thus unshorting the squib resistor. In VT Fuze Mk 53 Mods 3–6, this occurs about 0.6 seconds after firing. This time interval varies inversely with the spin frequency. It is selected to match the over-all arming time of the condenser.

REED SWITCH UNSHORTING TIME. The unshorting time for the reed switch is the time necessary for the spin forces to open the reed switch, thus unshorting the firing condenser. This occurs immediately after firing and does not affect the fuze arming time. The switch remains open as long as the spin remains greater than some specified value. Thus it is potentially a self-destruction factor, but in present fuzes the missile usually completes its trajectory before the rate of spin decreases to the specified value.

AUXILIARY DETONATING FUZE ARMING TIME. The arming time for the auxiliary detonating fuze is the time necessary for the rotor detents to be thrown outward by centrifugal force, permitting the two rotors to rotate until the explosive train is aligned. This occurs within a few feet of the gun muzzle.

FAULTY CONSTRUCTION. Delay in arming of the fuze may result from faulty construction or wiring of one or more of the components of the fuze. This may lead to a condition where the thyratron condenser circuit fires continuously, preventing the condenser from storing up a sufficient charge to detonate the squib. This condition may be temporary, so that the fuze may be operable during the latter part of its flight; or the condition may persist throughout its entire flight, leading to duddage.

External Factors Affecting Arming Range

FUZE TEMPERATURE. Arming time increases with the drop in temperature. At low temperatures the increased viscosity of the electrolyte and slower electrochemical reactions increase the energizer activating time. With the 5″/38 gun the arming time may increase to approximately 1.0 second at 10° F., the lower temperature limit for use of VT fuzes.

GUN EFFECTS. The arming time of the VT fuze may be affected by instable flight of the missile. Instability of the projectile, caused either by characteristic yaw or by side-slap in a worn barrel, will affect performance of the fuze. In such cases, mechanical distortion of fuze parts and erratic activation of the battery may occur, with subsequent delay in arming. Yaw may produce battery noise which, in turn, may trigger the thyratron, causing a premature.

Activation of the reserve energizer is dependent upon the breakage of the ampoule and the spin of the missile. The breakage of the ampoule containing the electrolyte for the battery must be complete to insure rapid activation of the battery. A considerable number of ampoules and breakers have been developed so that they will break satisfactorily in a particular gun. The activation time of a particular type of battery is less when fired in a high-spin gun than if it is fired in a low-spin gun.

WAVE EFFECTS ON ARMING TIME. When a VT fuzed missile travels along a very low trajectory over waves, the fuze may receive a succession of signals. In a rough sea the amplitude may be sufficient to fire the thyratron circuit. With the reed switch open, the firing condenser might be discharged repeatedly, preventing the accumulation of enough charge to detonate the squib and resulting in a dud. In the case of calmer waters, or higher trajectory, late arming or early bursts may occur. Influence of wave effects on arming of the VT fuze has been greatly reduced by the introduction of fuze models (with a wave-suppression feature) which automatically reduce sensitivity to the type of signal generated and received over a wave surface, but which retain their sensitivity to signals received from an airplane target.

ATMOSPHERIC EFFECTS ON ARMING TIME. Atmospheric effects, which affect operability, and especially electrostatic disturbances, may produce a succession of signals similar to wave effects described above, with similar results on the VT fuze.

Sensitivity

The maximum sensitivity of a VT fuze ultimately depends on the minimum positive amplifier output voltage necessary for the thyratron control grid to allow the condenser to discharge through the squib. In a given fuze circuit this corresponds to a detected signal of an optimum frequency, amplitude, and phase.

For practical use, the specific conditions for a detected signal that will cause the fuze to detonate must be translated into a distance from the target. Thus the sensitivity of a VT fuze is defined as the average maximum radial distance from a target at which a fuze that is operating properly will fire. An average value must be used, because the actual value varies with target size, shape, and material; orientation of target and shell; and rate of approach of target and shell. The actual value also varies from fuze to fuze of the same model, because of inherent difficulties in the manufacturing process. The average values are given in Table 1, Appendix B.

VT fuzes with the wave-suppression feature automatically decrease in sensitivity in the presence of spurious signals caused by such factors as the presence of ocean waves near the missile, atmospheric disturbances in the electrostatic class, or stray internal voltages. The reduction in sensitivity on such occasions reduces the number of malfunctions that might otherwise occur.

Life

The effective life of a fuze is considered over when the percent operability of the lot falls below 50% normal. The limiting factor on present fuzes has been found to be the deterioration of electrical components in the presence of high temperatures and especially of high humidity. Deterioration takes place in all climates, but is accelerated in regions of high temperature and humidity.

Life of VT fuzes is considerably prolonged by storage at 40°–50° F. under dry conditions and avoidance of exposure to salt spray. Under optimum conditions the average operability of current model fuzes is expected to decline slowly to about 50% normal after two years, with the remainder mainly duds.

Increasing deterioration with age has little effect on sensitivity, but the arming range gradually increases, thus eventually causing duds.

Refuzing

Because of the deterioration of VT fuzes, it may become desirable to refuze projectiles with new fuzes when the old ones have deteriorated to such a point that their effectiveness is greatly reduced. At the present writing there are no fuze-cavity liners in the projectiles and the fuze body is in direct contact with the explosive filler; therefore great care must be exercised in the refuzing operation to minimize the danger of explosion or fire. Refuzing is to be performed by authorized U. S. Navy Ammunition Depots.

The refuzing operation is to be accomplished in the most suitable location, removed from other explosives and vital installations. Only those persons essential for the work shall be in the vicinity, and the smallest number of rounds practicable shall be exposed.

To remove the fuze, a special wrench made to fit the slots in the steel nose ring of the fuze is used. After careful unscrewing and removal of the fuze, the fuze cavity is thoroughly inspected. Any loose grains of explosive are removed, and the screw threads are thoroughly cleaned. No metallic tools are used in the cleaning operation, because of the danger of sparks.

Before the new fuze is inserted, its threads are inspected and then given a coat of luting compound. The fuze is then carefully screwed into the projectile and thoroughly tightened with the special wrench.

Precautions

Avoid producing sparks.

Clean fuze cavity and threads thoroughly to avoid ignition of explosive grains by friction of the screw threads.

Keep area clear of unnecessary personnel.

Expose only the smallest practicable number of rounds.

Be certain that the new fuze is the proper one and of a size to fit the fuze cavity.

Old fuzes are to be disposed of by dumping in deep water.

Fuze-Cavity Liners

At the present time, work is in progress on design of a fuze-cavity liner for projectiles to accommodate VT fuzes. When these fuze-cavity liners are incorporated in the projectiles, it is planned to stow a certain percentage of a ship's allowance of projectiles without VT fuzes installed. The VT fuzes will be hermetically sealed in metal cans to prevent deterioration. The cans will remain sealed until it is necessary to fuze additional projectiles in order to maintain a ready ammunition supply.

When this plan is inaugurated, instructions for fuzing will be issued by the Bureau of Ordnance.

Chapter 8

ROUTINE TEST FIRING

Time of Test Firing

Routine test firing of VT fuzed ammunition by all ships shall be conducted quarterly or as nearly so as the opportunity offers. Each ship shall perform the routine test quarterly on all lots of VT fuzes (except obsolete models) of which there are 250 fuzes or more on board. This firing shall be in addition to target-practice allowances. The purpose of this routine test is to provide the Bureau with sufficient information about the functioning of these fuzes with the least expenditure of ammunition. Careful attention to the form and completeness of reports is therefore required.

Exchange of Ammunition

In contrast to the wartime practice, authorization to individual ships for the exchange of their VT fuzed ammunition on the basis of individual test firing is now rescinded.

The peacetime policy of the Bureau of Ordnance, now in effect, is to compile and analyze all test-firing reports and issue blanket recall and unserviceability orders upon the basis of these over-all results and upon the basis of other important considerations such as availability and distribution of replacements, availability of rework personnel, existence of improved type fuzes, etc. Replacement authorization will also be issued to individual ships or units in exceptional cases upon requests by the ship or unit commander or by higher fleet commands.

Detailed Instructions

Detailed instructions for the conduct of quarterly tests are as follows:

The routine test consists of firing over water of from 6 to 40 rounds, depending upon performance results, from each lot of ammunition containing 250 or more VT fuzes. The test rounds shall be taken from regular stowage and shall not be rounds held in ready service lockers. When practicable, the stabilized gun elevation shall be 15° for tests in five-inch and six-inch guns, 10° for those in three-inch guns, and 30° for those in five-inch rocket launchers. Other conditions of test are left to the discretion of the ship, but general information concerning these conditions is requested in paragraph 1 of the test report form (NAVORD FORM 1758). The test report form is shown in Figure 15. Detailed test results are requested in paragraph 2 of the report form. In paragraph 2, columns 5 and 6 of the test results table indicate the round at which the test shall be stopped. The method is to compare the number of **normal** rounds observed previously in the test (column 5) with reference numbers (column 6) as given in the table. This test procedure saves ammunition by stopping each test when sufficient information has been obtained about the lot. A few rounds will give adequate information if the lot under test is very good or very bad, but more are required if it is close to the limit of acceptable quality.

General Information

General information requested on the form is as follows:

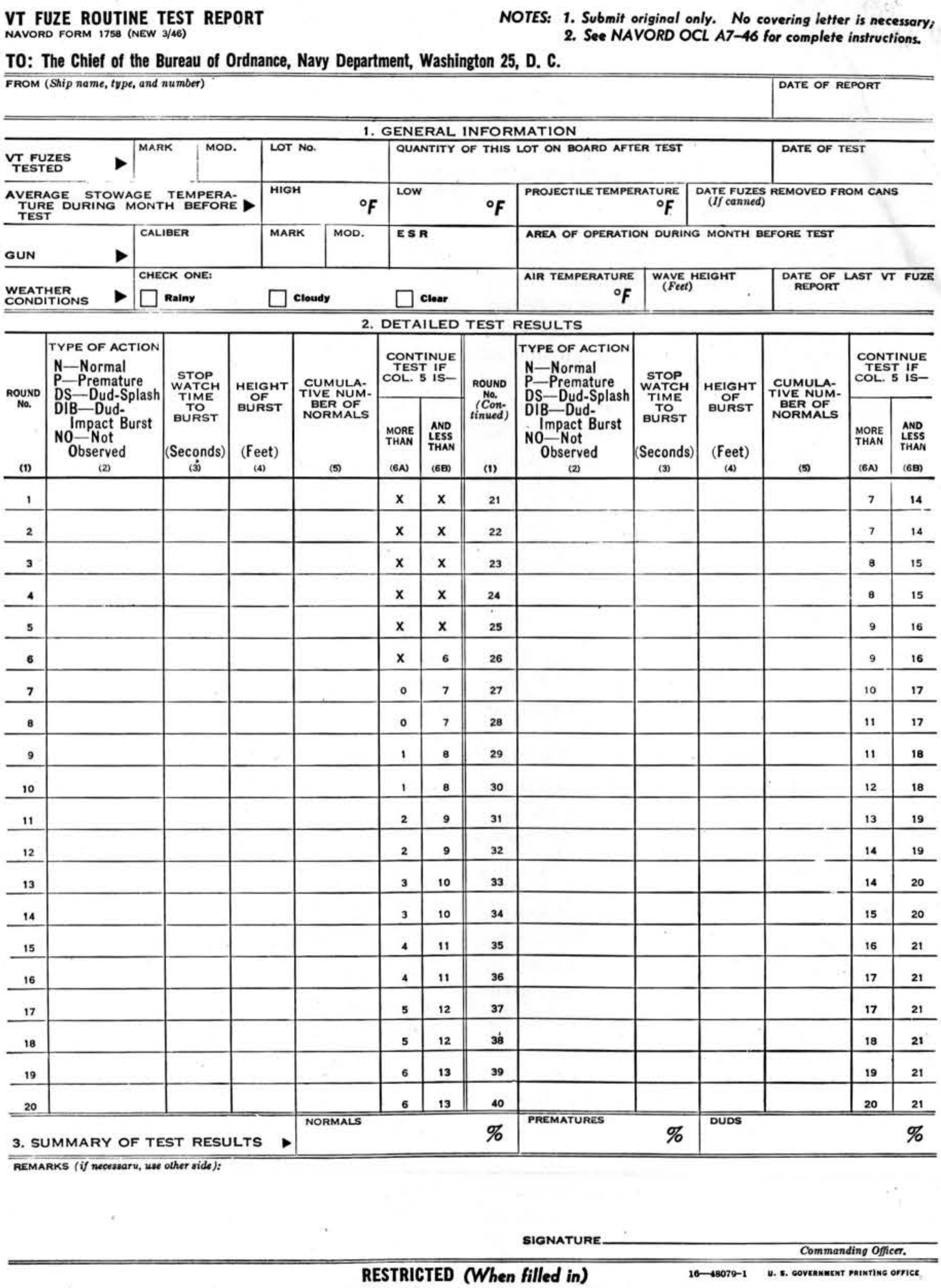
VT Fuzes Tested. Fill in Mark, Mod, Lot No., and total number of this lot aboard after completion of test.

Date of Test. Give day, month and year.

Average Stowage Temperature During Month Before Test. Fill in average high and average low temperatures, during past month, of compartment in which lot was stowed.

Temperature of Projectiles When Fired. Give best estimate of the actual temperature of the projectile or rocket just prior to loading in gun for firing.

Date VT Fuzes Removed from Cans (if canned). VT fuzes will be issued in cans in the near future. Fuzes unsealed for the same length of time shall be used in the test of the lot, if practicable.



VT FUZE ROUTINE TEST REPORT
NAVORD FORM 1758 (NEW 3/46)

NOTES: 1. *Submit original only. No covering letter is necessary;*
2. *See NAVORD OCL A7–46 for complete instructions.*

TO: The Chief of the Bureau of Ordnance, Navy Department, Washington 25, D. C.

FROM (*Ship name, type, and number*) | DATE OF REPORT

1. GENERAL INFORMATION

VT FUZES TESTED ▶	MARK	MOD.	LOT No.	QUANTITY OF THIS LOT ON BOARD AFTER TEST	DATE OF TEST
AVERAGE STOWAGE TEMPERATURE DURING MONTH BEFORE TEST ▶	HIGH °F		LOW °F	PROJECTILE TEMPERATURE °F	DATE FUZES REMOVED FROM CANS (*If canned*)
GUN ▶	CALIBER	MARK	MOD.	ESR	AREA OF OPERATION DURING MONTH BEFORE TEST
WEATHER CONDITIONS ▶	CHECK ONE: ☐ Rainy	☐ Cloudy	☐ Clear	AIR TEMPERATURE °F WAVE HEIGHT (*Feet*)	DATE OF LAST VT FUZE REPORT

2. DETAILED TEST RESULTS

ROUND No. (1)	TYPE OF ACTION N—Normal P—Premature DS—Dud-Splash DIB—Dud-Impact Burst NO—Not Observed (2)	STOP WATCH TIME TO BURST (Seconds) (3)	HEIGHT OF BURST (Feet) (4)	CUMULATIVE NUMBER OF NORMALS (5)	CONTINUE TEST IF COL. 5 IS— MORE THAN (6A)	AND LESS THAN (6B)	ROUND No. (*Continued*) (1)	TYPE OF ACTION N—Normal P—Premature DS—Dud-Splash DIB—Dud-Impact Burst NO—Not Observed (2)	STOP WATCH TIME TO BURST (Seconds) (3)	HEIGHT OF BURST (Feet) (4)	CUMULATIVE NUMBER OF NORMALS (5)	CONTINUE TEST IF COL. 5 IS— MORE THAN (6A)	AND LESS THAN (6B)
1					X	X	21					7	14
2					X	X	22					7	14
3					X	X	23					8	15
4					X	X	24					8	15
5					X	X	25					9	16
6					X	6	26					9	16
7					0	7	27					10	17
8					0	7	28					11	17
9					1	8	29					11	18
10					1	8	30					12	18
11					2	9	31					13	19
12					2	9	32					14	19
13					3	10	33					14	20
14					3	10	34					15	20
15					4	11	35					16	21
16					4	11	36					17	21
17					5	12	37					17	21
18					5	12	38					18	21
19					6	13	39					19	21
20					6	13	40					20	21

3. SUMMARY OF TEST RESULTS ▶	NORMALS %	PREMATURES %	DUDS %

REMARKS (*if necessary, use other side*):

SIGNATURE ____________
Commanding Officer.

RESTRICTED *(When filled in)* 16—48079-1 U. S. GOVERNMENT PRINTING OFFICE

Figure 15. Test Report Form—NAVORD Form 1758

Gun. Fill in caliber, mark and mod, and ESR (or caliber, mark, and mod of rocket launcher).

Area of Operation During Month Before Test. Give general area; for example, North Atlantic or South Pacific.

Weather Conditions. State whether rainy, cloudy, or clear.

Air Temperature. Give average surface temperature during test in degrees Fahrenheit.

Wave Height (in feet). Estimate height of waves in feet.

Date of Last VT Fuze Report. Give date of last previous VT fuze routine test report on any VT fuze lot.

Detailed Test Results

Under the detailed test results (paragraph 2) record the type of fuze action observed on each round, stop watch time to burst in seconds, the observed height of burst above the water in feet, and other significant data.

Type of Fuze Action. Fuze Action is classified into three general types, as follows:

NORMAL. A burst which occurs upon approach to the water at the end of flight is a **"normal"**, recorded as "N". With all modern types of Naval VT fuzes, these bursts will occur at heights above the water from a few feet to 200 feet. Average normal heights for A. A. fuzes incorporating the wave-suppression feature (Mks 53, 58, 59, etc.) are 15–20 feet. **However, record as "N" any burst under 200 feet.**

PREMATURE. A burst which occurs along the trajectory not near the end of flight is a **"premature"**, recorded as "P". **Bursts near the end of flight but above 200 feet are to be reported as prematures.**

DUD. A burst which occurs on impact with the water is a **"dud-impact burst"**, recorded as DIB. A round that enters the water without any explosive action is a "dud-splash" recorded as DS. Either of these is considered dud action so far as the VT fuze is concerned.

No Observation. "NO" shall designate a round in which the type of fuze action is not observed. This in effect designates the round as non-normal in fuze performance.

Distinction Between Low Normals and Duds. The operating radius or sensitivity of WSF (Wave-Suppression Feature) fuzes is automatically adjusted to a smaller value along low trajectories and upon approach to the sea. This latter fact has in the past caused some confusion in identifying normal operation in routine tests in which typical height of WSF fuze operation is 20 feet. A low normal burst can be distinguished from a dud-impact burst, however, by the appearance of the flash above the water and by a large "mushroom" of black smoke which appears just above the water; and at the same time fragments can usually be seen striking the surface over an area of forty or fifty feet in diameter. This is easily observed by the control officer or other persons located sufficiently high in the ship, and by using binoculars. A dud-impact burst, DIB, produces a vertical column of water and spray and a thin wisp of smoke, which usually blows away readily and disappears. Little or no fragmentation is noted in this case. Complete duds, DS, make only a small splash. Most duds occurring in routine firing tests of VT fuzes are of this splash type, as no VT fuzed projectiles thus far issued contain base detonating fuzes.

An estimate of the height of the normal bursts by any practical means is desired. A sextant, stadimeter, or mil scale in binoculars is suggested to assist visual estimates. **Close attention to distinguish low normal bursts from impact bursts is important.**

Use of Table to Determine Round at Which to Stop Test. Columns 5 and 6 are provided in the table to determine the round at which to stop the test. In column 5 the number of normals previously observed in the test are added together to provide a running cumulative total. Thus, if the following type action is observed from a series of rounds: N, DIB, N, N, P, P, N; the record in column 5 is 1, 1, 2, 3, 3, 3, 4. The 4 indicates that there were four normals at the end of seven rounds. This number is then compared with the reference numbers given in columns 6a and 6b (for this number of rounds) to decide when to stop the test. If the number in column 5 is equal to or less than the number in column 6a, or equal to or greater than the number in column 6b, stop the test. If the number in column 5 lies between the reference numbers in column 6, keep testing. The test will certainly stop at the end of 40 rounds. In the example given, the cumulative total in column 5 was 4 at the end of seven rounds, and the reference numbers for seven rounds are 0 and 7. Therefore the test was continued.

Other examples of the use of columns 2, 5, and 6 are as follows:

Example 1

Col. 1	Col. 2	Col. 5	Col. 6		
Round Number	Type of Action Normal N Premature P Dud-splash DS Dud-Impact Burst DIB No Observation NO	Cumulative number of Normals in this number of rounds	Continue test if number in Col. 5 lies between these numbers 6a (exclusive) 6b		
1	N	1	x	x	keep testing
2	N	2	x	x	"
3	N	3	x	x	"
4	DS	3	x	x	"
5	N	4	x	x	"
6	N	5	x	6	"
7	P	5	0	7	"
8	N	6	0	7	"
9	P	6	1	8	"
10	N	7	1	8	"
11	N	8	2	9	"
12	N	9	2	9	stop test (since Col. 5 equals 6b).

Example 2

Col. 1	Col. 2	Col. 5	Col. 6		
Round Number	Type of Action Normal N Premature P Dud-splash DS Dud-Impact Burst DIB No Observation NO	Cumulative number of Normals in this number of rounds	Continue test if number in Col. 5 lies between these numbers 6a (exclusive) 6b		
1	P	0	x	x	keep testing
2	DIB	0	x	x	"
3	N	1	x	x	"
4	N	2	x	x	"
5	N	3	x	x	"
6	DS	3	x	6	"
7	NO	3	0	7	"
8	N	4	0	7	"
9	P	4	1	8	"
10	DS	4	1	8	"
11	P	4	2	9	"
12	DIB	4	2	9	"
13	N	5	3	10	"
14	DS	5	3	10	"
15	P	5	4	11	"
16	DS	5	4	11	"
17	N	6	5	12	"
18	DIB	6	5	12	"
19	P	6	6	13	stop test (since Col. 5 equals 6a).

Instructions in Mailing Report

Upon completion of test firing, the completed test report form should be forwarded by RESTRICTED air mail to the Chief of the Bureau of Ordnance, with copies to appropriate commands.

Chapter 9

THEORY

Introduction

This chapter is not required reading for a general knowledge of VT fuzes sufficient for intelligent handling and use. It is primarily for those who have some knowledge of radio circuits and operation and who seek a more detailed explanation of VT circuits and wave behavior. It is a more detailed explanation of the theory of operation of the transmitter, receiver, amplifier, wave-suppression feature, and firing circuits.

Transmitter

A schematic diagram of a transmitter-receiver circuit is shown in figure 16. It is a modification of a "grounded-grid" Hartley oscillator circuit. (Navy VT fuzes also use a modification of the Colpitts oscillator circuit.) The tuned circuit is comprised of the coil, the distributed capacity (largely between the antenna and the projectile body), and the inter-electrode capacities of the tube. This "distributed capacity" is represented in the diagram by a condenser connected across the coil by dotted lines. The plate is held at projectile body voltage, so far as radio-frequency currents are concerned, by the bypass condenser.

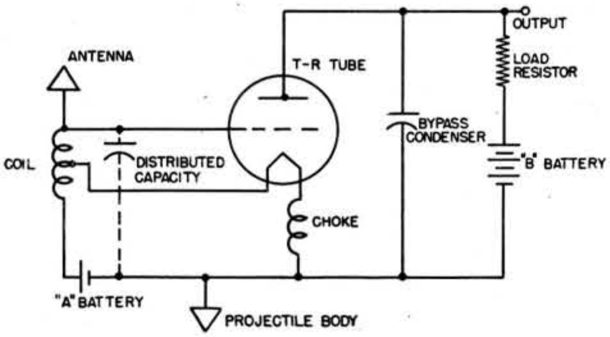


Figure 16. Schematic diagram of transmitter-receiver (T–R) circuit.

As with all radio-frequency oscillators, the oscillation is started by some stray electrical voltage in the circuit impressed on the grid of the tube. This is amplified by the tube, and enough of this amplified signal is fed back from the plate to the grid in the proper phase and frequency, through the resonant circuit, to sustain the process. The excess over that necessary to sustain the oscillation is emitted from the antenna as the radio signal.

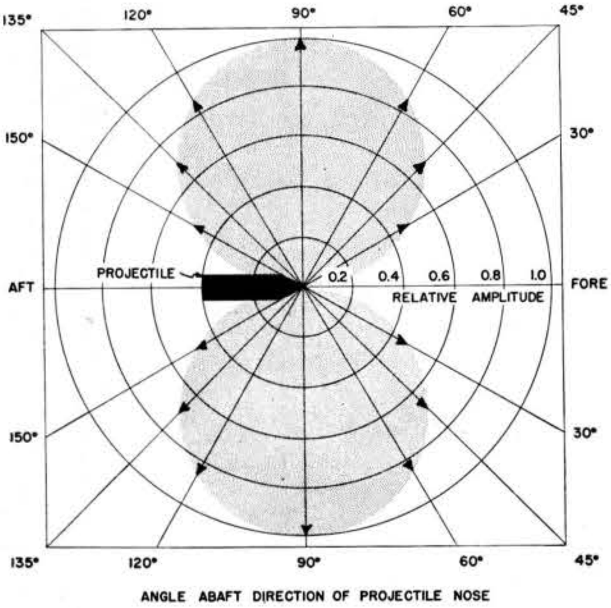


Figure 17. Standard dipole radiation pattern.

The radiation pattern is that of a standard dipole with its greatest strength perpendicular to the axis of the projectile body. This is modified by the amplifier-response characteristics to produce an effective sensitivity pattern that more closely matches the fragmentation pattern. The standard dipole pattern is shown in figure 17, and the effective sensitivity pattern is compared with the fragmentation pattern of a projectile in figure 18. The amplitude of the radiated wave also varies with the distance from the projectile, as shown by the curve in figure 19.

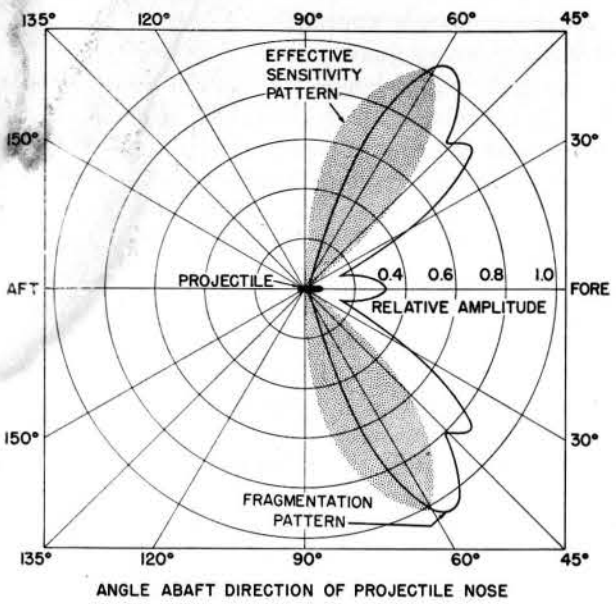


Figure 18. Effective sensitivity pattern of a VT fuze compared with the fragmentation pattern of a five-inch projectile.

Receiver

In the presence of a reflecting target a portion of the radiated wave is returned to the oscillator. As the amplitude of the radiated wave varies with direction and distance from the projectile, so will the amplitude of the reflected wave depend upon the direction and distance from the target, as well as on its size, shape, aspect, and material.

Figure 20 (right) pictures the relationship between the transmitted and reflected wave when

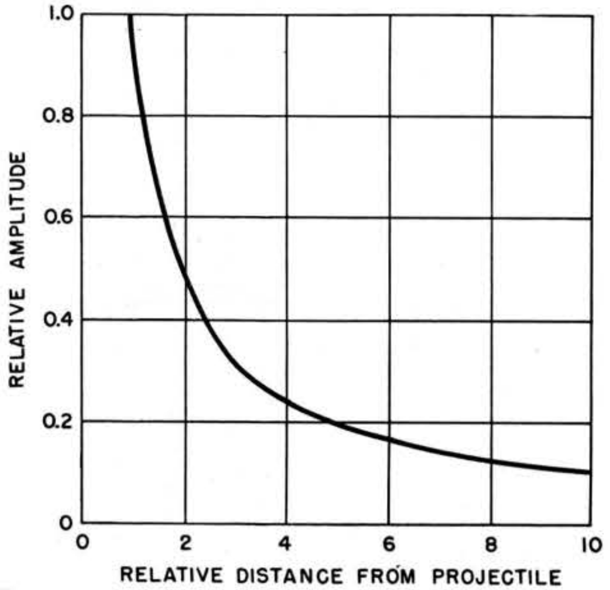
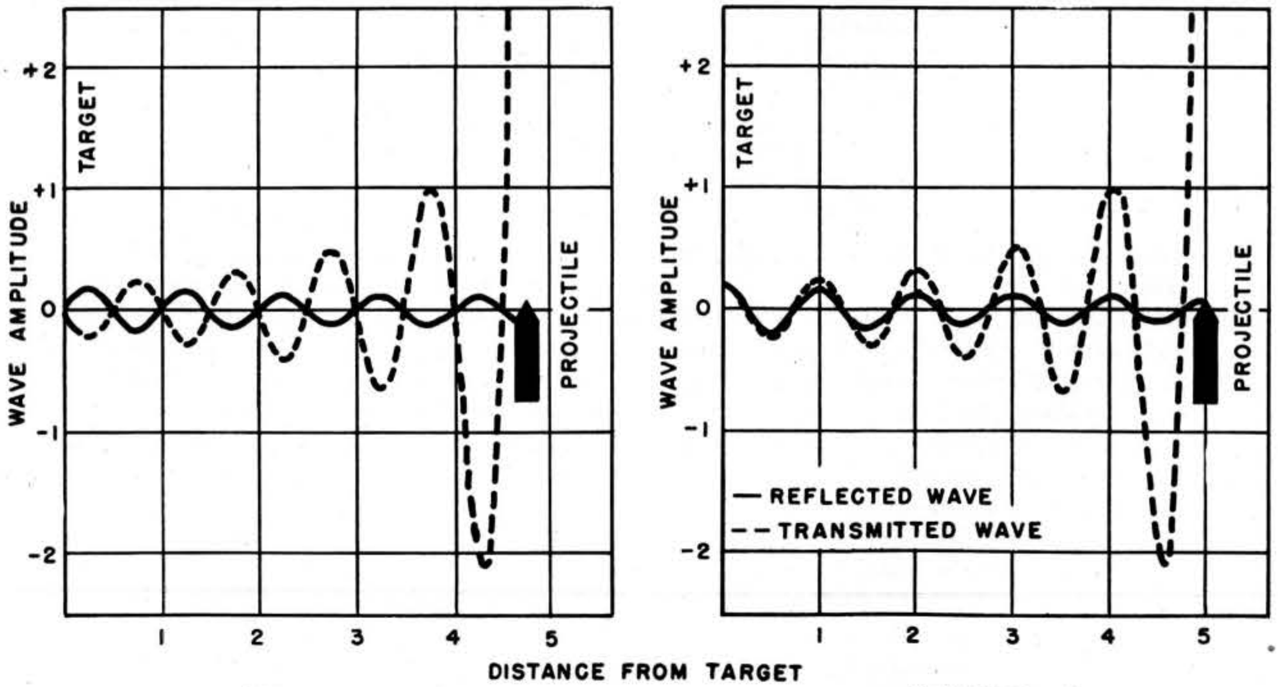


Figure 19. Variation of transmitted wave amplitude with distance from projectile.



OPPOSING

REINFORCING

Figure 20. Wave relationships between transmitted and reflected waves.

the total distance the wave has to travel to the target and back to the oscillator is an exact number of wave lengths of the radio wave. When this occurs, the signal returns to the oscillator an exact number of cycles later. As shown in figure 20 (right), the reflected signal is then of the same polarity as the transmitted signal. The two voltages therefore reinforce each other at the grid of the oscillator.

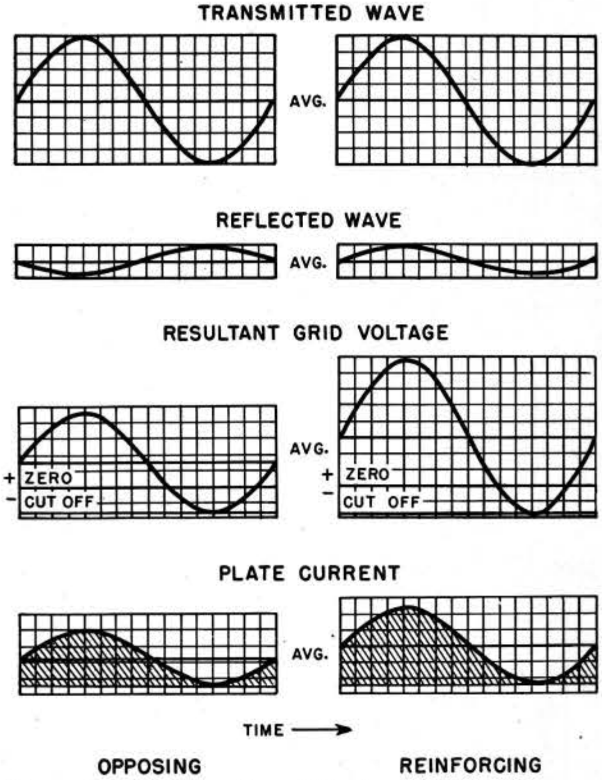


Figure 21. Relationships within transmitter-receiver of transmitted and reflected waves.

This results in a larger amplitude of oscillation than would occur if the oscillator were far from any reflecting target. This causes a greater average plate current, as shown by figure 21 (right).

If the oscillator is moved to a position where the total distance the radio wave has to travel is an odd number of half wave lengths, as shown in figure 20 (left), the conditions are reversed. The reflected signal is opposite in polarity to the signal being emitted; the two signals therefore subtract from each other; the amplitude of oscillation is less; and the resultant plate current, as shown in figure 21 (left) is smaller than that which occurs when the oscillator is far from a target.

As the projectile approaches a target, it passes alternately, every quarter wave length (equivalent to one-half wave length of total wave path), through regions in which the oscillations are reinforced, and the plate current is higher than normal, and through regions in which the oscillations are reduced, and the plate current is lower than normal. As the distance lessens these variations from the steady state become greater and greater. The frequency with which these variations occur is many times less than the frequency of the radio wave, because the projectile travels much slower than the radio wave; but the reversals still occur several hundred times a second.

The plate current drawn by the oscillator must flow through a load resistor, as shown in the circuit diagram, figure 16. The voltage drop across this resistor varies at a slow rate with the average plate current drawn by the tube. The radio-frequency current component does not pass through the resistor, but returns through the bypass condenser.

This is an idealized picture; actually the strength of the reflected wave from a target, such as an airplane, varies in a complicated way as the direction from the target changes. In spite of the complexity of this signal, it is characterized by regular fluctuation about the undisturbed value, increasing sharply in amplitude as the target is approached.

Amplifier

A schematic diagram of the amplifier circuit is shown in figure 22. The amplifier is connected, in effect, across the load resistor in the transmitter-receiver circuit. The output of the amplifier is connected to the input of the firing circuit and the wave-suppression circuit. Direct current from the wave-suppression circuit is fed back to the grid of the first amplifier tube through the grid resistor. The amplifier is connected electrically through the fuze body to the projectile body and by leads to the "A" and "B" batteries.

The main purpose of the amplifier is to take the weak signal developed by the transmitter-receiver in the presence of a target, and to amplify it until it is capable of operating the firing circuit.

This is accomplished by a conventional resistance-coupled pentode amplifier of two stages. The input blocking condenser keeps the positive

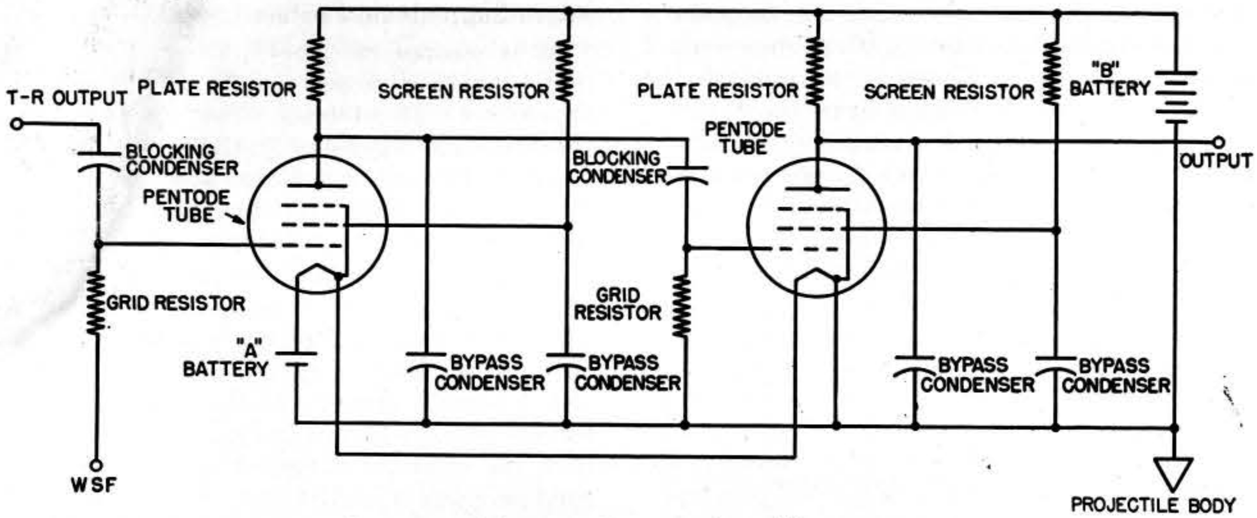


Figure 22. Schematic diagram of amplifier circuit.

plate voltage of the transmitter-receiver tube from the grid of the first pentode, but charges and discharges as the voltage across the oscillator load resistor varies. This charging current flows through the grid resistor of the first pentode, and thus impresses an alternating potential on the first pentode grid.

The varying potential on the first pentode grid causes a variation in the plate current of the first pentode. This in turn causes a proportional variation in the voltage drop across the first pentode plate resistor. The varying voltage drop, which is greater than that in the output of the transmitter-receiver, is in turn applied through a blocking condenser and grid-return resistor to the grid of the second pentode, and a similar amplified signal appears across its plate resistor. It is this signal which appears at the output of the amplifier and which operates the firing circuit and the wave suppression circuit.

In the pentodes, there are two grids in addition to the one to which the signal is applied. One of these shields the plate from the filament and therefore makes the plate current independent of the plate voltage. It is called the "screen" and is held at a positive voltage with respect to the filament. The other, called a "suppressor", is held at the same potential as the filament by a connection inside the tube. Its purpose is to prevent current flow from the plate to the screen in those instances in which the screen is more positive than the plate. The screen is connected to the positive side of the "B" battery through a screen resistor and is bypassed to ground by a condenser.

By a proper selection of values for screen and plate bypass condensers, the amplifier is made sensitive to a band of frequencies and insensitive to others. The frequency of a target signal lies between two extremes: that frequency generated when a projectile traveling at its maximum speed approaches a plane coming toward it at its maximum speed, and that frequency generated when a projectile traveling at its minimum speed approaches a plane going away from it at its maximum speed. The amplifier is made sensitive to these frequencies, and insensitive to others. Figure 23 shows how amplification varies with

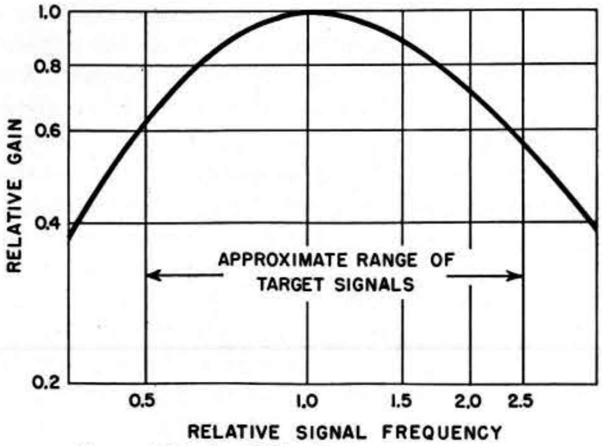


Figure 23. Amplifier frequency-response characteristics.

frequency. The limitation upon the frequencies that are amplified modifies, in effect, the standard radiation pattern of figure 17 to produce the effective sensitivity pattern of figure 18.

The amplifier is made less sensitive to relatively low frequencies by the screen bypass condenser, while a similar function is performed by the plate bypass condenser for relatively high frequencies.

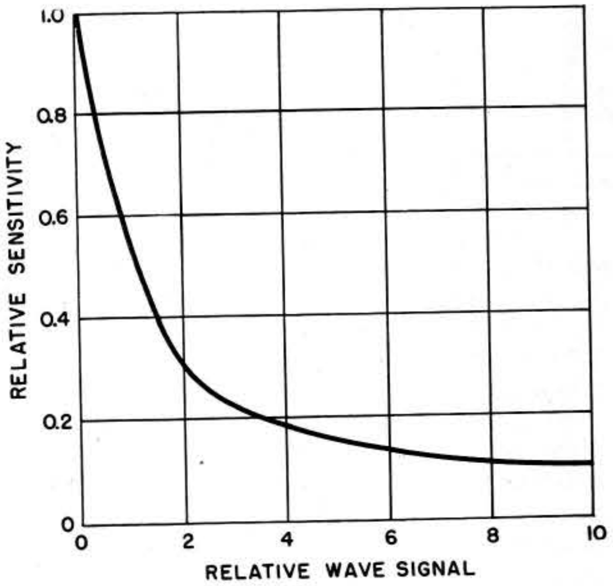


Figure 24. Wave-suppression-feature sensitivity curve.

When a relatively low frequency is impressed on the grid of the pentode, as the grid voltage increases the bypass condenser does not prevent the screen current (and hence, also, the screen voltage) from increasing. This is at the expense of the plate current and decreases the amplification of the applied signal. However, when a higher frequency is impressed on the grid, the screen is held at a substantially constant voltage because the bypass condenser cannot charge and discharge quickly enough to allow a corresponding variation in screen voltage. Thus the amplification of the signal is not affected.

In performing the complementary function, the plate bypass condenser decreases the amount by which relatively high frequency signals are amplified. Lower frequency changes are unaffected, and the amplified signal can produce its equivalent output voltage.

Wave-Suppression-Feature Circuit

As is pointed out above, the amplitude of a target signal increases rapidly as the projectile approaches. In contrast, other signals, such as those resulting when a projectile passes over ocean waves, have a nearly constant average amplitude. They are sometimes large enough so that the fuze would be operated by them, except for a wave-suppression circuit which decreases the sensitivity of the amplifier in the presence of steady signals. The curve in figure 24 shows how amplifier sensitivity is decreased as strength of signals increases.

A schematic diagram of the wave-suppression feature circuit is shown in figure 25. The output from the amplifier is applied through a blocking condenser and a load resistor to the plate of the diode tube in the wave-suppression-feature circuit. When the signal is positive, the diode draws current, and the resultant drop in the load resistor prevents the diode plate from becoming very positive; but when the signal is negative, no current flows in the diode, and the plate goes as far negative as does the amplifier output signal. The **average** rectified d-c voltage on the plate is therefore negative by an amount proportional to the amplifier output.

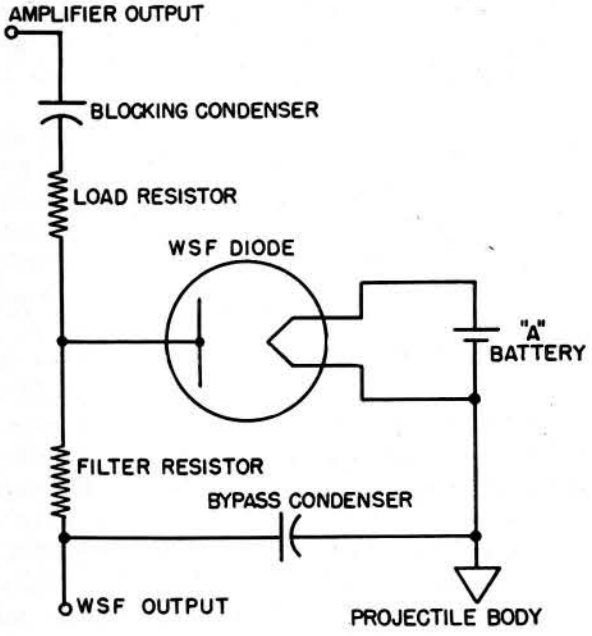


Figure 25. Schematic diagram of wave-suppression-feature (WSF) circuit.

This average d-c voltage is filtered by a filter resistor and bypass condenser and applied to the grid of the first amplifier pentode. This pentode is so designed that its amplification decreases with increasing negative voltage on the grid.

The filter resistor and bypass condenser cannot follow the rapid increase in signal amplitude as the target is approached, so that the target signal gets through the amplifier and operates the firing circuit before the wave-suppression voltage builds up. This assumes that the fuze is armed while over waves or that it approaches the waves gradually, as at the end of flight. In a sudden appearance of waves after the fuze is armed, the signal from the waves may get through and operate the firing circuit. A signal of constant amplitude, however, does not give sufficient output to operate the firing circuit, no matter how great its value.

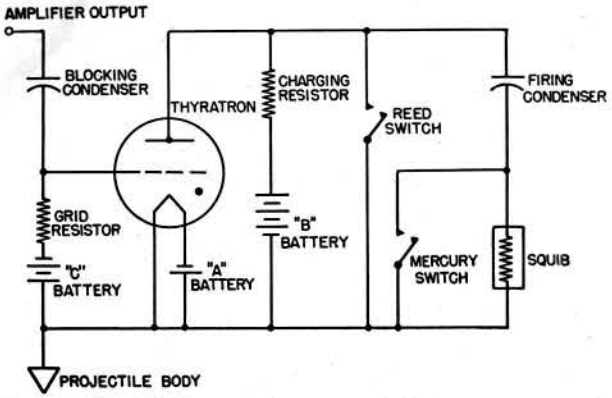


Figure 26. Schematic diagram of firing circuit, with safety switches.

Firing Circuit

Figure 26 is a schematic diagram of the firing circuit. When the round is fired, current flows from the "B" battery, through the charging resistor, into the firing condenser. This condenser provides a means of storing electrical energy which can be rapidly expended, when called upon, to fire the squib.

The rate at which energy accumulates in the condenser is limited by the charging resistor. Before the electrical arming time has passed, there is insufficient energy in the condenser to operate the squib; but after arming there is an excess of energy to insure reliable operation. This is shown by the curve in figure 27.

The thyratron is an electronic switch which discharges the condenser through the squib when the projectile is near a target. It is a triode radio tube with a small amount of argon gas in the bulb. The grid of this tube is normally maintained at a negative voltage with respect to the filament by a "C" or grid battery, shown in the circuit diagram of figure 26. This negative voltage prevents any current flow in the tube.

When a target signal is present in the output of the amplifier, however, the blocking condenser shown in the grid circuit of the thyratron charges and discharges with the signal through the grid resistor. The charging current, flowing through this resistor, causes the grid end of it to be alternately positive and negative with respect to the negative "C" voltage. A signal of sufficient amplitude will eventually swing sufficiently positive to overcome the control supplied by the negative voltage of the "C" battery, and current can flow in the thyratron.

As soon as current starts to flow, the argon gas in the thyratron is ionized, and a heavy current flow, carried by the argon ions, can take place between the thyratron plate and its filament. This current flow, which is now independent of the voltage on the grid, is so heavy that the thyratron plate is effectively shorted to the filament, and the firing condenser rapidly discharges through the thyratron and squib. The squib is exploded by the surge of current.

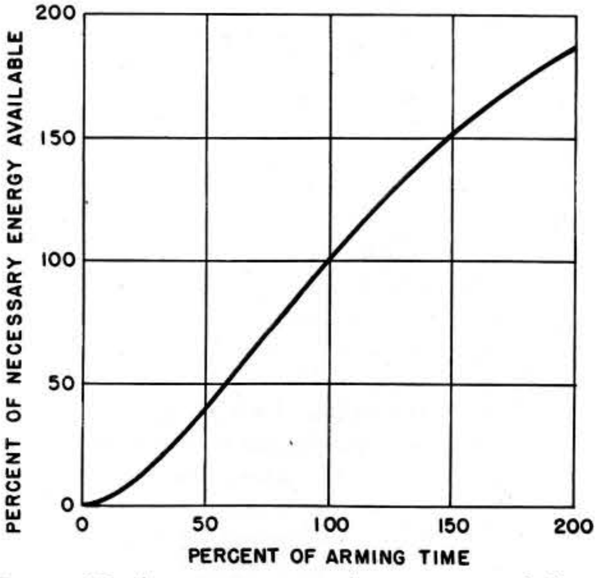


Figure 27. Average arming characteristics of firing condenser.

Appendix A

SAFETY FEATURES, HANDLING, AND PRECAUTIONS

This chapter is a summary of the safety features of VT fuzes and precautions to be observed in handling, stowing, and using the fuzes.

Safety Features

Energizer. The energizer remains inert until the ampoule is broken as a result of setback forces and the electrolyte distributed by spin forces imparted when the projectile is fired from the gun.

Charging Resistor. The charging resistor slows up the charging of the firing condensor until the projectile has traveled several hundred yards from the muzzle of the firing gun.

Reed Switch. A small reed-type spin switch provides a short circuit across the firing condensor which prevents the firing condensor from becoming charged in case of breakage of the ampoule previous to firing. The switch is opened by spin forces imparted to the projectile and the fuze when fired. Hence this switch is a handling safety device.

Mercury Switch. The mercury switch (two switches in parallel in some fuzes such as Mk 53) shorts out the firing squib until the switch is opened by centrifugal force imparted when the projectile is fired.

Auxiliary Detonating Fuze. In the auxiliary detonator, safety is provided by the fact that two rotors must be in line before the booster charge can be fired. The rotors are held out of line by detents until freed by centrifugal force when the projectile is fired. See OP 1212, Projectile Fuzes.

Arming Range. The distance the projectile travels along its trajectory until it becomes electrically operative is called the arming range. In different fuzes this distance varies from 500 yards to 1500 yards (1800 to 3300 yards for Rocket Fuze Mk 173). This allows the projectile to reach a safe distance from the firing ship before it can explode, without danger to the firing ship or its personnel.

Handling Precautions

VT fuzes should be given the same care in handling that is ordinarily given to all ammunition. Direct blows on the nose may result in breakage of the plastic nose, but have no effect on the safety of the fuze.

The ampoule of electrolyte in the energizer may be broken by more than a two-foot drop on armor plate. Breakage of the ampoule does not impair the safety of the fuze, and ordinarily no ill effects result if it is broken in the loading tray within 30 seconds of being fired. A dud will usually result, however, if the electrolyte enters the energizer more than 30 seconds before the round is fired.

Stowage

Deterioration of the VT fuze leads to a decrease in operability. Present models of fuzes, if exposed to spray, water, high humidity, and high temperatures will deteriorate. Constant effort is being directed toward the development of a completely moisture-proof fuze. They are designed to withstand temperatures from 0° F. to 120° F. Best stowage is in a cool, dry magazine. Brass waterproofing caps on some early issues of 5″/38 rounds provided protection against moisture and spray. They were not removed until it was necessary for firing.

Loading

VT fuzed five-inch projectiles should be passed through the ammunition hoists in the usual manner. Early fuzes were subject to occasional nose breakage upon removal from the hoists in the mount. Breakage of this type is seldom encountered with modern fuzes. Accomplishment of NAVORD ORDALT 1788 on the fuze pot, or setting of the fuze setter in manual at "safe" or 30 seconds, greatly minimizes the likelihood of nose breakage. The fixed setting can be employed only when 100% VT fuzes are being employed in any particular mount. Ships with open mounts and multiple fuze pots alongside the gun need not pass VT fuzed rounds through the fuze pot operation unless it is desired to do so in the interest of uniform handling procedure.

Mk 58 fuzed 3″/50 projectiles must not be used with any knife-type fuze setter which will cut or crack the plastic nose.

Disposal of Damaged Fuzes

Damaged fuzes shall be disposed of by dropping the fuzed projectiles over the side in deep water in accordance with latest instruction for disposal of ammunition. No VT fuze shall be disassembled or in any manner broken down for inspection by any but authorized representatives of the Bureau of Ordnance.

Disposal of Fired Duds

Fired duds lying on the ground are to be given the circumspection accorded to land mines. A VT fuze in the ground or lying on the ground is very unlikely to operate by influence even if undamaged, but an occasional one will detonate if disturbed. Almost all wet energizer fuzes are inoperative within a few minutes after being fired, and all such fuzes are entirely inert within a week.

Old fuzes with dry energizers remain dangerous if disturbed, for indefinite periods. Recovered Fuzes Mk 32 have been known to detonate as long as one year after being fired, even though the nose was smashed.

All such duds should be disposed of by competent bomb disposal personnel.

Degaussing and Deperming

VT ammunition need not be removed from a ship during degaussing, deperming, etc. These operations have no effect on the fuze.

Shipboard Radio and Radar

The frequency of VT fuzes is selected so that shipboard radio and radar equipment should have no effect on the operation or safety of U. S. Navy VT fuzes.

Firing Precautions

VT fuzes are subject to some prematuring after arming. These prematures and influence bursts of projectiles falling among friendly ships, personnel, or equipment present a hazard in VT fuzed fire. In shore bombardment, fire should clear crests by 500 feet if occupied by friendly troops, because of the danger of an influence burst.

In 5″/51 guns it was necessary to fire Fuzes Mk 32 and Mk 53 Mod 0 at a reduced charge of 2600 f/s. Mk 53 Mods 1–6 may be fired at full charge. Bombardment velocity of 1200 f/s is not satisfactory with any VT fuzes yet in production. Full charge should be used.

Appendix B

REFERENCE DATA

Table 1 contains pertinent data on VT fuzes for ready reference. The arming ranges given in the table are the distances from the gun at which 90% of all operable fuzes are fully armed and operative against a target. There is some spread of arming range among different fuzes, due to fluctuations in characteristics of components under mass-production conditions. For example, about 40% of the VT fuzes Mk 53 Mod 3 are armed by 400 yards; about 90% by 500 yards; a negligible number are armed at 300 yards.

TABLE 1. U. S. NAVY VT FUZES FOR PROJECTILES AND SPIN-STABILIZED ROCKETS

Fuze	Guns	Average Radius of Operation Against An Airplane (Ft.)	Arming Range (90%) (Yds.)	Type of Energizer	Used with Aux. Det.	Remarks
			Current Models			
Mk 47 Mod 0	6″/47 Projectile Mk 34.	75	800	Reserve	Mk 44	WSF CTW
Mk 53 Mods 5, 6	5″/38, 5″/25, 5″/51	75	500	Reserve	Mk 44	WSF CTW
Mk 58 Mods 3, 4	3″/50	50	600	Reserve	Mk 44	WSF CTW
Mk 59 Mod 0	5″/54	75	600	Reserve	Mk 44	WSF CTW
Mk 69 Mod 0	6″/47 Mk 39 Proj. for Double Purpose gun.	75	800	Reserve	Mk 44	WSF CTW Production scheduled for July 1946.
Mk 173 Mod 4	5.0-in. Rocket, Surface, High Capacity, Spin-Stabilized.	Not recommended for A. A. use. 75 ft. over water; 30–50 ft. over land.	3,300	Reserve	Mk 44	WSF CTW
			Obsolete and Obsolescent Models			
Mk 32 Mods 0–20	5″/38, 5″/25, 5″/51*	50	700	Dry	Mk 17, 46, or 54	Obsolete
Mk 32 Mod 30	5″/38, 5″/25	50	1,100	Reserve	Mk 17, 46, or 54	Obsolete
Mk 32 Mod 40	5″/38, 5″/25, 5″/51*	60	700	Dry	Mk 17, 46, or 54	WSF, Obsolete
Mk 40 Mods 0–5	5″/38, 5″/25	70	900 to 700 for different mods.	Reserve	Mk 17, 46, or 54	WSF, Obsolete
Mk 45, Mods 11, 12	3″/50	50	600	Reserve	Mk 44	Obsolete
Mk 53 Mods 0–2	5″/38, 5″/25, 5″/51*	75	800	Reserve	Mk 44	WSF, Obsolete
Mk 53 Mods 3, 4	5″/38, 5″/25, 5″/51	75	500	Reserve	Mk 44	WSF, Obsolete
Mk 58 Mods 0–2	3″/50	50	600	Reserve	Mk 44	WSF, Obsolete
Mk 173 Mod 0–2	5.0-in. Rocket, Surface, High Capacity, Spin-Stabilized.	Not recommended for A. A. use. 75 ft. over water; 30–50 ft. over land.	3,300	Reserve	Mk 44	WSF, Obsolete

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*Mk 32 all Mods except Mod 30, and Mk 53 Mod 0 were recommended for use in 5″/51 guns at reduced charge of 2600 f/s. All other Mk 53 may be fired at full charge.

WSF = Wave-Suppression Feature.
CTW = Compression-Type Waterproofing.

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