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Volume 1

Design and Development History of U.S. Aircraft Bombs With Applications for Development of Advanced Bomb Systems

Volume 1. Sections 1, 2, and 3

by
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Comarco, Inc.
for the
Advanced Bomb Project Office
Attack Weapons Department

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FOREWORD

The purpose of this report, published in two volumes, is twofold: initially to provide historical data on the evolution of Aircraft Bombs developed by the U.S. Army and Navy, and secondly to document the results of more recent efforts of the Naval Weapons Center (NWC) and other Air Force/Naval Field Activities to improve the operational, logistic, and safety characteristics of the current Mk 80 Series General-Purpose Bombs. The final section of the report covers design improvements, new developments, testing, and evaluations that have a direct bearing on the future development of the Advanced Bomb Family. This report also documents those research and development (R&D) activities sponsored by the Government that relate to the Advanced Bomb Family requirements. It is intended to ensure that technical personnel in government and industry will benefit from past government-sponsored R&D efforts.

This document is Volume 1 which consists of Sections 1, 2, and 3. Because of classification, Section 4 is published under separate cover as Volume 2.

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This report, published in two volumes to facilitate its usage, summarizes the evolution of U.S. aircraft bombs and presents a history of technological efforts, bombs designs and systems developed for the U.S. Navy. This document, Volume 1, includes the evolution of aircraft bombs developed by the U.S. Army and Navy from 1917 through World War II and investigative and development efforts to improve the operational, logistic, and safety characteristics of the Mk 80 series general-purpose bombs that have been in the inventory since the mid 1950s. Volume 2, published under separate cover because of classification, covers design improvements, new developments, testing, and evaluation sponsored by the U.S. Government, that will have a direct bearing on future advanced bomb development efforts.

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ACRONYMS

(For convenience of the reader, this list includes all acronyms from both Volumes 1 and 2.)

ABF	Advanced Bomb Family
AFFCS	Advanced fuze function control set
AGE	Auxiliary ground equipment
AGPB	Advanced General-Purpose Bomb
AIR	Air Inflatable Retarders
ALP	Approval for limited production
AM	Amatol (explosive)
AMRAD	Air Munitions Requirements and Development
AMW	Advanced modular weapons
AOAO	Active-optical-amplitude only
AP	Armor piercing
APAM	Antipersonnel/antimaterial (cluster weapon)
ASN,R&D	Assistant Secretary of Navy for Research and Development
BLU	Bomb Live Unit
BuOrd	Bureau of Ordnance
BuWeps	Bureau of Naval Weapons
CASS	Carrier Aircraft Support Study
CBU	Cluster Bomb Unit
CEP	Circular error probability
CF	Controlled fragmentation
CNO	Chief of Naval Operations
COMOPTEVFOR	Commander, Operational Test and Evaluation Force
DB	Depth bomb
DEMVAL	Demonstration and evaluation
DMOS	Dual Mode Ordnance System
DST	Destructors
DT&E	Development, test, and evaluation
EB	Electron-beam (welding)
ECP	Engineering change proposal
ESR	Electroslag refining
FAE	Fuel-air explosives
FCA	Flux-cored arc (welding)
FFC	Fuze function control
FOT&E	Fleet operational test and evaluation
FRAG	Fragmentation

GAC	Goodyear Aerospace Corporation
GMA	Gas-metal arc (welding)
GP	General purpose
GPHE	General-purpose high explosive (bombs)
GTA	Gas-tungsten arc (welding)
HBX	High blast explosive
HE	High explosive
HERO	Hazards of Electromagnetic Radiation to Ordnance
IHE	Insensitive high explosives
IMCO	Intercontinental Manufacturing Co.
ISR	Inflatable stabilizer/retarder
JMC	Joint Munitions Committee
JMEM	Joint Munitions Effectiveness Manual
KCAS	Knots calibrated air speed
KIAS	Knots indicated air speed
KTAS	Knots true air speed
LDGP	Low-drag general purpose
MCAAP	McAlester Army Ammunition Plant
MHTP	Moderate Hard Target Penetrator
MIG	Metal inert gas
NACA	National Advisory Committee for Aeronautics
NAD	Naval Ammunition Depot
NAVAIR	Naval Air Systems Command
NAVORD	Naval Ordnance Systems Command
NMC	Naval Missile Center
NOL	Naval Ordnance Laboratory, White Oak
NOTS	Naval Ordnance Test Station, China Lake, Calif. (pre-NWC)
NSRDC	Naval Ship Research and Development Center
NSWC/D	Naval Surface Warfare Center, Dahlgren
NSWC/WO	Naval Surface Warfare Center, White Oak
NWC	Naval Weapons Center, China Lake, Calif.
NWL	Naval Weapons Laboratory, Dahlgren, Va.
NWS	Naval Weapons Station
OD	Outside diameter
OPEVAL	Operational evaluation
OSD	Office of Secretary of Defense
PBX	Plastic-bonded explosive
POL	Petroleum, oil, and lubricant
PTA	Proposed Technical Approach
PWP	Plasticized white phosphorus
QSM	Quick-strike mine
R&D	Research and development
RASS	Remotely activated stores system

SAP	Semiarmor piercing
SMAW	Shielded metal arc welding
SMCA	Single Manager for Conventional Ammunition
SWM	Shallow-water mine
TAAS	Tactical Air Armament Studies
TAS	True air speed
TDD	Target detecting device
TEMP	Test and Evaluation Master Plan
TER	Triple ejection rack
TIG	Tungsten inert gas
V/STOL	Vertical/short takeoff and landing
VER	Vertical ejector rack
VT	Variable time
WASP	Weapon/Aircraft/Ship/People (Study)
WP	White phosphorus
WSESRB	Weapon System Explosive Safety Review Board

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Section 1. INTRODUCTION

This report summarizes the evolution of U.S. aircraft bombs in general, and presents, more specifically, a history of the technological efforts, bomb designs and systems developed for the U.S. Navy. It also includes an account of the investigative efforts directed previously by the Bureau of Naval Weapons and more recently by the Naval Air Systems Command to improve the Mk 80 series General-Purpose (GP) Bombs that have been in the inventory since the mid-1950s. The goals of the technological efforts were to provide near-term, cost-effective solutions to inherent performance, safety and logistic deficiencies and limitations of the low-drag Mk 80 series GP bombs.

The studies and conceptual hardware tests and evaluation efforts, conducted during the late 1960s through the mid-to-late 1980s, led to numerous warhead, fuze system, stabilizer/retarder, and explosive-fill improvement and development programs.

The intent of this report is to provide (1) a brief discussion of past U.S. Navy bomb designs and system development efforts leading to the present Mk 80 series GP bombs; (2) data for future program managers, project engineers, and weapon designers assigned responsibilities for improvement or development programs of advanced free-fall general-purpose or "dedicated" bomb systems; and (3) the rationale for technical decisions made and methods employed to achieve program goals and objectives relative to improvements to the Mk 80 series GP bombs by the NWC Bomb Development Branch from 1969 to 1987.

It is hoped that an understanding of the technical approaches taken and the results obtained will be useful to future weapon developers, at least to consider applying those methods/principals that have proven successful in the past and to be aware of the difficulties previously encountered and profit from "lessons learned".

To facilitate usage of this report, it has been divided into two volumes: Volume 1, consisting of Sections 1, 2, and 3, and Volume 2, consisting of Section 4 which is published under separate cover because of classification.

Section 2. AIRCRAFT BOMB DESCRIPTION

This section describes aircraft bombs from a historical perspective, providing generalized comments on bomb components, descriptions, functions, characteristics, types, and requirements. Included is a brief summary of the various bomb types that are representative of those previously (obsolete) and currently used.

GENERAL

The aircraft bomb is a type of ammunition which is designed to be dropped from aircraft in flight. Normally, bombs dropped in combat are intended to inflict damage on the enemy. In some cases, bombs are dropped to afford screening from enemy observation, to harass the enemy, or to provide target area illumination, including that for photographic reconnaissance operations. Practice bombs of various types and sizes are used to perfect bombing techniques. Since bombs are primarily aircraft weapons, their development is intimately linked with that of the airplane. The airplane made its first significant debut during World War I, and the planes of both sides were soon armed in one form or another. Small aerial bombs were initially used by both sides. They were dropped from planes by pilots or observers and were more effective from a morale standpoint than in terms of casualties produced or damage inflicted to enemy installations. Bombs and bombing came into universal strategic prominence during World War II. A large variety of bomb types was developed and special aircraft for their use came into being. Bombs that were used ranged in size from a few pounds to several tons. Developments included better methods of tracking, sighting, and computing. These improvements, plus the improvement of the weapons themselves and their fuzing systems, made bombing effective from both low and high altitudes and under adverse conditions of visibility. With the advent of high-speed aircraft, radar, and modern weapon technology, aircraft bombs became complex weapons of great power and wide versatility.

PRINCIPLES AND FUNCTIONS

Bombs are designed to be carried by aircraft and reach their targets by a ballistic trajectory, which is controlled by the altitude and speed of the aircraft at the time of bomb release, by the weight and shape of the bomb, and by the effects of barometric pressures

and air currents. Means of modifying the trajectory by variable glide systems or rocket assist may sometimes be employed.

Bombs are designed to achieve their desired effect through explosive, incendiary, chemical, or pyrotechnic means at some predetermined point in its flight path, after release from the aircraft. Initiation of the effect may be brought about by means of a proximity or airburst sensor, impact with a target, time after impact (delay), an external pressure change, or some act by the enemy after impact.

CHARACTERISTICS AND REQUIREMENTS

Bombs usually consist of (1) a metal container filled with explosives or chemicals, (2) a device for stabilizing it in flight so that it can be aimed accurately, (3) a mechanism for exploding the bomb at the target, and (4) such safety devices as may be necessary to make it reasonably safe to handle, carry, and drop. In the earlier bombs, the metal container—called the bomb body—usually was streamlined, with a rounded ogival nose and a tapered tail. A stabilizing device was attached to the tail end of the body and generally consisted of a sheet-metal fin assembly. The bomb body contained the payload of the bomb, which was either explosive, incendiary, chemical, pyrotechnic, or a combination of these. To initiate the payload, a fuze was generally placed in the nose or in the tail end of the body. Two or more fuzes were sometimes used in the same bomb to increase the functioning reliability. Safety devices were provided in the fuze and were protected by sealing wires and cotter pins during shipment and storage prior to use. An arming wire was substituted for the sealing wire and/or cotter pin when the bomb was readied for use.

Classification of Bombs

Bombs are classified by their filler, intended use, and overall weight class as follows:

1. Filler: explosive, chemical, incendiary, pyrotechnic, or inert

2. Intended use: armor piercing (AP), general purpose (GP), fragmentation (FRAG), depth bomb (DB), semiarmor piercing (SAP), gas, smoke, incendiary, photoflash, target identification, leaflet, practice, and dummy

3. Overall weight class: 5, 20, 100, 250, 325, 500, 650, 1000, 1600, 2000, 3000 lb, etc.

These classifications are frequently combined to describe a bomb in more detail; for example, a 500-lb high-explosive (HE) loaded, GP bomb.

Identification of Bombs

Bombs were identified in accordance with NAVORD OP 2238 (NAVAIR II-1-117) *Identification of Ammunition.* Currently, bombs are identified in accordance with NAVAIR 11-5A-17, dated 15 February 1980, Change 3 as of 15 October 1987 (Reference 1). The Army used the model designation which consisted of the letter "M" followed by an Arabic numeral. Modifications to the original design were indicated by the addition of the letter "A" and the appropriate Arabic numeral to the model designation; for example, M38A2 designated the second modification of the item originally adopted as M38. The Navy used the term "Mark", expressed as "Mk", to designate a basic item, followed by one or more Arabic numerals to indicate the number of the Mk. When a basic item was modified, a modification indicator, expressed as "Mod", was used, followed by the modification number. When the Army and Navy standardized a basic item, its original model or Mk was preceded by the letters AN- followed by either the Army M designation or the Navy Mk designation, depending on which service originally designed the item.

The Air Force and Navy currently use a three-letter designator which indicates the type and purpose; for example, "CBU" is the designation for Cluster Bomb Unit, or "BLU" for Bomb Live Unit. This is followed by a dash and a series of Arabic numerals indicating the model and capital letters indicating any modifications; for example, 7A is the seventh model and first modification. This is followed by a slash and a capital letter indicating the installation designator; for example, the letter "A" following the slash indicates an aircraft-installed item which may or may not be expended on a mission. The letter "B" indicates an aircraft-installed item which normally would be expended on the mission. BLU-7A/B would thus read "Bomb Live Unit, Model 7, Modification 1, aircraft-installed, should be expended on mission."

Components of a Complete Round

A complete round (bomb) consists of all the components and accessories necessary for the ammunition (bomb) to function in the manner intended. To facilitate safe handling of the bomb, sensitive or fragile components are packed separately and assembled to the bomb prior to its use. Figure 2-1 illustrates the major elements of a complete bomb round. The components of a typical bomb round are as follows:

Bomb Body. The body or warhead is a container that holds an explosive, chemical, or inert filler. It may consist of a single piece of metal or several pieces welded or otherwise joined together.

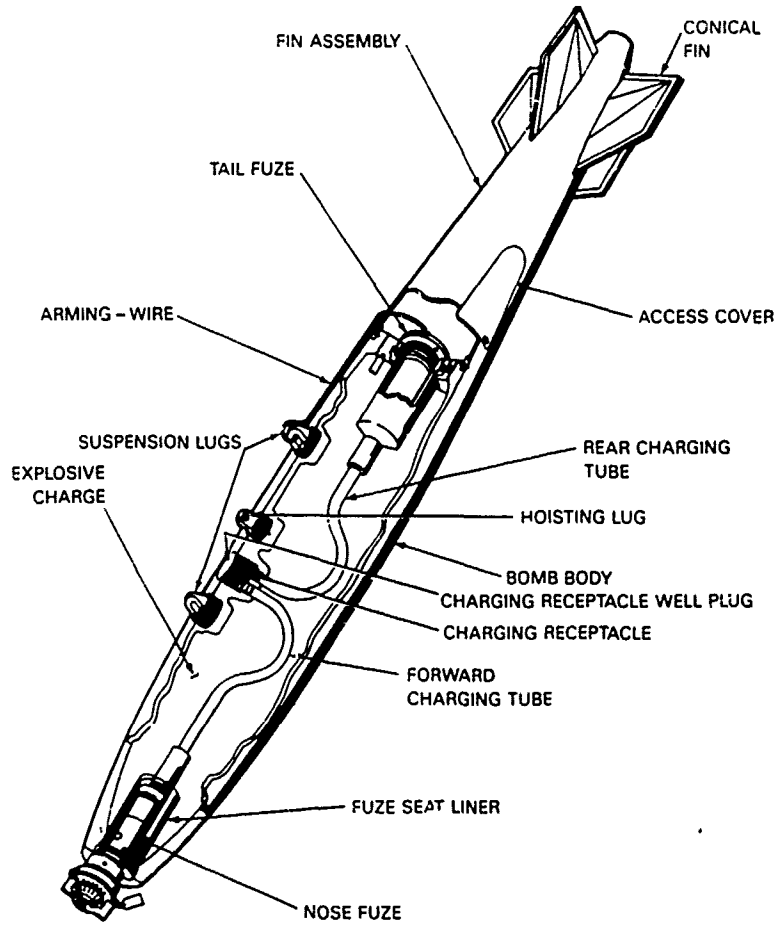


FIGURE 2-1. Typical Low-Drag General-Purpose Bomb, Sectional View.

Fin Assembly. There are three basic types of fin assemblies that have been used with bombs: box, conical or streamlined, and retarding. The box type consisted of a fin sleeve which fit over the bomb tail, and sheet-metal blades which were joined to the fin sleeve or to each other to form a box-like assembly. These ceased to be used since shortly after World War II. The conical or streamlined-type fin assembly consists of a conical-shaped body with metal blades joined to the body to give a streamlined configuration. The retarding-type fin assembly consists of streamlined folded blades that open in an umbrella-like fashion, or a parachute, or a ram-air-inflated form to impart high drag.

Fuze. Fuzes are mechanical, electrical, or chemical devices used to initiate bombs under the circumstances desired.

Arming-Vane Assembly. An arming-vane assembly is a small propeller device of sheet metal blades, which is attached to certain types of fuzes. Arming vanes differ in pitch, shape, and length of blade.

Arming-Wire Assembly. Arming-wire assemblies generally consist of one or two strands of wire attached to a swivel loop.

Functioning of a Complete Round

Bombs are carried either internally or externally on single- or multiple-bomb racks, whichever is applicable to the particular aircraft. Hooks engage the suspension lugs attached to the bomb body. Arming wires may be attached in several different ways, depending on the particular aircraft and method of carriage. These wires are passed through holes or eyelets in the fuze, maintaining it in an unarmed condition until the bomb is dropped. Fahnestock (safety) retaining clips were placed over the protruding ends of the arming wires to prevent the wires from slipping out of the safety devices of the fuze prior to bomb release. Currently, Dexter clips have replaced the Fahnestock clips. If a bomb had to be released over friendly territory, the arming wire, or the swivel loop of the arming wire, was released with the bomb and stayed in place as the bomb fell, thus preventing the fuze from arming. When the bomb was released to arm, the arming wire, or the arming wire swivel loop (depending on the configuration used), was retained with the aircraft. As the bomb dropped, the wire was pulled from the fuze which then was free to arm. The armed bomb then detonated at the predetermined time to fulfill the mission requirements.

BOMB COMPONENTS AND ACCESSORIES

Components of the Bomb Body

The bomb body is composed of the case, the explosive charge, adapter-boosters, auxiliary boosters, base plugs, closing plugs, and fuze seat liners.

Case. The case is normally a cylindrical steel body with an ogival nose and usually a tapered after- or tail-end. There is normally a threaded cavity in the nose, fitted with a fuze seat liner, into which the nose fuze is screwed when the bomb is made ready. A shipping plug is installed in the nose fuze cavity until the bomb is ready to fuze. The rear end of the case normally is internally threaded to receive the base plug which is also threaded and fitted with a fuze liner, into which a tail fuze can be assembled when the bomb is readied.

The cylindrical section of the bomb case is fitted externally with either the suspension and lifting lugs, or trunnions, or the threaded pads by which the bomb is attached to the bomb rack.

Base Plug. The base plug closes the filling hole of the bomb case and forms the base. The plug usually contains an adapter booster into which a tail fuze may be installed, and may be provided with some means for attachment of the stabilization/retardation system.

Payload of the Bomb. The empty case is filled with the material that forms the payload of the bomb. This may be high explosive, incendiary mixtures, chemicals, or pyrotechnic mixtures. The specific types of loadings will be discussed under the individual bombs in later paragraphs.

Closing Plugs. During shipping and storage, the openings to the fuze cavities are closed by metal or plastic plugs. These plugs serve to protect the fuze seat cavity and threads.

Fuze Seat Liner. The fuze seat liner is a metal cup that is assembled inside the nose, tail, or in some cases amidship or athwartship position of the bomb to keep a cavity clear for the installation of a nose, tail, or athwartship fuze.

Fin Assembly or Stabilization/Retardation Systems. These assemblies or systems may be fins, parachutes, ram-air inflated form, or drogue-type units attached to the base plate or contained within the after portion of the bomb case.

Explosive Components

There are various explosive components, other than the main charge, that are associated with bombs. These explosive components are described below.

Fuzes. Fuzes are major components of prime concern, that are discussed in detail later in this Section (see page 22).

Adapter-Boosters. An adapter-booster is a bushing with an assembled booster, which is threaded externally for assembly to the bomb body or base plug and threaded internally to receive a fuze. Adapter-boosters, normally assembled in high-explosive or chemical bombs, were drilled for the insertion of lock pins which prevented their removal when antiwithdrawal fuzes were assembled to the bomb. Since most general-purpose bombs accommodate large-diameter nose fuzes, a nose fuze adapter-booster is issued separately to adapt these bombs for use with small-diameter fuzes. New series low-drag

general-purpose (LDGP) bombs, developed for both mechanical and electrical fuzing, require nose and tail adapter-boosters when mechanical fuzes are installed. Adapter-boosters usually contain tetryl or tetryl-type explosive materials.

Auxiliary Booster. Auxiliary boosters consist of a column of boosting type explosive, usually grade-A granular TNT (housed in a suitable container) that acts to relay and amplify detonating waves to insure the explosion of the main charge. Auxiliary boosters may be cast within the main charge of the bomb adjacent to the fuze seat liner or the adapter-booster, or they may be issued separately for installation in fuze seat liners. Some of the large HE bombs require two auxiliary boosters to complete the explosive train between the fuze and the main charge of the bomb.

Primer-Detonators. A primer-detonator is a unit consisting of a primer and a detonator. Primer-detonators are interchangeable screw-in percussion- or stab-type explosive devices. A delay element between the primer and the detonator is present in some units, and when so equipped, the delay element is used to provide a selection of nondelay or various delays in some models of bomb tail fuzes. The exact delay time of each is usually indicated on the detonator face. Typical times are nondelay, 0.01, 0.025, 0.10, 0.24, 4 to 5, and 8 to 15 seconds delay.

Delay Elements. Small individual insert elements provide the delay element for the explosive train of certain bomb fuzes. The appropriate delay is selected and inserted into the bomb to adapt the fuze to a particular mission requirement prior to installing the fuze into the bomb.

Bursters. A burster is an explosive charge designed to rupture a bomb body to release the filler. Bursters are used in cluster bombs to open the cluster and allow the bomblets to fall free. The burster consists of a long plastic, paper, metal, or chipboard tube closed at both ends. The tube is filled with TNT, black powder and magnesium, tetryl pellets, or other explosive and non-explosive material. When the burster is installed in the bomb, it fits into either the burster well or the igniter cavity.

Igniters. Igniters are explosive incendiary devices for activating the fillers of incendiary and fire bombs. Igniters vary considerably in their shape and methods of operation. A representative igniter contains a main charge of white phosphorus (for land bombing) or sodium (for water bombing), an explosive burster, and some type of fuze.

Signals. Signals are for use with practice bombs and are of several general types: those that resemble a 10-gage shotgun shell, older versions that consisted of a fuzed container of black powder which were attached to practice bombs and operated on impact, and those that contain chemicals (liquid) that when, upon impact, mixed with air and generated white smoke. Some signals contain colored dyes.

Spotting Charge. One such item was available for a 250-lb practice bomb. The charge consisted of 10.2 lb of 80% black powder and 20% flaked aluminum powder in a cylindrical terne-plate case. The igniter of the spotting charge was a detonating cord assembly containing PETN, which connected the charge to the fuze and acted as an explosive relay between the charge and the fuze.

Miscellaneous Details

There are a variety of minor details of assemblies and small parts required to complete the bomb assembly and to adapt the bomb and its components, as required, to meet approved bomb assembly specifications.

Arming-Wire Assemblies. These are attached to the aircraft and provide the means by which the bomb fuzes are maintained safe during flight. Arming wires are provided in single- or double-wire lengths to fit bombs of all sizes, from 5- to 3000-lb or larger classes.

Arming-Vane Assemblies. These are the air-driven propeller-type vanes which rotate to arm the majority of mechanical bomb fuzes in service use. Arming vanes are normally issued as part of the fuze assembly. However, in certain cases different vanes were used with a particular series of bombs and were separate issue items.

Stabilizing Components. These components consist of the various box- and conical-type fin assemblies with their various lock nuts and coupling tube assemblies as previously discussed. In addition, special types of conical fins have been developed for use with certain chemical clusters. Also available are retarding-fin assemblies that open out like an umbrella or a parachute or a pear-shaped ram-air inflated form, on release from an aircraft, to provide a high-drag bomb trajectory. A low-drag release can be achieved with these latter stabilizer/retarder tail assemblies by the pilot electing not to energize a specific rack solenoid that would pull the lanyard/arming wire that functions the retarding device.

Brace Kits. Brace kits were provided to reinforce regular bomb fins when the bomb was to be carried externally on high-speed aircraft.

Drag Plates and Spoiler Rings. These were square metal plates fastened across the end of the bomb fins, and circular pieces secured to the nose, which increased air drag and slowed down the bomb as it fell. When these were provided for use with photoflash bombs they were designated trail kits.

Initiators. Initiators resemble igniters for fire bomb fuzes in appearance, but are really electrical power sources used to fire associated fuzes in certain bombs. They are actuated by the withdrawal of a cap when the bomb falls away, whereupon a thermal battery in the initiator is activated. After a short delay, the thermal battery produces an electrical pulse through an attached cable to actuate the associated fuzes.

Cable Assemblies. Cable assemblies serve to electrically connect the initiator to the fuzes in some types of bombs.

Flexible Shaft and Coupler Drive Assemblies. Flexible shafts with fittings on both ends are used to connect a nonaligned and remote internal fuze to an externally mounted drive assembly in order to transmit rotary motion between the two elements.

Fuze-Arming-Drive Assembly. Vane-rotated devices mounted on the exterior of the bomb are connected by a flexible drive assembly to transmit the rotation of the drive assembly to arm the fuze.

Accessories

Accessories include such things as the bomb's suspension and release hardware, and items necessary to secure bombs in flight, to provide for means of release, and to control fuze arming. These components must be flexible, because the time and conditions under which a pilot must release his bomb load can vary widely. The system must provide the means for jettisoning all bombs in a safe condition as well as releasing them in a variety of modes to arm and function. Bombs are suspended from racks or shackles by suspension lugs and are released by manual or electrical means.

Suspension Lugs. U.S. bomb suspension lugs were of many designs, such as U-shaped eyebolts, brackets, T-lugs, or solid inverted U-shaped lugs. Lugs could be welded directly to the bomb case, secured by cap screws, or fashioned to screw directly into threaded seats provided in the bomb body. The standard system uses two lugs spaced either 14 or 30 inches apart, depending on the bomb size. Where detachable lugs were used, provisions were made for the use of either the 14- or 30-inch lug spacing. Older bombs had a single lug opposite the two lugs, for use with the British single-lug system; this dated from World War II. Lugs must be positioned to plumb the center of gravity and distribute the bomb's weight evenly. Where permanently-attached lugs were used, they were protected by shipping bands that were retained in place until the bomb was prepared for use. Single-suspension lugs are used on small bombs, such as the smaller fragmentation and practice types.

Hoisting Lug. A third lug was the hoisting lug, positioned between the suspension lugs on larger bombs. This lug was secured in the same manner as the suspension lugs, but with its opening at right angles to the longitudinal axis of the bomb. The hoisting lug was used to lift a bomb into position on the bomb rack or shackle in the aircraft.

Bomb Racks. Bomb racks are installed to support the bombs when attached to the aircraft. The racks can be installed on the underside of the wings, the underside of the fuselage, or internally in the bomb bays.

Bomb Shackles. Light portable, flexible bomb suspension devices—or shackles—were suspended in the aircraft and used to attach bombs along the sides of bomb bays, one above the other. When the lower bombs were released, the shackles remained attached in the bomb bay but swung clear of the bomb above, which could then drop clear when released.

BOMB FUZES

A bomb fuze is the device for initiating the explosive fill or initiation train of a bomb at the appropriate time to fulfill mission requirements. The fuze consists of a safety-arming device that prevents the initiation of the warhead in the storage and carriage environments, an environmental sensor to ensure that the fuze cannot arm until intentionally released from the aircraft, and a target-sensing device which usually senses impact with a target.

Fuzes may be positioned in the nose, in the tail, or sometimes transversely or "athwartship" in the bomb body. Figure 2-2 illustrates a typical athwartship fuze.

Classification of Fuzes

Historically, fuzes have been classified by technology used (mechanical or electrical), by their position in the weapon (nose or tail fuzes), by their functioning mode, or a combination of these features. Bomb fuzes generally have been classified as described below.

Mechanical Nose Fuzes. Mechanical nose fuzes probably have the widest usage of any bomb fuze. Arming energy is usually derived from an air-driven rotating vane that, during storage and carriage, is locked in a fixed position by either an arming wire or a safing pin. After release from the aircraft, the vane is unlocked and the free-fall air stream rotates the vane that provides the energy required to operate timing mechanisms and to arm the fuze. These types of fuzes normally function when the weapon impacts the target; however, they also incorporate pyrotechnic delay trains to permit functioning after impact. A typical mechanical impact nose fuze is shown in Figure 2-3.

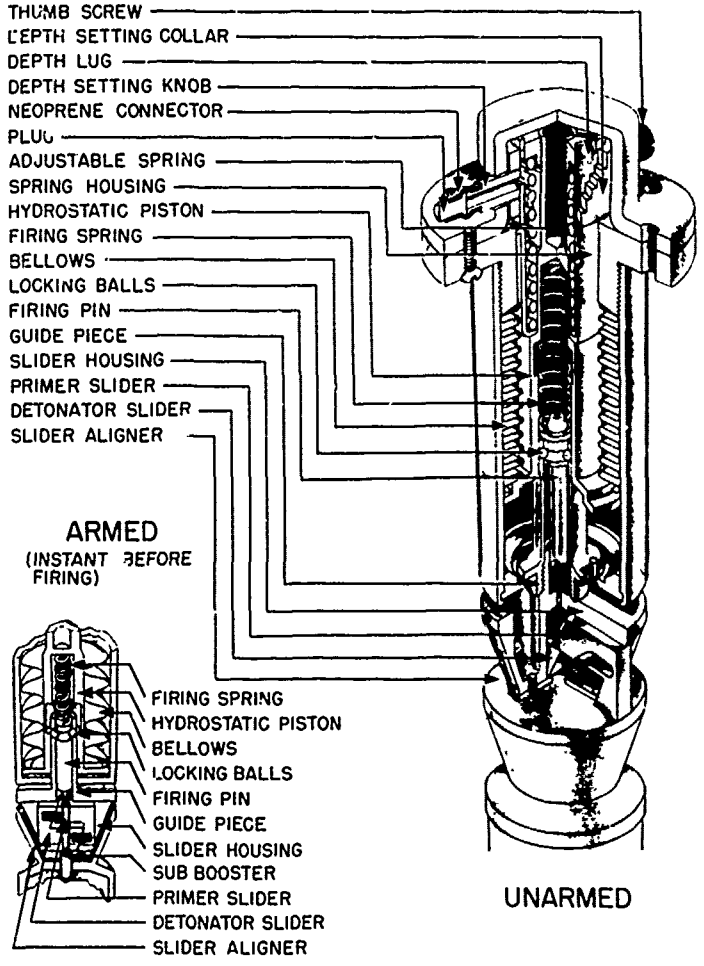


FIGURE 2-2. Athwartship Hydrostatic Fuze AN-Mk 234.

Mechanical Tail Fuzes. Mechanical tail fuzes are similar in operation to the mechanical nose fuzes except that they are installed in the tail of the warhead. They generally use inertial sensors to sense target impact rather than true impact sensors. Since these fuzes are located in the tail of the weapon, the arming vane is usually an accessory part that attaches to the outside of the weapon and provides arming energy to the fuze via a flexible drive cable.

Mechanical tail fuzes are most often used in conjunction with nose fuzes to insure positive functioning of the bomb at impact. These fuzes are also used in applications where a nose fuze is impractical, such as armor-piercing bombs. Figure 2-4 is typical of a mechanical tail fuze.

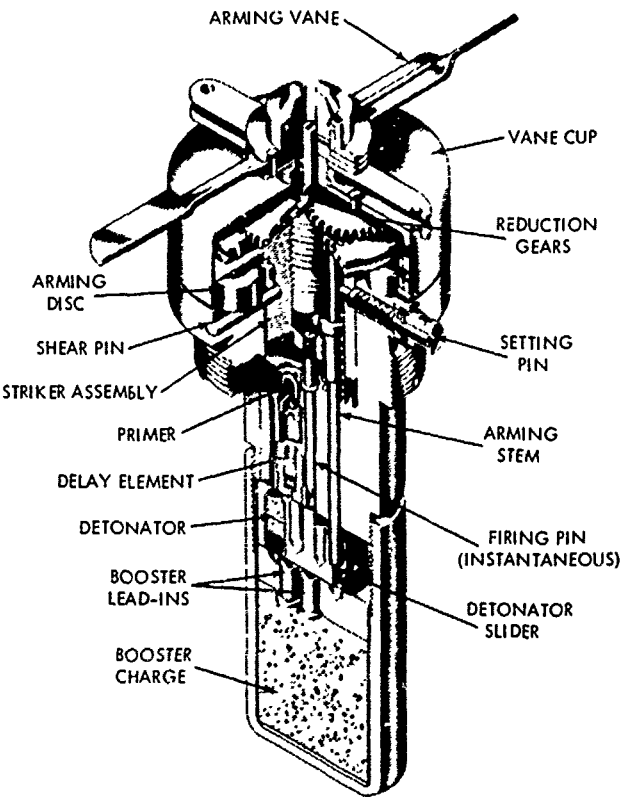


FIGURE 2-3. Typical Mechanical Impact Nose Fuze.

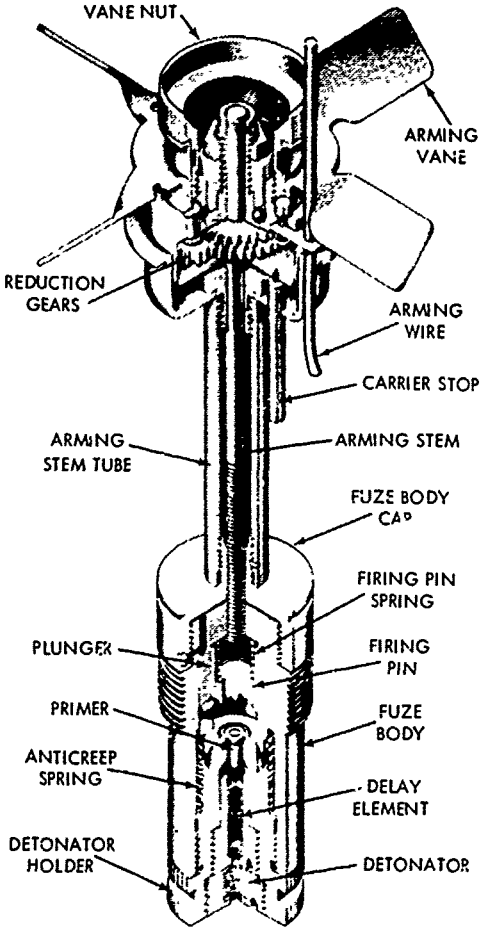


FIGURE 2-4. Typical Mechanical Impact Tail Fuze.

Proximity Fuzes. Most proximity fuzes are better characterized as sensors rather than fuzes, although there are some proximity devices that are truly fuzes (e.g., FMU-113). These devices or variable-time (VT) fuzes are used with general-purpose bombs or cluster munitions to improve their effectiveness in specific tactical deployments.

Typically proximity fuzes are actually miniature radars that determine the distance between the weapon and the target. When the proper distance is sensed, an electrical pulse is sent to an electric tail fuze to detonate the weapon. Figure 2-5 illustrates a typical proximity fuze (target-detecting device).

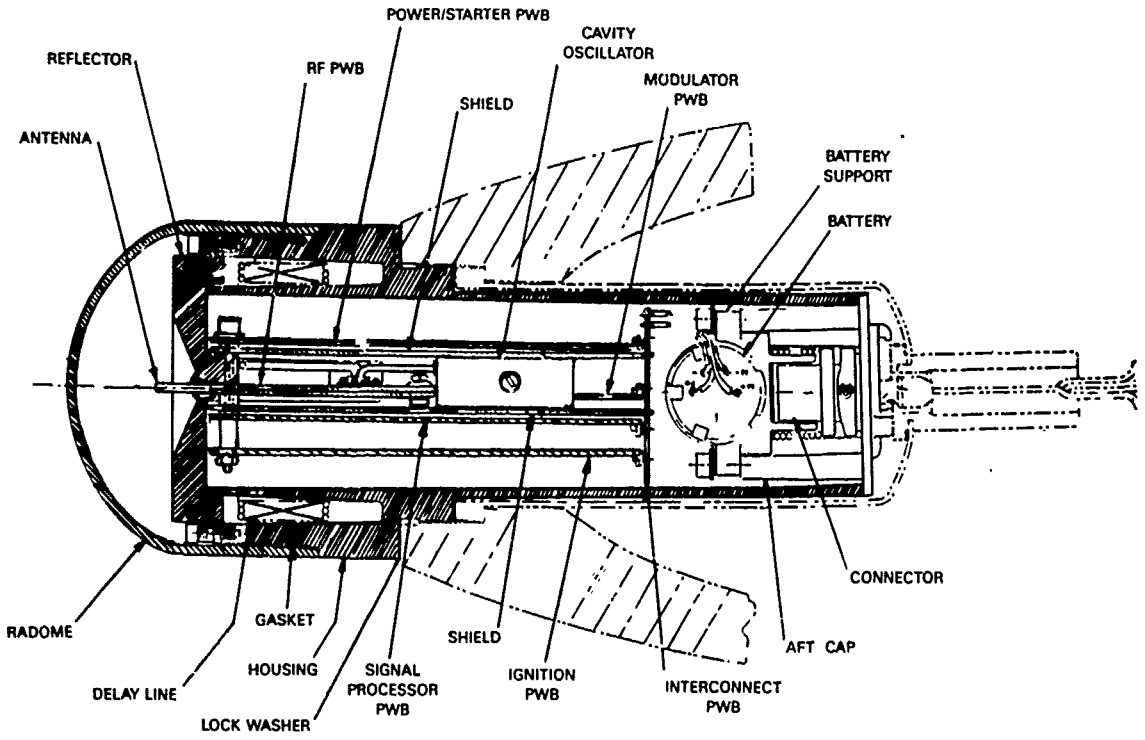


FIGURE 2-5. DSU-30/B Target Detecting Device.

Long-Delay Tail Fuzes. Long-delay tail fuzes are generally used for interdiction, harassment, and aerial denial missions. These fuzes may be either mechanical or electric and will detonate at a predetermined time (from minutes to days) after impact with the ground. These devices generally contain an antitamper or "booby-trap" feature, so that any attempt to remove the fuze after impact will trigger an antiwithdrawal mechanism, causing an instantaneous detonation of the bomb. Figure 2-6 illustrates a typical long-delay tail fuze.

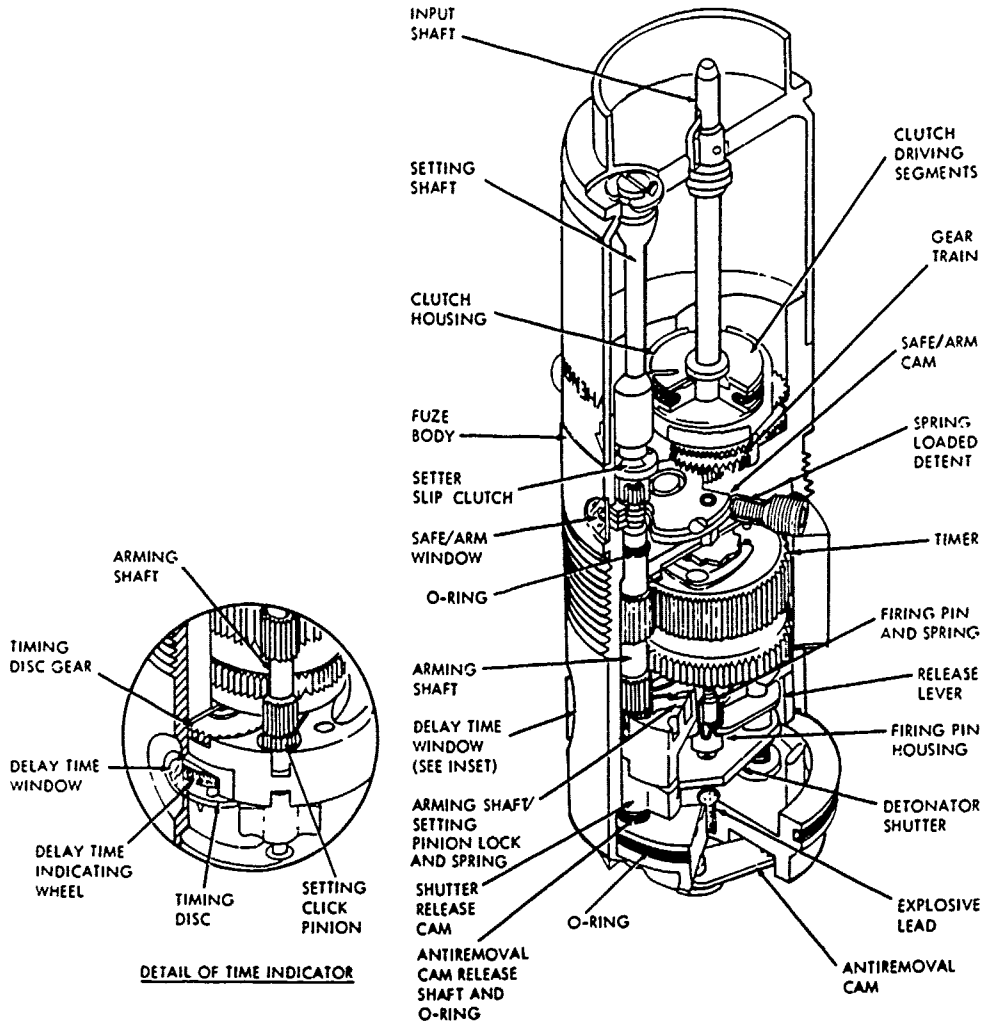


FIGURE 2-6. Long-Delay Tail Fuze Mk 346.

Hydrostatic Fuzes. Hydrostatic fuzes permit general-purpose bombs to be used as depth bombs. With these devices, arming energy can be derived in the same manner as with mechanical nose fuzes. However, water pressure is used to operate a hydrostatic mechanism which causes the fuze to detonate the warhead after the weapon has reached a specific water depth. Figure 2-7 illustrates a current type of hydrostatic fuze.

Electrical Fuzes. Recent advances in technology have created a series of fuzes that are either electrical or electronic. These fuzes obtain their arming energy from aircraft systems or by air-driven power supplies. Because of the versatility of electronics,

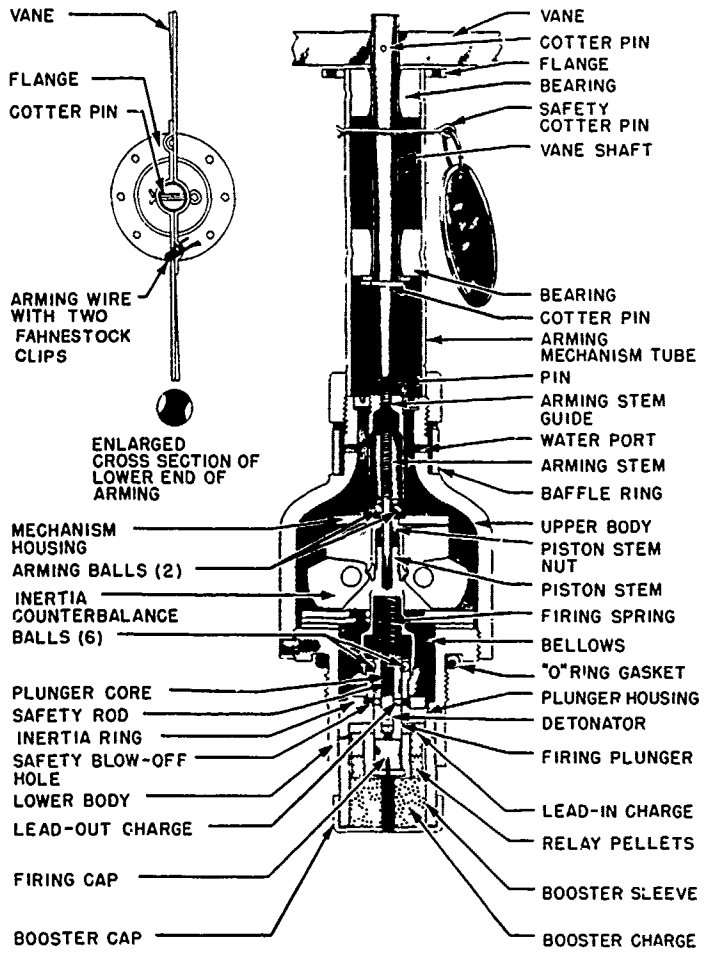
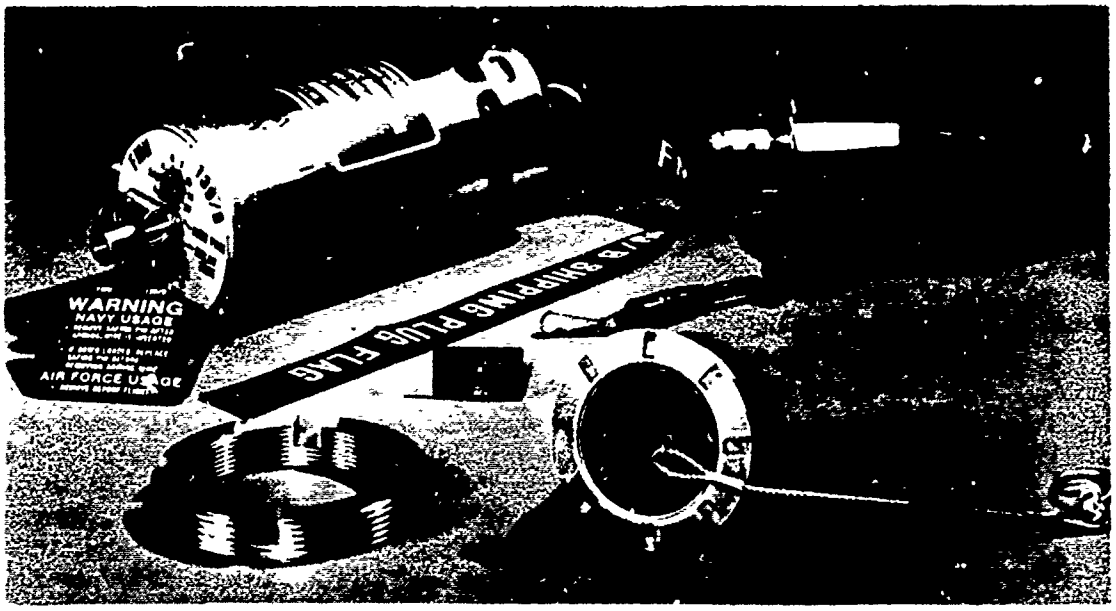


FIGURE 2-7. Tail Hydrostatic Fuze Mk 231 Mod 0.

these fuzes can incorporate several different arming times and functioning delay times. The timing function in the fuzes is accomplished either by discrete electronic components (e.g., a resistor-capacitor circuit) or, in more modern fuzes, by microprocessors.

Electrical fuzes have several distinct advantages over the mechanical fuzes. They can have numerous arming and functioning times, and these times can be set by an appropriate electrical signal provided by the aircraft at the time of weapon release. This capability provides the pilot the opportunity to change fuze settings just prior to delivering the weapon. Figure 2-8 illustrates a typical electric fuze.



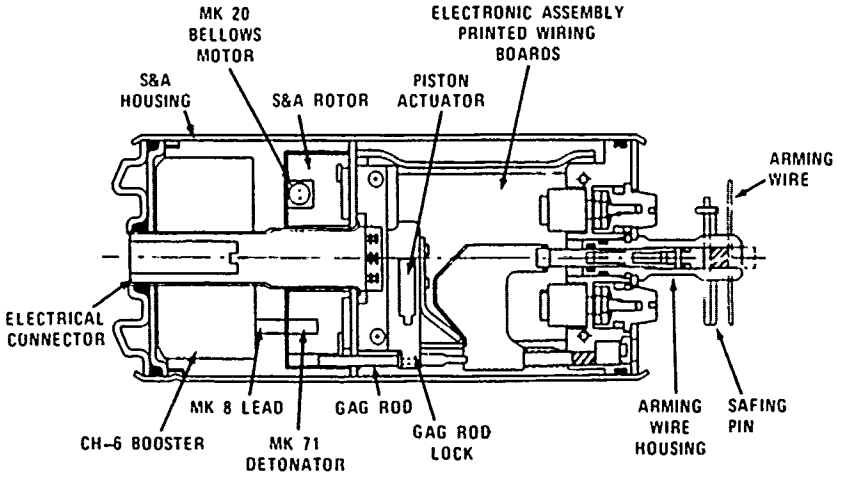


FIGURE 2-8. Typical Electrical Fuze (FMU-139/B); External View (top) and Cutaway View (bottom).

Fuzing Systems

Because of the many variations available to fuze bombs, the fuzing arrangement along with the external components required are generally referred to as a fuzing system. For example, with a bomb that is to be used in a proximity sensing mode, the fuzing system would consist of a proximity sensor in the nose, an electric fuze in the tail, the associated

wiring between the sensor and the fuze, the arming wires required, and the aircraft systems that provide the power and logic to the fuze at the time of weapon release. A typical fuzing system is shown in Figure 2-9.

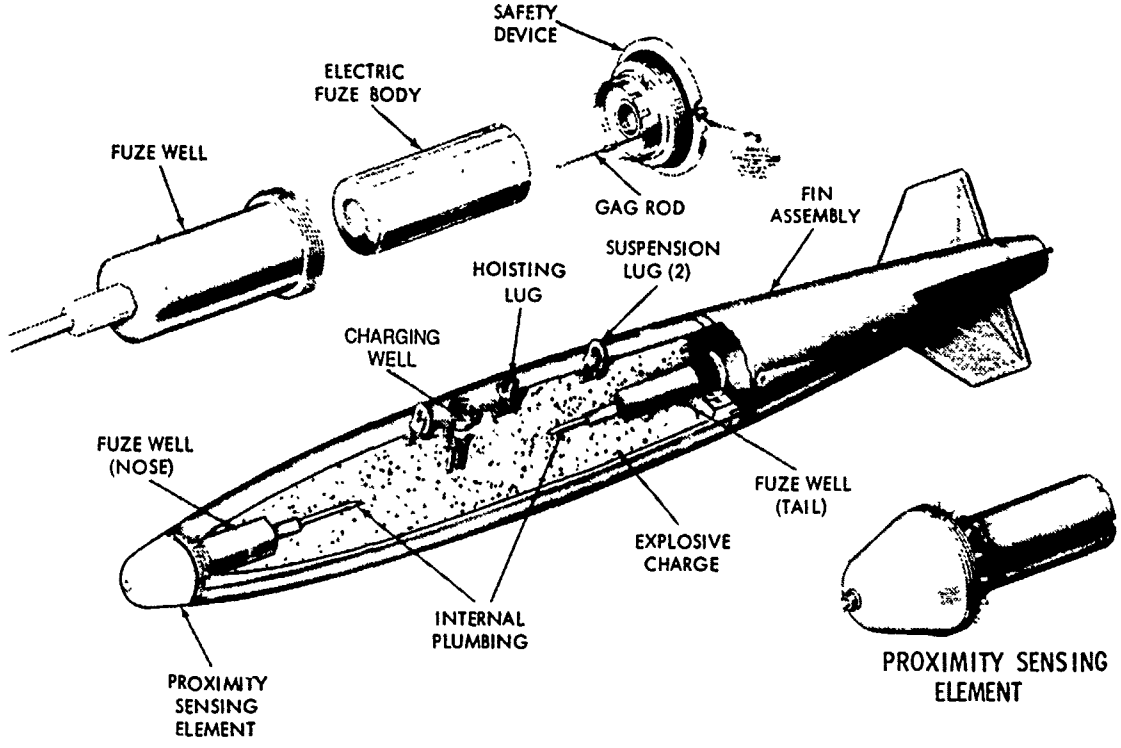


FIGURE 2-9. Typical Electrical Bomb Fuzing System Installed in a Low-Drag GP Bomb.

Safety Features

Fuzes generally have numerous safety features. These features are necessary because although the explosive material in the warhead is relatively insensitive to normal environments, the detonators or initiators in the fuzes contain sensitive explosive materials. The requirements for fuze safety features have consistently become more stringent over the years. For the Department of Defense, fuze safety requirements are described in MIL-STD-1316 (Reference 2) and are all based on the requirement that the fuze safety failure rate must be less than 1 in 1 million.

Typical safety features include (1) an out-of-line explosive train, (2) at least two locks on the explosive train, (3) no arming energy being available prior to an intentional release of the weapon, (4) no stored arming energy, (5) arming energy being derived from a

unique environment that can only be seen after an intentional release of the weapon, and (6) other requirements. Early bomb fuzes did not have all of these requirements.

Tactical Use of Fuzes

The purpose of a fuze is to provide safety in the storage, handling, and aircraft carriage environments, to ensure that the delivery aircraft will not be damaged by the detonation of its own ordnance, and to provide the capability to initiate the warhead at the proper time. Since these functions are sometimes contradictory (ensuring that the warhead does not function when it is unsafe to do so and that it does function properly to accomplish the mission), fuzes can decrease the tactical flexibility of the weapon. ***The goal of the fuze designer is to meet all the safety and reliability requirements without impacting tactical flexibility.***

Tactical flexibility can be restricted because of the requirement to arm the fuze only after the weapon is a safe distance from the releasing aircraft. This requirement can affect the minimum release altitude of the weapon, as well as the maximum time permitted to release a series of weapons. The impact of these restrictions can be reduced by requiring the pilot to execute specific maneuvers after weapon release.

TYPES OF BOMBS

A wide variety of bombs have been developed and used over the years. At the end of World War II, bombs of up to 44,000 lb were available. Since that time, the very large bombs of the type used in World War II have disappeared from inventory. Certain other types, such as the armor-piercing, semiarmor-piercing, and light-case bombs, are no longer used. Bomb types are briefly discussed in this section and are representative of the current or previous types used. Obsolete bombs are summarized as to major characteristics only and noted as "no longer in service". More detailed information on specific bomb types is given in Section 3.

GENERAL-PURPOSE BOMBS

The GP bomb is the workhorse of the explosive bomb types. The very large GP bombs (over 3,000 lb) are no longer in service. Figure 2-10 illustrates the later types of these bombs, including an antiricochet version of the low-drag bomb.

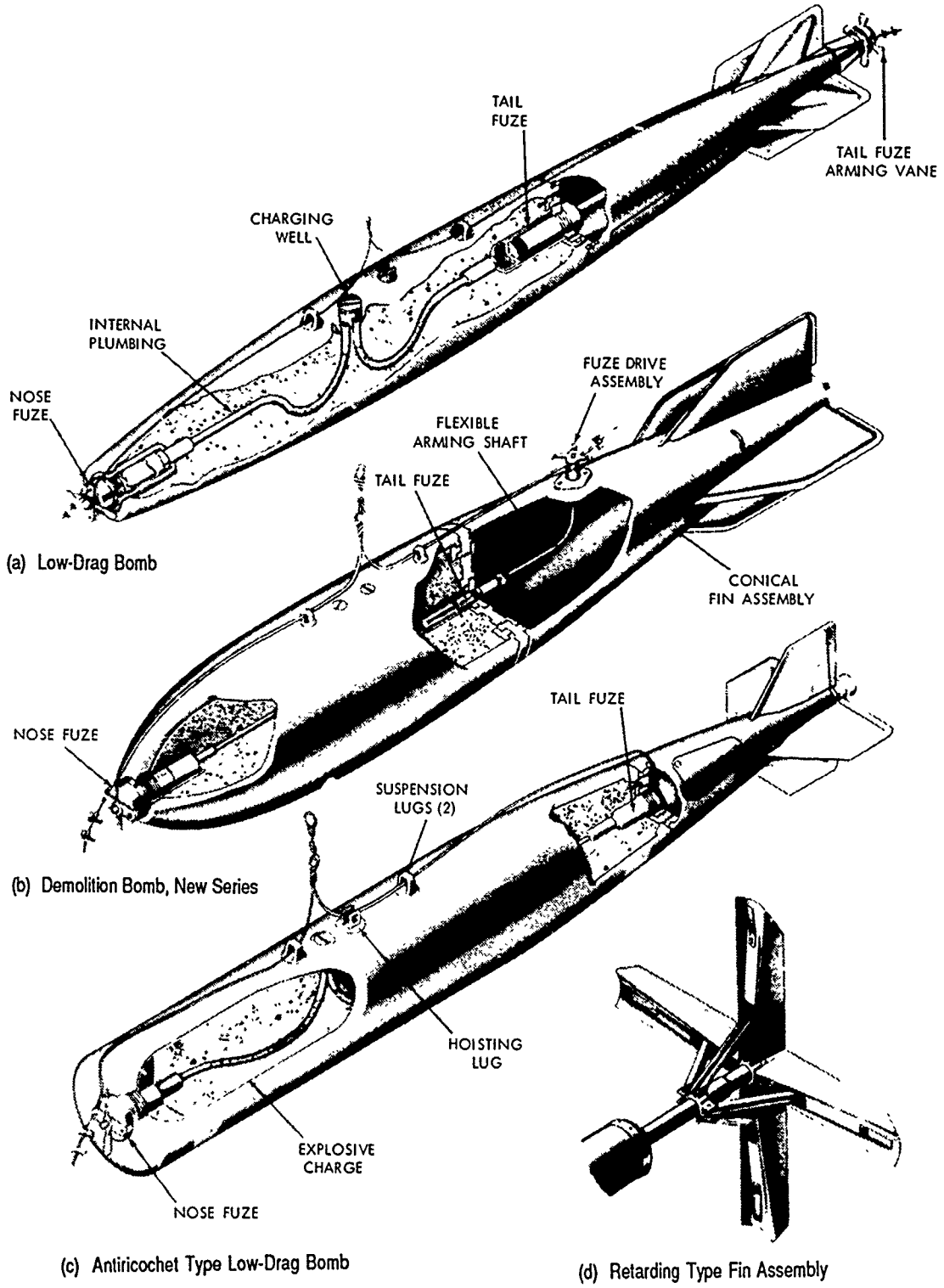


FIGURE 2-10. Typical GP Bombs.

General-purpose bombs are divided into three distinct types: old series GP bombs, which ranged in weight from 100 to 2,000 lb; the later streamlined series GP bombs, which ranged in weight from 750 to 3,000 lb; and the current low-drag general-purpose (LDGP) bombs which range in weight from 250 to 2,000 lb.

Function. GP bombs will produce blast, fragmentation, and deep-mining effects. Their functions are determined by the action of the fuzes and fuze components with which they are armed. For example, when old-series GP bombs were fuzed with long-delay tail fuzes, the chemical delay acted to detonate the bomb from 1 hour to 6 days from the time of release. Under those circumstances there was no need for a nose fuze, therefore the steel nose plug was retained in the bomb nose. Normally, old-series GP bombs used a nose fuze (which produced instantaneous or short-delay action) and a tail fuze to increase functioning reliability. GP bombs gain their principal effect from their high explosive content.

Explosive Filler. The explosive filler of GP bombs represents approximately 50% of the total weight. The bomb cavity is completely filled with explosive filler, except for thin pads of inert wax sealers at the nose and tail portions and a liner material between the case and explosive. The type of explosive filler used, as with fuzes, depends upon the use or function of the bomb. GP bombs can be loaded with tritonal, amatol, TNT, Comp B, high-blast explosive (HBX), and, in some cases, plastic-bonded explosive (PBX).

New Developments. Following World War II the development of high-speed aircraft made changes necessary in both external and internal design of GP bombs. The later demolition and LDGP type bombs, as well as the stream-lined conical fin assemblies, were designed (1) to reduce air resistance and give better ballistic accuracy and aerodynamic performance in the transonic and supersonic ranges, and (2) to use electric fuzing. However, other nose and tail fuze combinations were also authorized. Old-series demolition and GP bombs were shipped with adapter-boosters installed. The later series bombs were shipped without adapter-boosters. A later model of the LDGP series (Snakeye I) incorporated a retarding-fin assembly (Figure 2-10) that provided a high-speed low-altitude bombing capability.

SEMIARMOR-PIERCING BOMBS

The semiarmor-piercing (SAP) bomb was used where penetration against resistant targets was desired. These bombs had a heavy case and accommodations for both nose and tail fuzes. Since a nose fuze was rarely used, the nose seat was closed by an armor-piercing plug. SAP bombs provided greater penetrative ability than that afforded by a comparable GP bomb; however, in some instances they were used as general-purpose bombs by the addition of a nose fuze. The SAP bomb is no longer in service.

FRAGMENTATION BOMBS

Fragmentation bombs are especially designed to produce a large dense pattern of lethal fragments on detonation. They are basically an antipersonnel weapon, although some are effective against material targets. The old series fragmentation bombs ranged in size from 4 lb bomblets to 260-lb bombs.

DEPTH BOMBS

The aircraft depth bomb, similar to a light-case bomb, was designed for use against underwater targets, submarines in particular. The bomb case contained a bursting charge that represented approximately 60% of the total weight. The cylindrical case normally had a flat nose that reduced ricochet upon impact. The bomb functioned at a predetermined depth, dependent upon the setting of the hydrostatic fuze assembled to the bomb. Generally, depth bombs were fuzed with hydrostatic tail fuzes only (see Figure 2-7); however, provisions were also made for nose fuzing in the event that surface detonation was desired in certain tactical situations.

CHEMICAL AGENT BOMBS

Chemical bombs are those that contain chemical agents as their main filler. The chemical agent used was generally the nonpersistent gas, GB. Bombs of this type are used to produce casualties among personnel and for the purpose of area-denial.

Chemical bombs come in a variety of sizes, ranging from small bomblets dropped in clusters to individual bombs of 500- and 750-lb sizes. Chemical agent bombs are usually fuzed for instantaneous functioning on impact. However, VT fuzing for airburst is authorized for certain types. On fuze actuation, the burster charge is exploded to rupture the case and disperse the agent filler.

INCENDIARY BOMBS

Incendiary bombs are filled with agents that burn such as thickened-oil fuels and metallic oxidizing materials that, when ignited, produce a very fierce and hot fire that is difficult to extinguish. These bombs are designed to start fires and spread conflagration in combustible materials and structures.

Incendiary bombs cover a variety of types and sizes, ranging from the small 4-lb scatter-type bombs dropped in clusters to the larger types that include the 500-, 750-, and 1000-lb class oil-filled types, which are dropped individually. The larger bombs are referred to as Fire Bombs. They are usually thin-walled containers filled with thickened fuels, such as napalm for use against dug-in troops, supply installations, wooden structures, and land convoys. In the smaller scatter-type incendiaries, the most commonly used filler was thermite or thermite with magnesium. The bomb body was generally made of magnesium alloy that used a simple nose or tail fuze to ignite the thermite. Once ignited, the body burned fiercely. Some versions had randomly initiated explosive charges to discourage fire fighters. Dispensers containing about a 4-lb incendiary bomb were widely used in World War II by almost all combatants, especially in Europe.

SMOKE BOMBS

Smoke bombs are generally used for screening purposes to conceal combat areas, the movement of troops and ships, for marking targets, and for antipersonnel effects. The standard filling for these types of bombs is white phosphorus (WP) or plasticized white phosphorus (PWP), which is a smoke-producing agent. Both WP and PWP produce a mild incendiary effect and will set fire to clothing, dry bush, paper, canvas, and such other materials having similar low kindling points.

AIRCRAFT SPRAY TANK

These are not bombs as such, but are bomb-shaped, liquid-dispensing tanks carried externally on aircraft bomb stations. They are used to release solid or liquid chemicals over an area in the form of dust or fine spray for the purpose of defoliation. They contain pressurized systems by which the agent may be forced out of the tank in a spray or cloud form when actuated from the cockpit.

PYROTECHNIC BOMBS

Pyrotechnic bombs include photoflash and target-identification bombs. Both of these bombs are no longer in service use.

Photoflash Bombs. These bombs are essentially pyrotechnic items, but are classified with explosive bombs because of their explosive nature and because they resemble explosive bombs in appearance. Photoflash bombs are thin-walled bombs designed to burst in the air to produce a light of high intensity for night photography. These bombs use mechanical time nose fuzes. They range in weight from 100 to 150 lb.

The bomb cases are loaded with either a charge of photographic flash powder or metal alloy dust, representing approximately 45 to 75% of total bomb weight. Photoflash bombs are hazardous items which react with a violence comparable to an HE bomb when detonated.

Target Identification Bombs. This type of bomb was also pyrotechnic in nature. It consisted of a modified GP-bomb case having a nose fuze, an expelling charge, and a number of pyrotechnic candles that were ignited by the expelling charge and burned with a characteristic color and pattern. Target identification bombs were used by "Pathfinder" planes that preceded bomb groups and identified or designated a target, thus facilitating sighting and reducing the probability of error for the following aircraft.

PRACTICE BOMBS

Practice bombs are used for target practice and the training of bombing crews, and are designed to simulate service bombs. There are various methods for spotting the points of impact of practice bombs. One type provides a colored target on snow-covered ranges. Others function to detonate a blank cartridge on impact, causing a signal to fire. The explosion of the signal produces a flash and a large puff of smoke, permitting observation of bombing accuracy. Under freezing conditions, practice bombs that are filled with water, or with a mixture of water and sand, have antifreeze added to prevent bursting of the bomb case caused by freezing of the filler. Practice bombs make use of devices such as cartridges and a variety of signals. They may be positioned in the nose or in the tail of the bomb, depending on the type.

Figure 2-11 illustrates several old and current U.S. practice bombs and shows their impact-indicating systems in cut-away view.

EMPTY AND INERT-FILLED TRAINING BOMBS

Empty and inert-filled training bombs are provided for training of ground crews in assembling, fuzing, and handling of bombs. These bombs and their components are completely inert and are usually constructed from the inert metal parts of service bombs which they are intended to simulate. They differ from inert training bombs in that practice bombs are expendable.

CLUSTER ADAPTERS, STATIC DISPENSERS, AND CLUSTER BOMB UNITS

Cluster adapters and static dispensers were used to carry small bombs and bomblets and to release them in groups or clusters at the proper time. Currently bomblets are

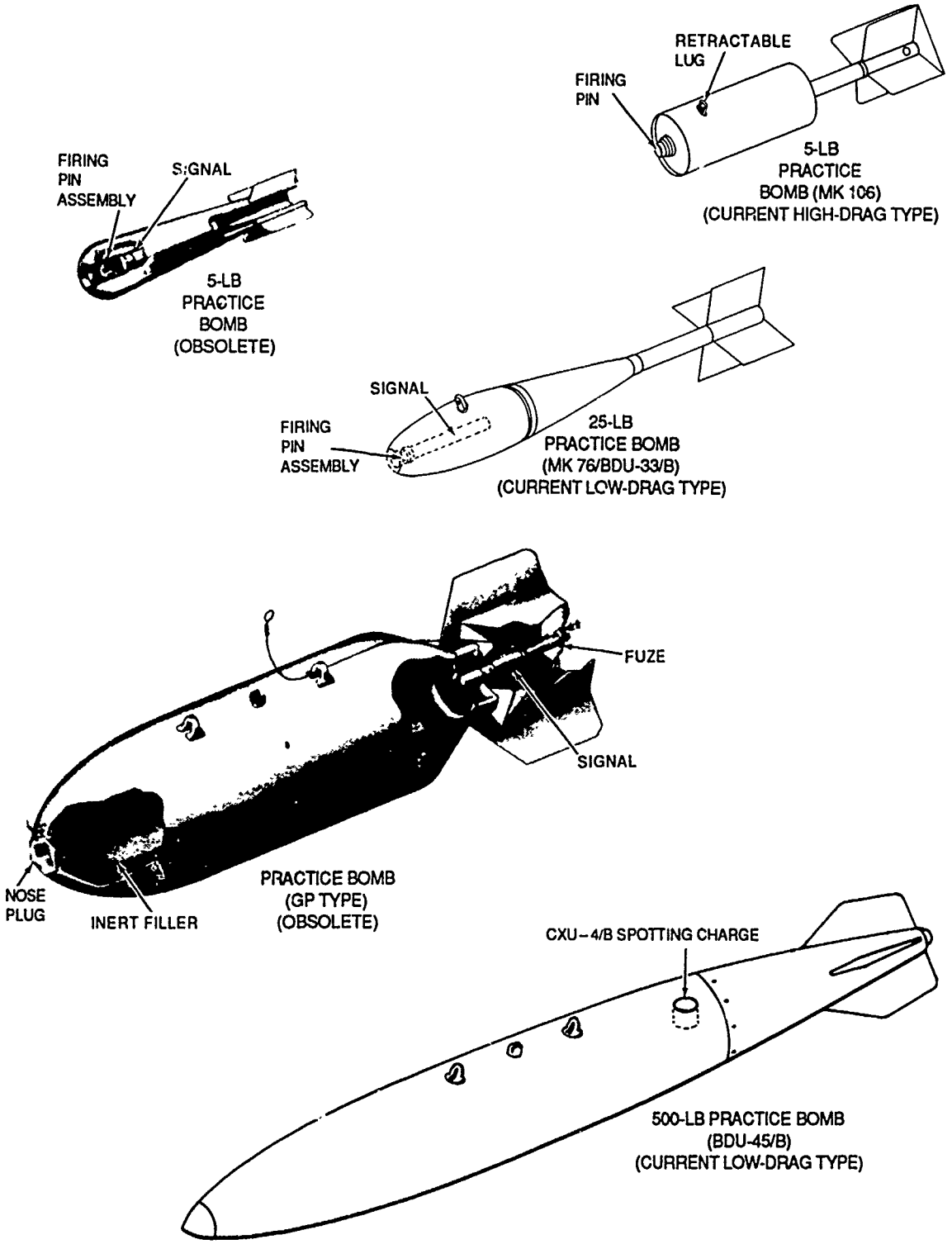


FIGURE 2-11. Typical Practice Bombs.

carried and released from containers designated as cluster bomb units (CBU) such as the CBU-59/B (APAM) or a cluster munition such as the Mk 20 Mod 12 (Rockeye). Figure 2-12 illustrates a typical static dispenser, a cluster bomb unit, and a cluster bomb.

Cluster Adapters. These were containers or frames in or on which the small bombs or bomblets were carried on the aircraft. A cluster bomb was the adapter with its bombs installed in place. The cluster bomb was an assembly of small-bombs which were suspended as a unit in a bomb station designed for a single large bomb. The cluster was released as a unit for area bombing. After release from the aircraft, the individual bombs were released from the cluster to fall and arm individually. There were two general types of cluster adapters: the quick-opening cluster and the aimable cluster. The cluster adapters are no longer in service.

Static Dispensers. These were streamlined containers which carried bomblets in tubes from which they were ejected rearward in rapid succession when desired. The bomblets were then free to fall and arm individually. The dispenser remained with the aircraft. Various methods of forcing the bomblets out of the dispenser were used, such as compressed gases, ejection charges, or the ram force of the surrounding air as the aircraft moves through it at high speed. Currently the only static dispensers in use by the Fleet (Marine Forces primarily) are the Mk 12 Smoke Tank and SUU-44 flare dispensing system.

Cluster Bomb Units. These are typically unguided free-fall weapons designed to defeat a wide variety of tactical targets. The CBU systems in inventory (500-lb Rockeye Mk 20, 750-lb APAM CBU-59/B, and 950-lb Combined Effects Munition CBU-87/B) are carried on and released from high-performance aircraft. Sometime after release from the aircraft, the bomblets (incorporating shape charges, controlled fragmentation cases, and incendiary materials) are released from their dispensers providing a wide pattern of coverage against ground targets including heavy armor. The most recent innovation in bomblet design was the incorporation of a pop-out, air inflatable retarder system to retard the ballistic flight of the bomblets and allow high-speed, low-altitude attacks.

BOMBLETS

Bomblets are a large family of very small sophisticated bombs, normally dropped as clusters or released from dispensers in large numbers. The majority of bomblets were Air Force designs and therefore carry Air Force designation. Details of many of these devices are classified since most were of special design and used for special purposes. There were various high-explosive-loaded bomblets designed for specific purposes such as antitank shaped-charge, impact fragmentation, and time-fired fragmentation. These bomblets were fuzed in a number of ways to be air-armed and impact-fired. Figure 2-13 illustrates typical HE bomblets.

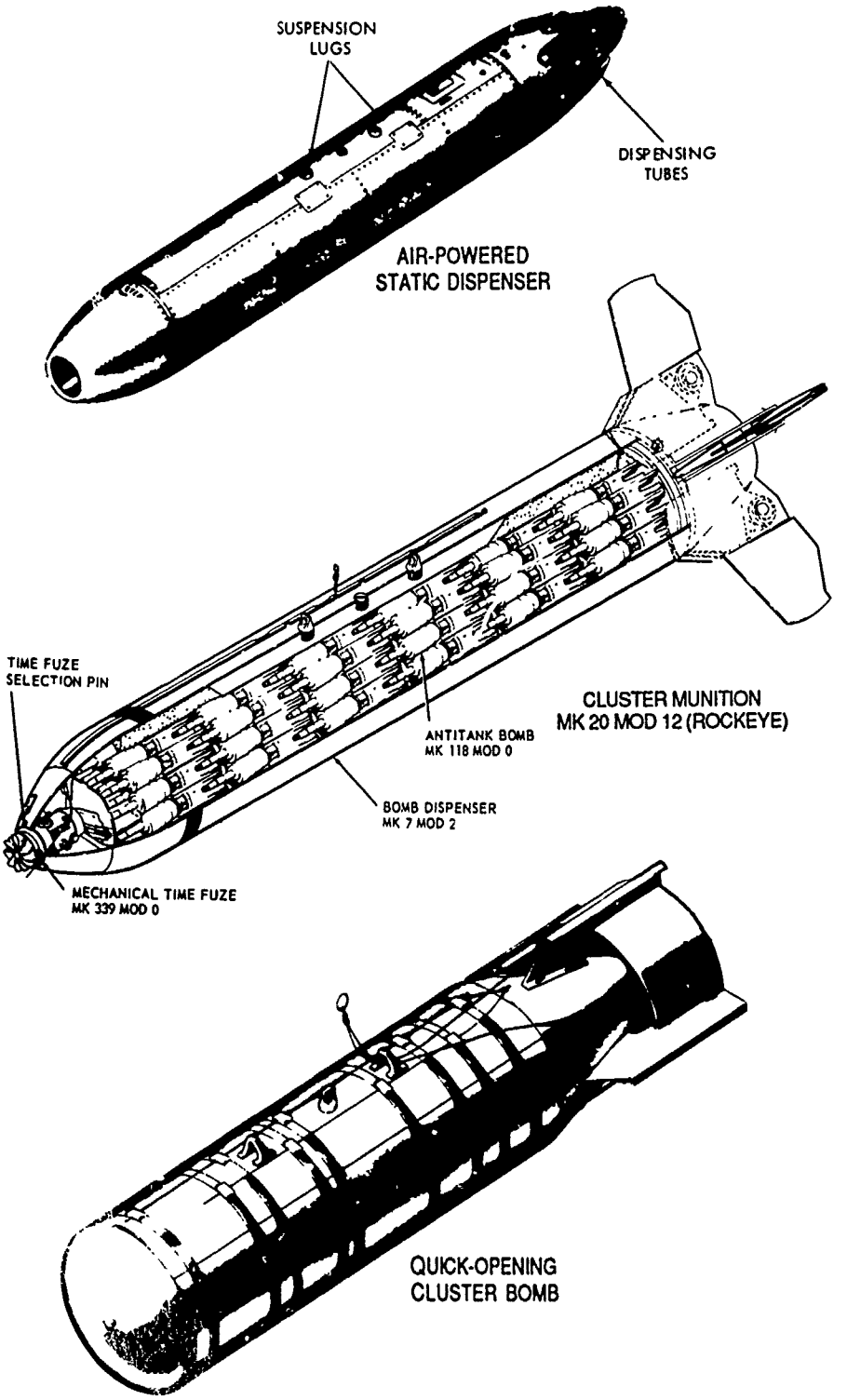


FIGURE 2-12. Typical Static Dispenser, Cluster Bomb Unit, and Cluster Bomb.

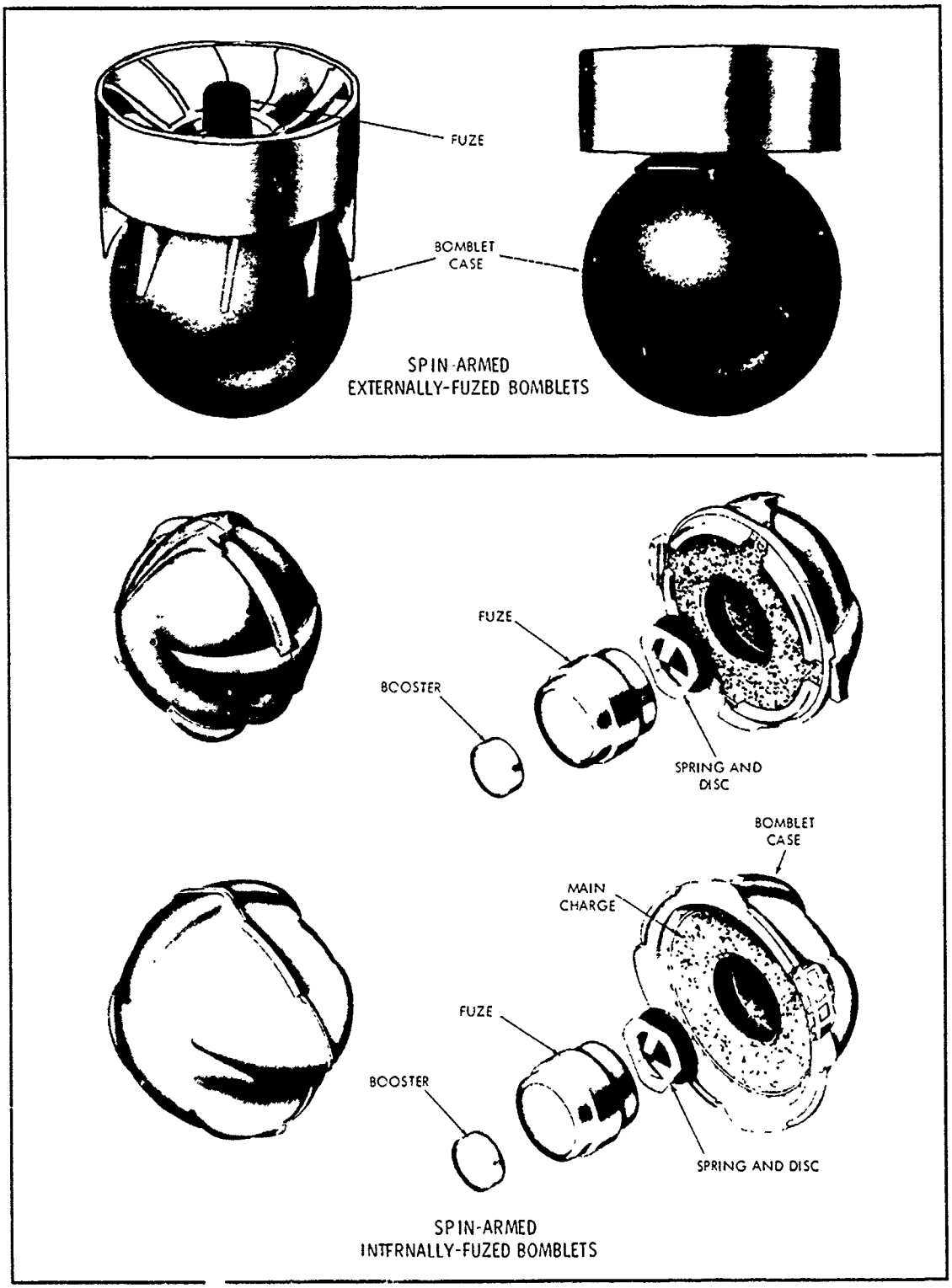


FIGURE 2-13. Typical High-Explosive Bomblets.

Section 3. HISTORICAL DEVELOPMENT OF ARMY–NAVY BOMB SERIES

This section covers the historical data on the evolution of aircraft bombs developed by the U.S. Army and Navy, and the technological efforts, designs, and systems development leading to the present Mk 80 series low-drag general-purpose bombs.

GENERAL HISTORY

AIRCRAFT BOMBING

According to Reference 3, from the time that aviation became a practical possibility, it was recognized that one of the chief functions of the military airplane would be to drop bombs. It appeared that optimism as to the possibilities of bombing reigned supreme at that time, and little attention was therefore paid to the difficulties which might arise as development progressed. Writers referred to the aerial bombs as the artillery fire of the air that would reach any target in enemy territory within flying distance of the airplane that carried it a distance greater by several hundred miles than the longest range of a gun.

Long before World War I, bomb-dropping exhibitions were given at aviation meetings. However, the airplanes carrying the bombs were constructed of frail, open framework with small engines and very limited lifting power, and therefore the bombs dropped were of necessity very small. Some "bombing" in those early contests consisted of dropping oranges and bags of flour upon targets outlined upon the ground. The first use of bombs in warfare was made by the Italians in their campaign in Tripoli in 1912. The first bombs that appeared were converted from some other type of fragmentation ammunition and were used primarily against personnel. With each increase in the lifting capacity of the airplane came an increase in the number of such bombs carried until a capacity was reached which permitted the use of a single large bomb where the explosive effect was the chief result sought.

BOMB DESIGN

In July 1917, a French official brought to the United States, samples of the Gros Andreau bombs, which were being used in large quantities by the French at that time.

Those bombs were adopted as models for U.S. Army development work and the design of three sizes was undertaken. Those bombs were known as the bomb, demolition, 25-lb, Mk I; bomb, demolition, 50-lb Mk I; and bomb, demolition, 100-lb Mk I.

In December 1917, the American Expedition Forces specified requirements for demolition bombs heavier than 100 lb. By February 1918, drawings were completed and orders placed for demolition bombs varying in weights from 25 to 1100 lb. The first fragmentation bombs made in the U.S. were those converted from rejected 3-inch artillery projectiles, which weighed approximately 17 lb, and those later manufactured, which weighed approximately 25 lb. Those bombs were streamline in shape and were identical with the British Cooper bombs. All demolition bombs, as originally designed, were of the streamline-body or "tear-drop" type. Subsequent bomb designs incorporated a more cylindrical body.

Following the Mk I demolition bomb development efforts during and shortly after World War I, tests were conducted to demonstrate the capability of tactical aircraft to attack and disable or destroy enemy combat ships with free-fall, heavy-case, low-capacity weapons. Specifically, as stated in Reference 4, tests conducted in 1924 against the decommissioned battleship U.S.S. *Washington* demonstrated that it was technically possible to construct a free-fall bomb capable of penetrating the protective deck armor of a battleship (4 to 5 inches of armor). However, this type of bomb would (1) "have a very low explosive-filler content and therefore be relatively ineffective in producing underwater damage," and (2) "need the striking velocity necessary for penetration of deck armor which could only be achieved from high altitudes from which accurate bombing was then impracticable."

Based on the low probability of damage from high-altitude bombing with a dedicated penetrator bomb, with its low charge-to-mass ratio, the Chief of the Bureau of Ordnance (BUORD) decided to develop and procure high-capacity (high charge-to-weight ratio) bombs with very light cases and a maximum amount of explosive fill. These latter bombs would be more suitable for the then-current attack aircraft and their bomb delivery equipment. This decision was made with the knowledge that (1) recent advances in the design and performance of bombing aircraft, together with greatly improved bombsights and accessory equipment, would permit effective high-speed, low-altitude attacks, and (2) sufficient accuracy and striking velocity could now be achieved to enable low charge-to-mass ratio, armor-piercing bombs to penetrate armored decks and produce acceptable percentages of direct hits.

The Bureau of Ordnance procured sufficient light-case, heavy demolition bombs to meet the needs of Forces Afloat as well as reserve requirements for the 500- and 1000-lb class weapons. Both classes of bombs were equipped with mechanical delay fuzes which functioned 0.1 second after impact. It was recognized at this time, that a longer delay fuze was desirable to function below the ship's draft to increase the kill probability against

capital ships that incorporated torpedo protection devices or armor. However, after a series of tests of various bomb case designs against deck target structures, an improved type of bomb employing a low-capacity, heavier case design was developed by BUORD. This design would ensure high-order detonation after penetration of at least one unarmored deck of a modern capital ship and retain sufficient strength to ensure against case breakup, loss of explosive fill, or failure to penetrate after striking structural irregularities such as heavier plates, deck beams stanchions, hatch coamings, and other lesser fittings.

The physical characteristics, charge-to-weight ratios, etc. of these light- and heavy-case demolition-type 500- and 1000-lb bombs are delineated in Reference 4 along with other low-capacity heavy-case armor-piercing bombs in the 1000-, 1250-, 1575-, and 2000-lb class, designed to defeat deck armor ranging from 2.5 inches of homogeneous armor, corresponding to the heaviest treaty cruiser deck protection, to 4.5, 6.0, and 7.0 inches of deck armor for battleships. These latter heavy-case armor-piercing bombs had explosive fills ranging from 4.4 to 14.6% of their total warhead weight, while the demolition bombs ranged from 66 to 74% (light-case bombs) and 51 to 54% (heavy-case bombs).

It was the opinion of BUORD that high-capacity-type bombs, sometimes referred to as light case, ranging from 50 to 75% by weight of explosive fill, were the optimum type for use against unarmored or unprotected targets. For use against harder targets (battleships), the advantages of an armor-piercing bomb was sufficiently important as to warrant continued investigation.

In light of the operational capabilities/limitations of tactical aircraft, the target spectrum and required damage thereto, and logistic considerations of that era, BUORD summarized the advantages and disadvantages of armor-piercing bombs (which inferred probability of their being used against capital ships) as follows:

Advantages:

1. Penetration of horizontal armor and consequently greater destructive effect by direct hits against armored targets

Disadvantages:

1. Decrease in underwater damage
2. Ineffectiveness except with high ceilings
3. Ineffectiveness with dive release
4. Decrease in total hits due to necessity for release at high altitudes
5. Decrease in damage to structures and installations above horizontal armor
6. Complications arising form diversity of bomb types

ORDNANCE NOMENCLATURE BACKGROUND

Prior to 1941, the Army and Navy had separate manufacture and designs for all bombs, and each Service had distinctive nomenclature to indicate a particular piece of ordnance. The Navy nomenclature was prefixed by the word "Mark" (abbreviated Mk), and the number of the design was given by a roman numeral; modifications to the original design were indicated by the abbreviation "Mod", followed by the number of the change; i.e., Mk XII Mod 2, 500-lb GP Bomb. The Army nomenclature, prior to 1 July 1925 was similar to this , differing only in method of designating modifications. A modification was designated by the letter M followed by a roman numeral; i.e., Mk I MII, 100-lb GP bomb.

In 1925, the Army changed its method of nomenclature to avoid confusion with the Navy, and all items since then have been named "M" (for Model) followed by an Arabic numeral. Modifications are indicated by adding the letter "A" and the appropriate number (thus, M38A2 indicates the second modification of the 38th design of the bomb).

Early in 1941, a Joint Committee for Standardization of ordnance known as the Army–Navy Standardization Board was created; since its inception, bomb production, with very few exceptions, was of the types approved by this board for joint issue to Army, Navy, and British Forces. The responsibility of designing bombs for land targets was given to the Army, and bombs for naval objectives or for carrier use were to be developed by the Navy. Designs accepted by this committee were designated by the prefix "AN" followed by the Army or Navy name of the design. Thus, for example, an Army bomb approved for joint production would be named AN-M64A1, and a Navy bomb which was accepted would be named AN-Mk 33.

The sections that follow describe the series of bombs in the order in which they were developed and list the fundamental characteristics of the bombs within each of the series, specifically:

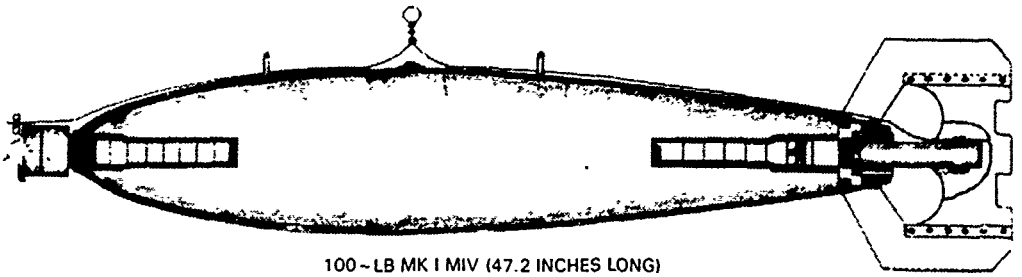
1. U.S. Army "Modified Mark" Series Bombs
2. U.S. Army "M" Series Bombs
3. U.S. Navy "Mk" Series Bombs
4. U.S. Army–Navy "AN" Series Bombs
5. U.S. Army–Navy "AN-GP" Series Bombs
6. U.S. Army–Navy "AN-GP A1" Series Bombs
7. U.S. Navy "Mk 80" Series General Purpose Bombs

U.S. ARMY "MODIFIED MARK" SERIES BOMBS

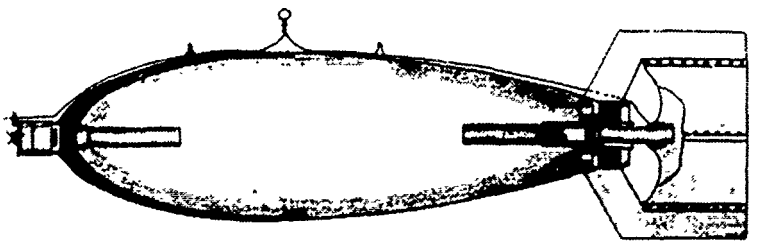
DESCRIPTION "MODIFIED MARK" BOMB

Prior to the development of the first series of Aircraft Bombs during the early 1920s, the military commands established that the most important type of explosive bomb for military aircraft was the high-capacity demolition-type HE bomb (Reference 4). The first series of Aircraft Bombs designed and manufactured in the U.S. was the U.S. Army's "Modified Mark" series Demolition Bombs. The "Modified Mark" Series Bombs (see Figure 3-1) consisted of the 100-lb Mk I MIV, the 300-lb Mk I MII, the 600-lb Mk I MII and MIII, the 1100-lb Mk III MI (not shown), the 2000-lb Mk I MIII, and the 2000-lb Mk I MIV and MV. Basically they were thin-walled, high-capacity bombs with charge-to-weight ratios ranging from 50.0 to 58.0%. The suspension lugs were U-shaped bar-steel eyebolts welded to the body along the longitudinal axis for the 100- through 1100-lb class bombs, and two U-shaped eyebolts on plates secured to the bomb body by cap screws for the 2000-lb class. The physical characteristics of each of the bombs are delineated in Table 3-1. The primary use of these bombs was for general bombardment and demolition of targets. As stated in Reference 3, the destructive effect produced by these types of bombs was the result of detonation of the high-explosive content.

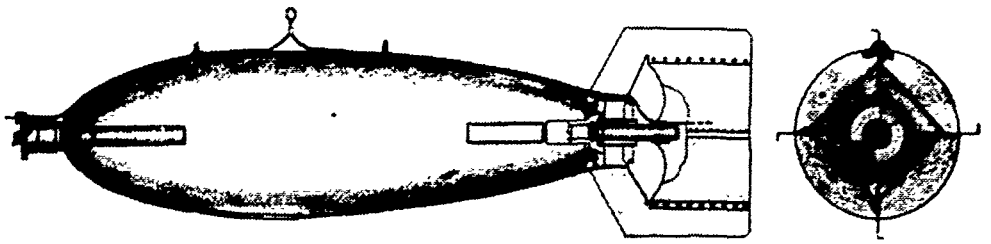
The HE detonation produces a vast amount of blast, the destructive effects of which increase with the amount of explosive in the bomb body. When the detonation takes place above ground as a result of instantaneous fuze action, metal fragments from the body casing are scattered at high velocities for great distances. Experiments conducted indicated that fragments from the metal case carry destructive effects to much greater distance than blast. However, within a limiting radius and against certain types of target, blast is far more effective than fragments. Blast was thus considered more desirable than fragments for demolition effect, and thin-case demolition bombs carrying the largest practicable percentage of high explosive were adopted. The blast effect naturally decreases as the distance from the target increases. A direct hit with even a small bomb is immeasurably superior to near hits with considerably larger bombs. The mining effect resulting from the detonation of the explosive below the surface of the earth, obtained through the use of delayed fuze action, is of great importance in demolition bombs to destroy the target directly or undermine its foundation. The explosive materials used as fillers for these bombs were Amatol, Lyconite, or TNT. The early standard demolition bombs varied in weight from 100 to 2000 lb. The bombs were fuzed with both nose and tail fuzes and could be equipped with detonators to give either instantaneous, 0.05-second delay, or 0.1-second delay action, depending on the mission to be accomplished. Table 3-2 lists the classification and class of demolition bombs used as standards for manufacture (Reference 3).



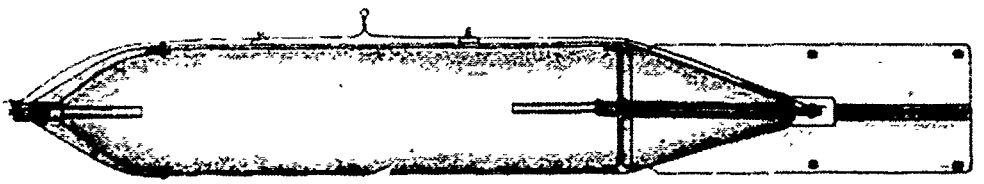
100 – LB MK I MIV (47.2 INCHES LONG)



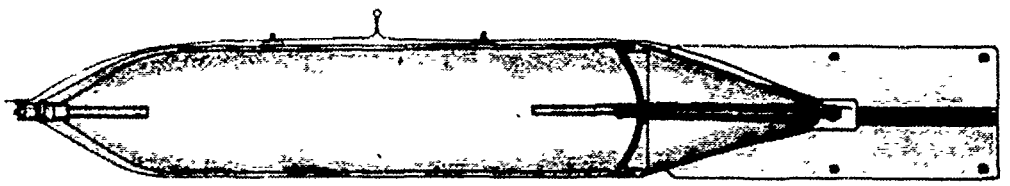
300 – LB MK I MII (51.2 INCHES LONG)



600 – LB MK I MII (63.0 INCHES LONG)



2000 – LB MK I MIII (135.8 INCHES LONG)



2000 – LB MK I MIV AND MV (135.8 INCHES LONG)

FIGURE 3-1. U.S. Army "Modified Mark" Series Bombs (Obsolete) (Reference 5).

TABLE 3-1. U.S. Army "Modified Mark" Series Bombs (Obsolete) (Reference 6).

Bombs	100-lb Mk I MIV	300-lb Mk I MII	600-lb Mk I MIII	1100-lb Mk III MI	2000-lb Mk I MIII	2000-lb Mk I MIV & MV
Fuzes		Nose: M105		Tail: M106		
Overall length	47.2″	51.2″	63.0″	68.5″	135.8″	
Length of body	39.5″	40.6″	52.2″	61.6″	97.0″	
Body diameter	7.9″	12.2″	16.5″	20.8″	18.5″	
Wall thickness	0.16″	0.12″	0.2″	0.15″	0.50″	
Wall material			Steel			
Length of tail	8.5″	12.0″	14.0″	33.5″	49.2″	
Width of tail	11.0″	15.0″	20.5″	28.5″	26.1″	
Material of tail		Sheet steel			Sheet steel with cast-steel tail cone	
Weight of tail	2.6#	6.1#	5.0#	55.0#	140.0#	
Type of filling			Cast TNT			
Weight of filling	65.0#	148.0#	355.0#	650.0#	960.0#	
Total weight	119.4#	285.9#	611.0#	1175.0#	1920.0#	1830.0#
Charge/weight ratio	54.5%	52.0%	58.0%	55.3%	50.0%	52.4%
Body construction	Streamlined body formed by welding three cast-steel sections together				Cast-steel nose riveted to seamless steel tubing; rear not tapered	Seamless steel tubing
Tail construction	A cast-steel sleeve secured to body by a fin locking nut; four fins or vanes; internal box-type struts			Four vanes with bar struts, attached to body by screws	Four vanes riveted to tail cone; two sets of external bar struts to reinforce vanes; cone secured to flange on base plate	
Construction of suspension	Two U-shaped bar-steel eyebolts welded to body along longitudinal axis				Two U-shaped eyebolts on plates secured to body by cap screws	
Type of suspension	Horizontal					
Color and markings	Prior to March 11, 1942, these bombs would have been yellow all over with black manufacturers' markings; but since that date will be olive-drab with one-inch yellow bands around nose and base and a ¼-inch band around center of gravity.					

TABLE 3-2. Classification and Class of Demolition Bombs.

Present nomenclature	Obsolete nomenclature
Standard for manufacture:	
Bomb, demolition, 100-lb, Mk III	Bomb, demolition, drop, Mk I-C
Bomb, demolition, 300-lb, Mk III	Bomb, demolition, drop, Mk IV-C
Bomb, demolition, 600-lb, Mk III	Bomb, demolition, drop, Mk V-C
Bomb, demolition, 1100-lb, Mk III	Bomb, demolition, drop, Mk VI-C
Bomb, demolition, 2000-lb, Mk I MII	.....
Substitute standard for manufacture:	
Bomb, demolition, 100-lb, Mk I MI	.....
Bomb, demolition, 300-lb, Mk I MI	.....
Bomb, demolition, 2000-lb, Mk I MI	.....
Obsolete:	
Bomb, demolition, 25-lb, Mk I	Bomb, high-capacity, drop, Mk II
Bomb, demolition, 50-lb, Mk I	Bomb, high-capacity, drop, Mk III
Limited standard:	
Bomb, demolition, 100-lb, Mk I	Bomb, high-capacity, drop, Mk I
Bomb, demolition, 600-lb, Mk I MI	.....
Bomb, demolition, 2000-lb, Mk I	.....

Body Characteristics

From the point of view of body characteristics which were evident upon visual examination, demolition bombs available for use in the field were classified as follows:

1. The streamline-body type, which included the Mk I series of bombs (25-, 50-, and 100-lb sizes); the Mk I MI series of bombs (100-, 300-, and 600-lb sizes); and the Mk III series of bombs (100-, 300-, 600-, and 1100-lb sizes).

2. The cylindrical-body type, which included the 2000-lb demolition bombs Mk I, Mk I MI, and Mk I MII.

The contour of the original stream line-body type of bombs was based on the contour of the Eiffel dirigible IV (Reference 3). The requirement of this form was that the curvature would change in some regular and progressive manner, similar to the change in direction of a streamline. This form was chosen because it was believed that a bomb of such form would encounter the least resistance in its flight to the target and would also least retard the airplane in its movement while carrying the bombs, should these bombs be suspended from external racks. However, experience with artillery projectiles, when fired from howitzers or mortars at low velocities as compared with velocities attained by bombs in flight, indicated that although the air resistance may vary greatly, depending upon the shape of the projectile, the path of the projectile was not much different. As a result, in the later

development of bombs, the design shifted more toward the cylindrical-body type, which was more practical from a manufacturing and explosive-loading standpoint.

Mk I Series Demolition Bombs (25, 50, 100 lb)

The Mk I series of streamlined demolition bombs were designed and manufactured during World War I. These bombs existed initially in weights of 25, 50, 100, 300, and 600 lb. Later, they were available only in the 50- and 100-lb weight ranges. The bombs proved to be structurally unsatisfactory because their bodies or cases were not of sufficient strength, due largely to the numerous welded joints, both circumferential and longitudinal. The stabilizing fins were not sufficiently strong, nor were they properly attached to ensure against distortion either in handling of the bombs or in the flight of the bomb after release. In order to insert the tail fuze, which was the only fuze with which these bombs were equipped, the fins had to be removed in the field. The tail fuze did not function dependably and carried the further objection that it armed simultaneously with the release of the bomb from the airplane. The 25-, 50-, and 100-lb bombs were made entirely of sections of sheet steel, while the 300- and 600-lb bombs had cast-steel noses and sheet-steel rear sections. When these bombs were designated as obsolete, they were issued for training purposes only.

Mk I MI Series Demolition Bombs (100, 300, 600 lb)

Shortly after the World War I armistice, a modification of the Mk I series of streamlined demolition bombs was undertaken with a view of eliminating, in so far as possible, the unsatisfactory features and functioning which had been experienced with these bombs. The 25- and 50-lb bombs were not considered in the modification, due to the fact that their size and weight were insufficient for demolition purposes. The 100-, 300-, and 600-lb bombs were provided with nose fuzes of the arming-vane type, which armed only after the bomb had fallen a definite distance from the airplane. The 300- and 600-lb bombs were also equipped with an arming vane type tail fuze. The original fuzing arrangement in the tail of the 100-lb bomb was retained because of the great amount of modification which would have been required to introduce the improved arming vane type of fuze. New boosters and detonating arrangements were provided when a new type of fuze was added or substituted for the old. The new fuzes were in reality mechanical firing mechanisms inasmuch as they contained no explosive; the primer detonators were made up as a separate assembly. The stabilizing fins were strengthened by the addition of fin braces. After modification of these three bombs in the manner described, their nomenclature was changed from Mk I to Mk I MI. The 100- and 300-lb Mk I MI demolition bombs were included in the *substitute standards* class for manufacture. The 600-lb demolition bomb, Mk I MI, was placed in the *limited standard* class.

Mk III Series Demolition Bombs (100, 300, 600, 1100 lb)

To eliminate the unsatisfactory features which were not and could not be removed by modifying the Mk I bombs to Mk I MI bombs, the Mk III series of streamlined demolition bombs was designed. This series included the 100-, 300-, 600-, and 1100-lb bombs. The Mk III series bombs used both nose and tail fuzes of the arming-vane type. The 100-lb bomb was built up with a deep-drawn nose and rear body section that were joined together with circumferential welds. No longitudinal welds were used. The 300-, 600-, and 1100-lb bombs were designed with a cast-steel nose and deep-drawn rear body section, joined together with circumferential welds only. This body construction was much stronger than that used in the Mk I and Mk I MI types, due to the absence of longitudinal seams. The fin assemblies were designed as units, capable of easy adjustment and assembly to the bombs in the field. The units did not require removal from the bomb body in the fuzing procedure. The fin assembly of the Mk III series bombs was much more rigid than that for either the Mk I or Mk I MI series of bombs; the added strength was obtained by its construction as a unit and by use of fin braces. These bombs became the *standard for manufacture* at that time.

Mk I, Mk I MI, Mk I MII Demolition Bombs (2000 lb)

The nose of the cylindrical-body type of demolition bombs was designed in a form of a modified ellipse, and was either secured to or integral with the cylindrical portion. Because of several advantages of the cylindrical body type, as compared with the streamline type, it was adopted in the 2000-lb demolition bomb. It had been found that these bomb bodies could be manufactured cheaper inasmuch as the facilities of the tube and pipe industries could be utilized, the number of drawing operations in manufacture reduced, and loading operations facilitated. Greater strength was also obtained through the use of forged steel and the absence of seams, welded joints, and steel nose castings. The realization of these advantages was not obtained at the expense of either satisfactory flight or other important ballistic qualities. The 2000-lb demolition bomb Mk I MII was the *standard for manufacture*. The 2000-lb Mk I MI was the *substitute standard for manufacture*, while the 2000-lb Mk I was the *limited standard*. These 2000-lb bombs were fuzed, both nose and tail, with arming-vane types of fuzes. The fin assembly was designed as a unit with advantages similar to those outlined above for the fin assemblies of the Mk III series of demolition bombs.

TEST AND EVALUATION

Hard-Surface Test

A hard-surface test was designed to determine the strength of the bomb case. One of the first requirements of a demolition bomb was that the metal parts of the body or casing

would have sufficient strength to withstand the forces of impact on targets against which the bomb was to be used. This requirement was necessary so that when delay fuze action was used, the bomb could penetrate the target and keep the explosive charge intact until the fuze functioned. There are targets, such as armor plate, which no demolition bomb was expected to penetrate; in order to give the bomb case sufficient strength to accomplish this, the explosive content would be so small that the blast effect resulting from the detonation would be relatively ineffective. A direct hit with such a heavy bomb case would be necessary to produce any damage.

All demolition bombs were designed so that the bomb case theoretically would have sufficient strength to withstand impact on unprotected targets. This strength requirement, which was the same for all sizes of demolition bombs, specified that the bomb case must penetrate a standard hard surface at the Aberdeen Proving Ground, Md., without breaking up when dropped from an altitude sufficient to allow penetration of the maximum diameter of the bomb below 1 foot of concrete. This altitude was approximately between 2000 and 3000 feet, depending on the size and weight of the bomb. The hard surface for testing was a block of concrete 200 feet square by 1 foot thick lying on a bed of crushed rock 2 feet deep. This strength requirement would provide personnel using demolition bombs an idea of what was meant by the term "unprotected targets". This type of target did not include armor plate. All the bombs of the Mk III series and the 2000-lb Mk I MII, representing the then-*standard for manufacture*, passed the hard-surface test. The 2000-lb Mk I and Mk I MI bombs had also passed this test. The other bombs, classified as *substitute for manufacture*, *limited standard* and *obsolete*, all failed to pass this test.

High-Panel Test

The high-panel test was conducted to determine the relative magnitude of blast and destructive effect of the bomb fragments resulting from the detonation of the bomb. The test installation consisted of a piece of heavy armor plate that was set horizontally and flush with the surface of the ground on a concrete foundation in an open field. Facing this plate at distances of 75 and 150 feet were stout frames, 90 deg apart, carrying vertical panels faced with 2-inch oak plank. The panels at 75 feet from the bomb were 6 feet wide by 32 feet high, while those at 150 feet were 12 feet wide by 32 feet high. Occasionally 50-foot long panel installations were used that were made up of panels 4 feet wide by 21 feet high. Simple blast meters were placed at 50-ft increments from the bomb at a height of about 4.5 feet above the ground, some 90 deg apart and others 180 deg apart, in the direction of the wind. These blast meters, some as far as 300 feet from the bomb, were staggered so as not to be obstructed by the panels. The blast meters consisted of two wooden boards clamped together, with a series of 10 matched holes passing through both sides. The holes were graduated in size from 0.25 inch to 5.65 inches in diameter, each hole having twice the area of the next smaller hole. Between the boards was clamped a sheet of paper of tested material. The bomb, with its nose in contact with the armor plate was detonated statically in a vertical position at the center of the panel installation.

After the detonation, the panels were examined and a count was made of the perforations for each panel section. The sizes of the perforations were measured, and photographs of perforations in a given panel section were taken. A record was also made of the smallest hole blown through in each blast meter. Although no actual pressures resulting from the blast were measured, the smallest hole blown through gave an indication of the relative blast with respect to other bombs, since the actual pressure is nearly inversely proportional to the area of the hole blown through.

Functioning Test

The functioning test consisted of testing the bomb in action. This was a test of the satisfactoriness of the suspension arrangement, fuzing, and explosive train, and more particularly of the loading. When the test was conducted for acceptance of a certain lot of bombs, the bombs were equipped with fuzes and instantaneous-primer detonators of lots previously tested. To pass this test, the detonations had to be high order. The functioning test was also used for the purpose of obtaining the crater effect of the various sizes of demolition bombs, with instantaneous and delay-action primer detonators. The principal dimensions of the maximum craters obtained with delay-fuze action on normal soil were approximately as shown below:

Weight of bomb, lb.....	100	300	600	1100	2000
Diameter of crater, ft.....	20	27	37	45	53
Depth of crater, ft.....	5	7	10	13	16
Soil displaced, cu. yd.....	30	70	170	330	600

The behavior of the bomb in flight was also noted and recorded.

Trajectory Test

It was very important to know the various ballistic characteristics of bombs with a degree of accuracy not obtainable from visual observation. Of primary importance were the range, deflection from line of flight, time of flight, and ballistic accuracy of the various bombs when dropped from various altitudes and speeds. For the determination of the range of bombs, there were two cameras installed at the Aberdeen Proving Grounds—one known as the vertical camera obscura and the other as the oblique camera obscura. The cameras were placed at the ends of a surveyed baseline of about 12,000 feet. By means of these cameras, images of the airplane were reflected on plotting boards; the image positions were plotted at the same-second intervals as at both cameras. The plotting at the same-second intervals was made possible as a result of the two cameras being connected by a telephone, with a clock giving signals at intervals of 1 second in the circuit. When the plotter, using a specially constructed pencil, marked the position of the airplane on the plotting board, a contact was made which closed a circuit to a chronograph and recorded the actual time the contact was made.

When the bomb was released, the carrying hooks of the shackle opened and caused a radio signal to be sent, which was also recorded on the chronograph. By means of the chronograph record and the plot of the airplane images from both cameras, the position of the airplane in space when the bomb was released was determined by computation. The direction and speed of the airplane were also thereby determined. The position of the point of impact was determined by azimuth observations from two observation towers on a 2800-ft baseline. Knowing the point of release and the point of impact, the range of the bomb was obtained. By means of microphones constructed on the bombing field, the time of impact was recorded on the chronograph. Knowing the time of release and the time of impact, the time of flight of the bomb was computed. The range and deflection data obtained from a number of the same type of bombs, when reduced to the same conditions, gave an indication of the ballistic accuracy of the bombs.

DISPOSITION

The "Modified Mark" series of bombs, streamlined and filled with 100% TNT, was not satisfactory for war use, and the bombs were abandoned except for limited use for target practice and training purposes.

U.S. ARMY "M" SERIES DEMOLITION BOMBS

Prior to the organization of the Army-Navy Standardization Board in 1941, the "M" series bombs were also designated as "Demolition HE Bombs." Under the standardization policy, they were retitled as "General-Purpose High-Explosive (GPHE) Bombs."

The primary target spectrum for the "M" series of bombs included ammunition dumps, railway engines and cars, all types of construction, and aircraft on the ground.

DEMOLITION HE BOMBS

Weight Class and Mods

The "M" series demolition HE bombs included the 100-lb M30, 250-lb M57, 300-lb M31, 500-lb M43, 600-lb M32, 1000-lb M44, 1100-lb M33, and 2000-lb M34. These bombs were thin-walled, high-capacity bombs with charge-to-weight ratios ranging from 49.4 to 54.7% (see Table 3-3). The explosive fill could be either (1) 50-50 Amatol with TNT surrounds around the nose and tail booster sleeve to seal the amatol from moisture since Amatol is hygroscopic; or (2) 100% TNT. All of this series bombs, except the 100-lb M30, contained two built-in M104 auxiliary tetryl boosters—one in the nose and one in the tail. The 100-lb M30 had the auxiliary booster in the nose only. The M102 adapter booster (tetryl) was threaded to the base plate of all bombs in the series and received the tail fuze.

TABLE 3-3. "M" Series Demolition Bombs (Obsolete) (Reference 6).

Characteristics	100-lb M30		300-lb M31		600-lb M32		1100-lb M33		2000-lb M34	
Overall length, in.	36.0		48.6		59.5		68.7		90.4	
Length of body, in.	30.0		40.2		49.5		54.7		70.0	
Diameter of body, in.	8.2		10.9		15.2		19.8		23.3	
Thickness of wall, in.	0.16		0.27		0.35		0.43		0.5	
Length of tail, in.	9.75		12.1		13.9		18.5		25.7	
Width of tail, in.	11.0		14.9		20.4		27.0		31.6	
Weight of tail, lb	5.5		6.0		12.6		22.5		38.6	
Filling	Amatol 50-50	TNT	Amatol 50-50	TNT	Amatol 50-50	TNT	Amatol 50-50	TNT	Amatol 50-50	TNT .....
Weight of filling, lb	53.3	54.0	135.5	137.0	319.3	336.0	588.0	618.0	1061.0	1077.0
Total weight, lb	106.3	107.0	272.5	274.0	586.5	621.0	1111.0	1141.0	1971.0	1987.0
Charge/weight ratio, %	50.1	50.6	49.4	50.0	54.4	54.1	52.9	54.1	53.8	54.7
Fuzing	These bombs take the M103 Fuze in the nose and the M106 Fuze in the tail.									

Colors and Markings

The colors and markings of the "M" series bombs are the same as described for "Modified Mark" series bombs (see Table 3-1).

Body Construction

bomb body construction of the "M" series bombs could be from any one of (1) seamless steel tubing in which the nose of the bomb body was formed by swaging and the tail by drawing to the necessary diameter, (2) a one-piece forging, or (3) formed from cast sections welded together. The aft closures incorporated a female base-filling plate. Typically, the nose shape (ogive with a threaded opening for a nose fuze) was joined or formed to a cylindrical body that in turn was necked down ("V" shaped) to approximately one-half the major bomb diameter at the back end to interface with a fixed-fin low-drag stabilizer. Figure 3-2 is an example of two classes of the "M" series demolition bombs.

Suspension System

The suspension lugs were similar to the previous Modified Mark series, 14-inch spacing through the 1000-lb class and 30-inch spacing for the 2000-lb class. The eyebolts were formed from bar steel into "U" shapes and then welded to the bomb body along the longitudinal axis.

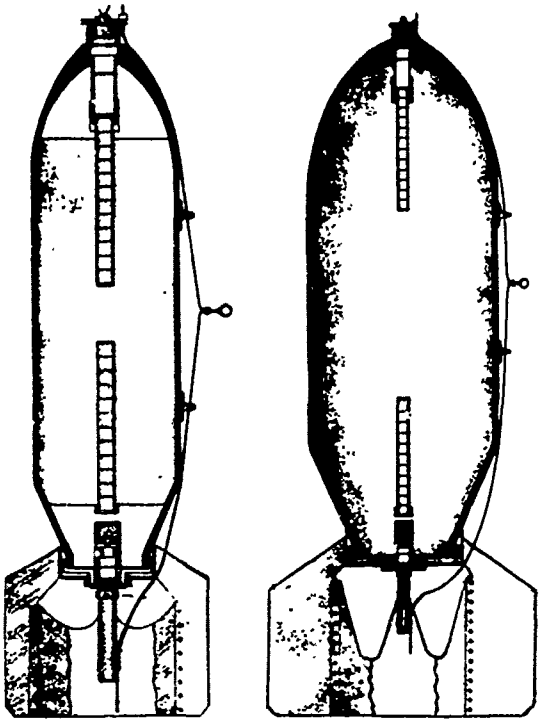


FIGURE 3-2. "M" Series Demolition Bombs, 600-lb M32 and 1100-lb M33 (Reference 5).

Tail Construction

The tail consisted of (1) a cast steel sleeve secured to the body of the bomb by a fin-locking nut, (2) four fins or vanes, and (3) internal box-type struts. One vane and one strut were pressed from a single piece of metal and the four pieces were then welded together and to the sleeve. The fins, vanes and box-type struts were sheet steel.

ARMOR-PIERCING HE BOMBS

All of the "M" series armor-piercing (AP) HE bombs were low-capacity, low charge-to-weight ratio bombs ranging from 2.5 to 5.5% of Explosive D fill (see Table 3-4). These latter bombs were converted artillery projectiles from which the rotating bands were removed. All the cases were single-piece steel forgings. The modifications to the M52 and M62 bombs differed only slightly in external dimensions and all were equipped with a nose cap for streamlining. The truncated tail cones were secured to the bomb base by a locking nut at the top of the fuze body. The four fins or vanes were supported by internal box-type struts.

TABLE 3-4. "M" Series Armor-Piercing HE Bombs (Obsolete) (Reference 6).

Bombs	600-lb M62	800-lb M61	900-lb M60	1000-lb M52	1400-lb M63
Overall length, in.	62.1	58.7	61.7	70.9	69.1
Length of body, in.	46.9	38.6	41.3	50.0	45.7
Diameter of body, in.	10.1	12.4	12.2	12.3	14.3
Wall thickness, in.	.....	.....	.....	2.3	.....
Length of tail, in.	17.5	22.7	22.76	22.76	24.0
Width of tail, in.	13.8	16.6	16.6	16.6	19.6
Weight of tail, lb	15.12	22.4	22.4	21.0	.....
Filling	Explosive D	Explosive D	Explosive D	Explosive D	Explosive D
Weight of filling, lb	33.61	32.68	43.34	58.35	35.0
Total bomb weight, lb	634.0	853.0	889.0	1077.0	1412.0
Charge/weight ratio, %	5.5	3.8	4.8	5.4	2.5

The suspension system consisted of two U-shape eyebolts welded to plates that were welded or riveted to suspension bands. The bands were secured to the case by tightening bolts on the underside of the bombs.

Figure 3-3 is an example of three classes of the "M" Series AP Bomb. Fuzes for these bombs were the M102 and AN-M102, including the A-1 and A-2 modifications, all tail mounted. The target spectrum for the armor-piercing HE series included armored naval craft, reinforced concrete, and heavy steel construction.

There was one semi-armor piercing bomb included in the "M" series, the 2000-lb SAP M103. The bomb body was cylindrical in shape, fabricated from thick, seamless steel tubing, somewhat streamlined in shape, with a semi-pointed solid nose permitting tail fuzing only. The suspension lugs were 30-inch apart and were welded to the case similar to the GP bombs. Later, suspension bands were available for 14-inch suspension racks.

A box-type tail was used as on the GP bombs. The explosive fill was Picratol, a mixture of 52% Explosive "D" and 48% TNT. Wax material was poured into the nose end of the bomb to cushion the explosive against premature detonation on impact with hard targets. An adapter booster, M115A1 was used with the AN-M102A2 fuze and the M104 auxiliary booster (see Figures 3-4a and 3-4b). For regular missions, the AN-M102A2, AN-M102A1, and M162 fuzes were used; for special missions, the M114, M114A1, M117 (minimum altitude bombing), M125, M125A1 (long delay), and M134 fuzes were used. For a simple comparison between AP, SAP, and GP bombs, see Figure 3-5. Note the heavy wall and the absence of a nose fuze in the nose section of the AP bomb.

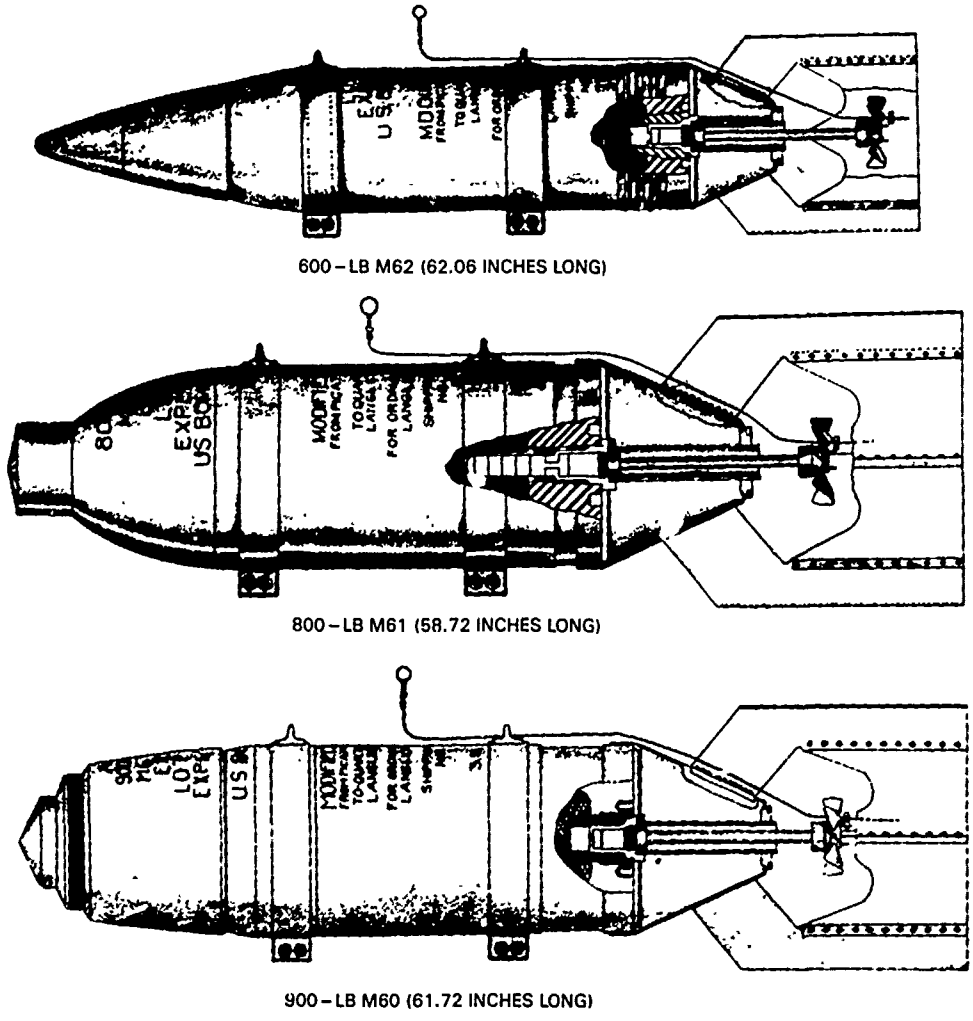


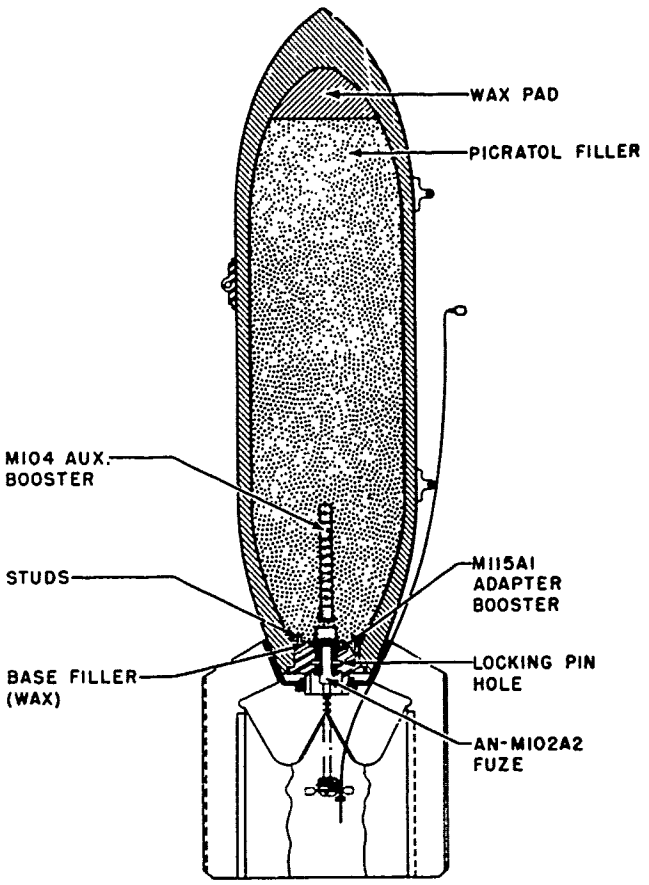
FIGURE 3-3. U.S. Army "M" Series Armor-Piercing Bombs (Obsolete); Converted Artillery Projectiles (Reference 5).

OTHER BOMB TYPES, "M" SERIES

Other bombs that carried the "M" designation, although not actually classified in the "M" series, included fragmentation bombs, fragmentation bomb clusters, and parachute-fragmentation bombs as described in the following paragraphs.

4-lb Fragmentation "Butterfly" Bomb M83

The 4-lb M83 fragmentation bomb was an adaption of the German SD-2 "butterfly" bomb and, except for minor details, was an exact replica of that bomb. The target spectrum was airfields, roads and troop movements, industrial districts, residential areas, etc. The



Overall length, inches	89.29
Body length, inches	68.5
Body diameter, inches	18.63
Wall thickness, inches	1.3
Tail length, inches	25.6
Tail width, inches	25.8
Tail weight, lb	52.7
Filling	Picratol
Weight of filling, lb	556
Total weight, lb	2039
Charge/weight ratio	27%

FIGURE 3-4a. 2000-lb Semiarmor-Piercing Bomb M103 (Reference 6).

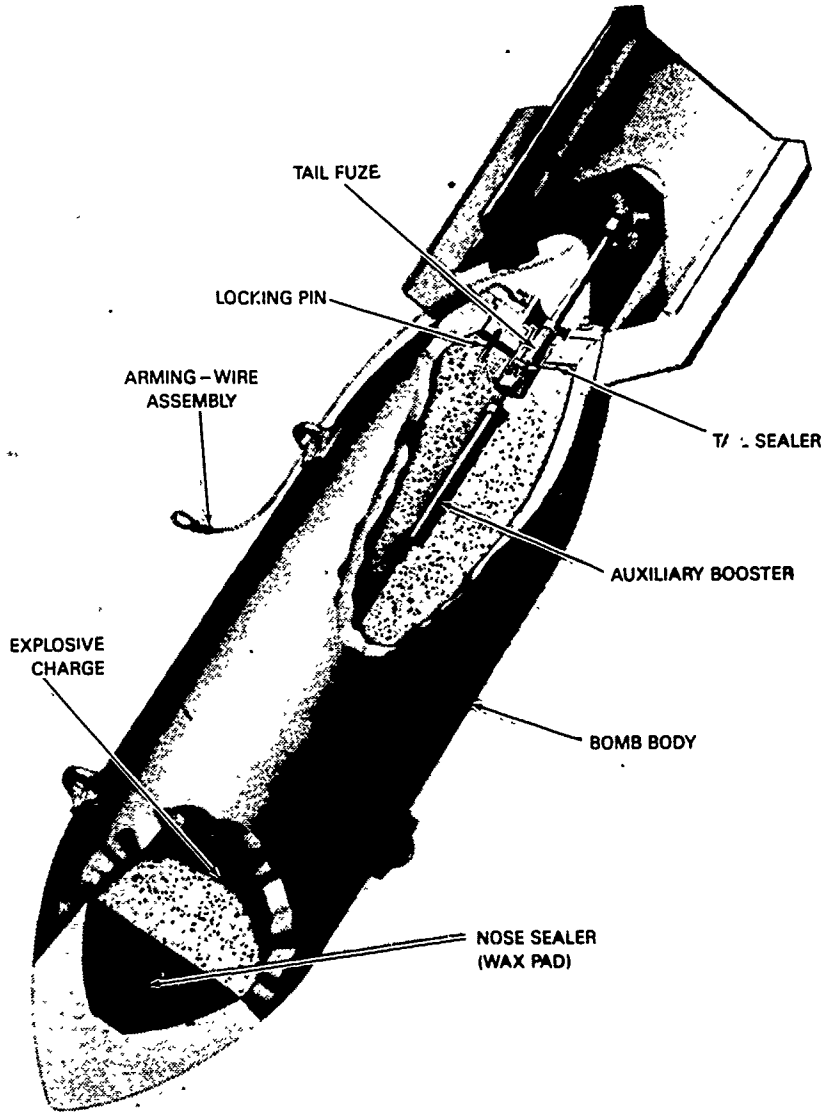


FIGURE 3-4b. 2000-lb Semiarmor-Piercing Bomb M103, Cutaway View (Reference 6).

bombs were cylindrical in shape, made from two steel castings (half sections) and welded together. The fuze cavity, positioned athwartships in the body, was 1.75 inches in diameter and incorporated a left-hand thread to prevent unscrewing of the fuze while the bomb was in flight (see Figures 3-6 and 3-7).

Two semi-cylindrical surfaces (butterfly wings) and two discs (propeller blades) inclined at a slight angle, were spring-hinged together, independent of the bomb. In the unarmed position, these four pieces, or vanes, were folded around the bomb forming a

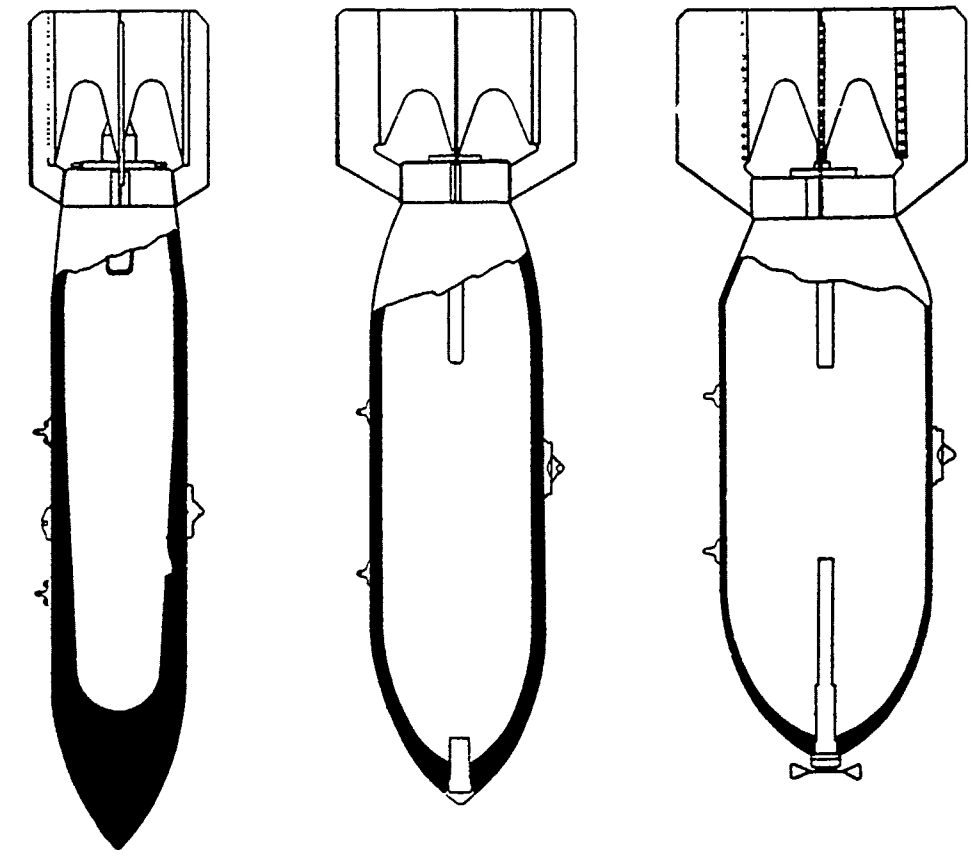


FIGURE 3-5. Comparison of Armor-Piercing, Semiarmor-Piercing, and General-Purpose Bombs (Reference 7).

cylindrical outer bomb casing which could be held closed against the pressure of the vane coil spring by means of a safety clip. A cable extension/arming spindle projected from the fuze through the folded outer bomb casing. The bomb used either the M129 fuze (air or ground burst), the M130 fuze (mechanical time delay), or the M131 fuze (anti-disturbance) for respective tactical employment. The fuzes, mounted on the bomb case midway between the cylinder ends, were installed and their firing actions set at the time of manufacture. Approximately 12% of the complete weight of the bomb was explosive filler Composition B, Ednatol, or TNT.

When the bombs were packed into cluster adapters, the safety clips were removed; however, the bombs remained in their closed status due to their proximity to each other. When the cluster adapter burst open, the individual bombs scattered and the vane assembly on each bomb, under the influence of its coil springs, spread open. The air resistance (flow) then caused the vane assembly to raise up the arming spindle. The square head on

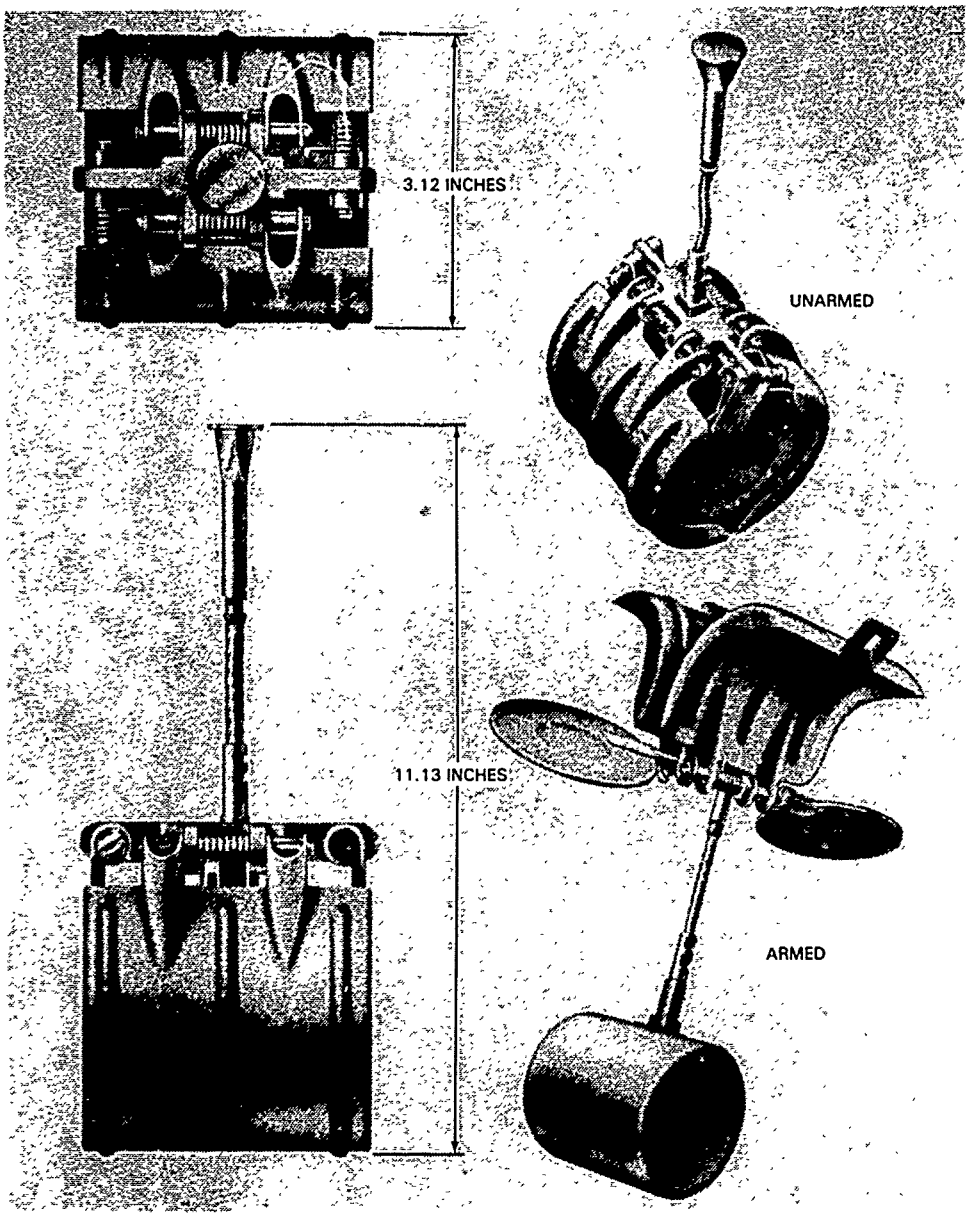
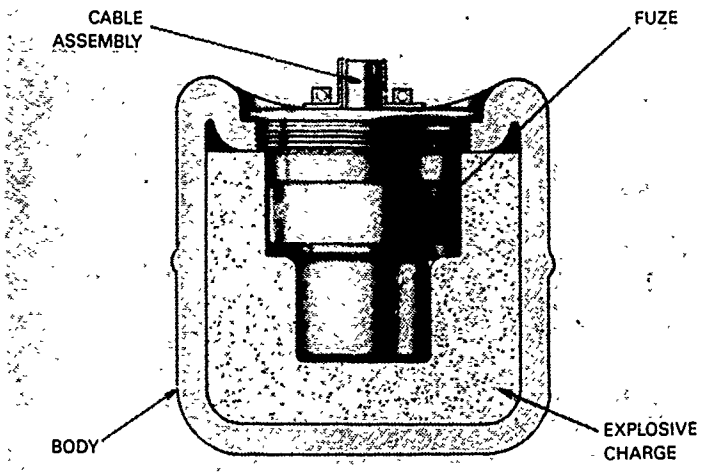


FIGURE 3-6. 4-lb Fragmentation Bomb M83, Exterior View (Reference 7).

the spindle engaged a square hole in the hinge of the vane assembly. The two butterfly wings reduced the velocity of descent of the bomb; the two propellers, being set at angles to each other, caused the vane assembly to turn in a counterclockwise direction, unscrewing the arming spindle out of the fuze body and thereby permitting the fuze to arm. The arming spindle was not withdrawn completely from the fuze, being retained by a collar on the spindle.

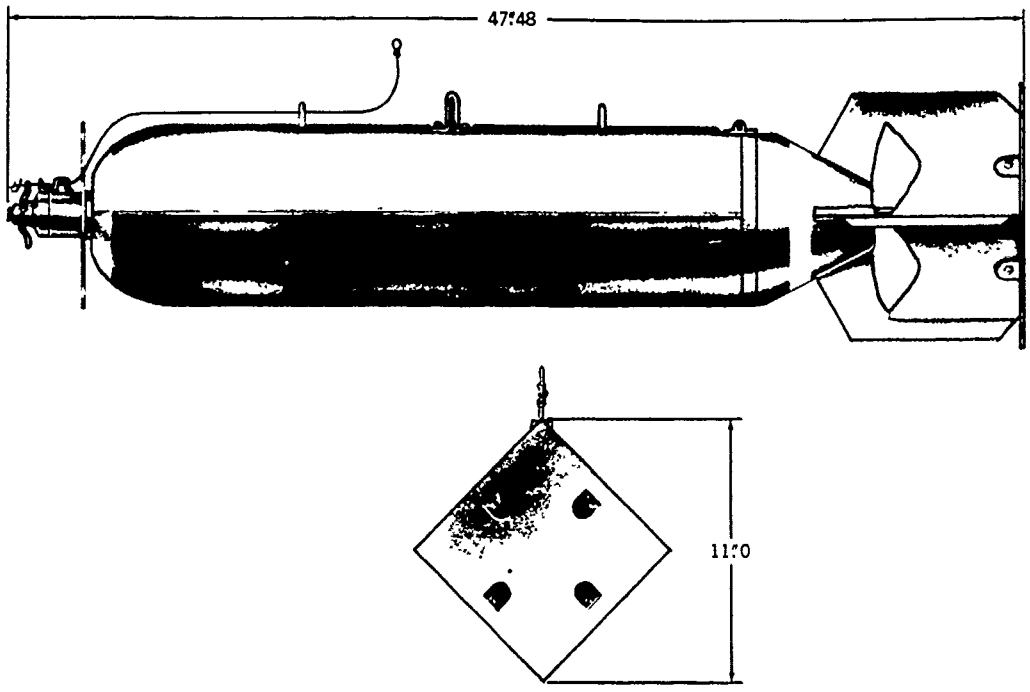


Model	M83
Assembly drawing no.	82-0-106
Length of assembled bomb, inches	11.13
Body diameter, inches	3.12
Butterfly-wing span, inches	9.5
Butterfly-wing length, inches	3.0
Weight of explosive charge, lb	0.5
Weight of assembled bomb, lb	
Loaded with Composition B	3.82
Loaded with Ednatol	3.81
Loaded with TNT	3.80
Fuze (integral)	M129, M130, M131
Bomb cluster	
100-lb size	M28A2
500-lb size	M29A1
Cluster adapter	
100-lb size	M15A2
500-lb size	M16A1

FIGURE 3-7. 4-lb Fragmentation Bomb M83, Cutaway View and Physical Characteristics (Reference 7).

There were two sizes of cluster adapters (containers or dispensers) for these bombs:

1. The 100-lb M15, that contained 24 M83 bombs and was designated the M28 Fragmentation Bomb Cluster (Figures 3-8 and 3-9)
2. The 500-lb M16 that contained 90 M83 bombs and was designated as the M29A1 Fragmentation Bomb Cluster (Figure 3-10)



Model	M28A2
Assembly drawing no.	82-0-107
Length of cluster, inches	47.48
Diameter, inches	8.0
Cluster adapter	
Model	M15A2
Length, inches	43.67
Fin span, inches	11.0
Fragmentation bombs	
Model	M83
Number required	24
Weight of each bomb, lb	3.81
Weight of cluster, lb	115.7
Fuze (cluster-opening)	AN-M146A1
Bushing, case locking	438075

FIGURE 3-8. 100-lb Fragmentation Bomb Cluster M28A2, Exterior View (Reference 7).

Both clusters used the M111A2 or M146 aerial-burst fuze. Tactical deployment or release of the cluster bombs was from altitudes of 3000 to 5000 feet, with the fuze set to function 5 to 8 seconds after release, respectively. With these settings, the M83 bombs formed a pattern of approximately 200 x 300 feet on the ground.

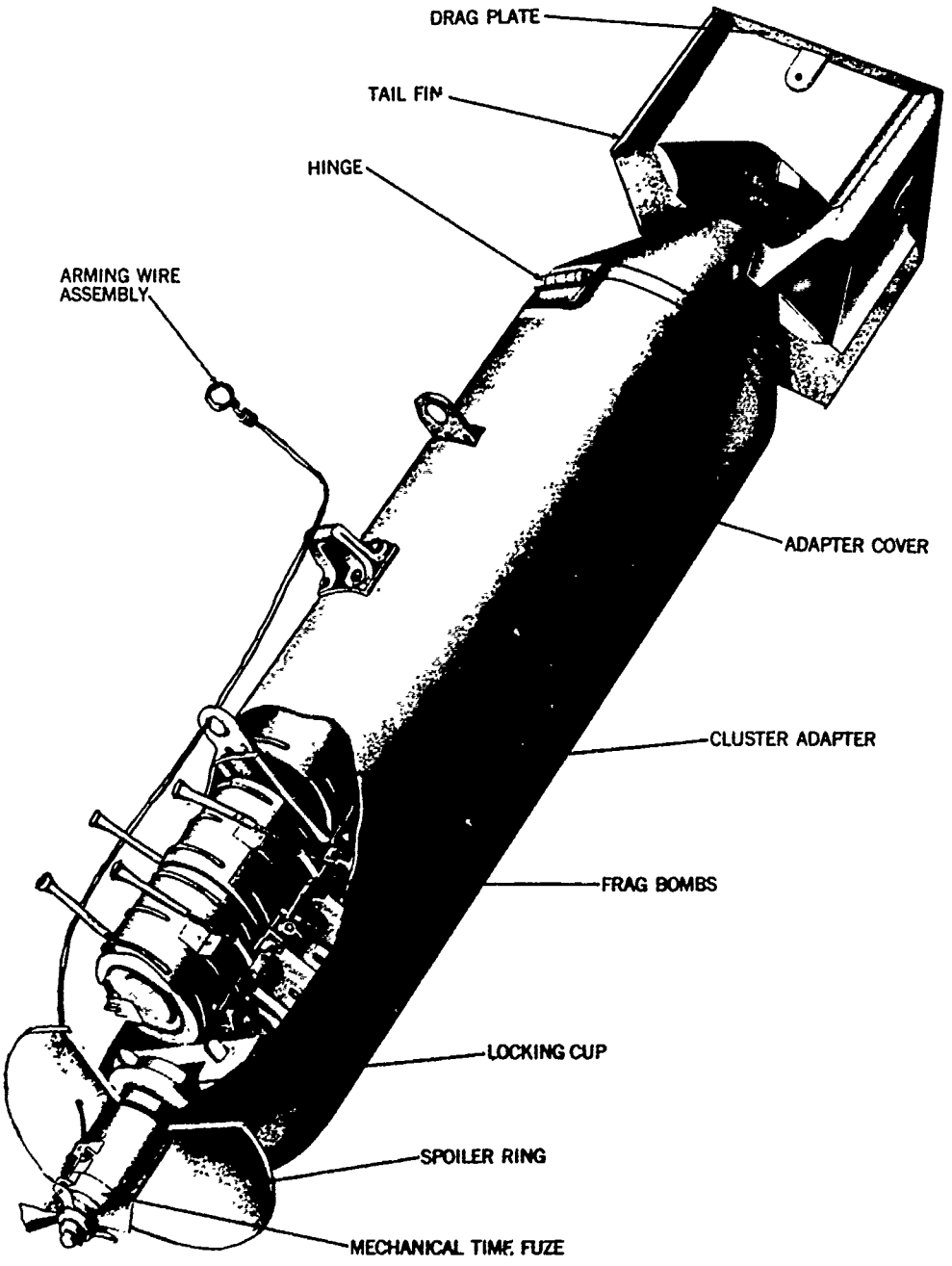


FIGURE 3-9. 100-lb Fragmentation Bomb Cluster M28A2, Cutaway View (Reference 7).

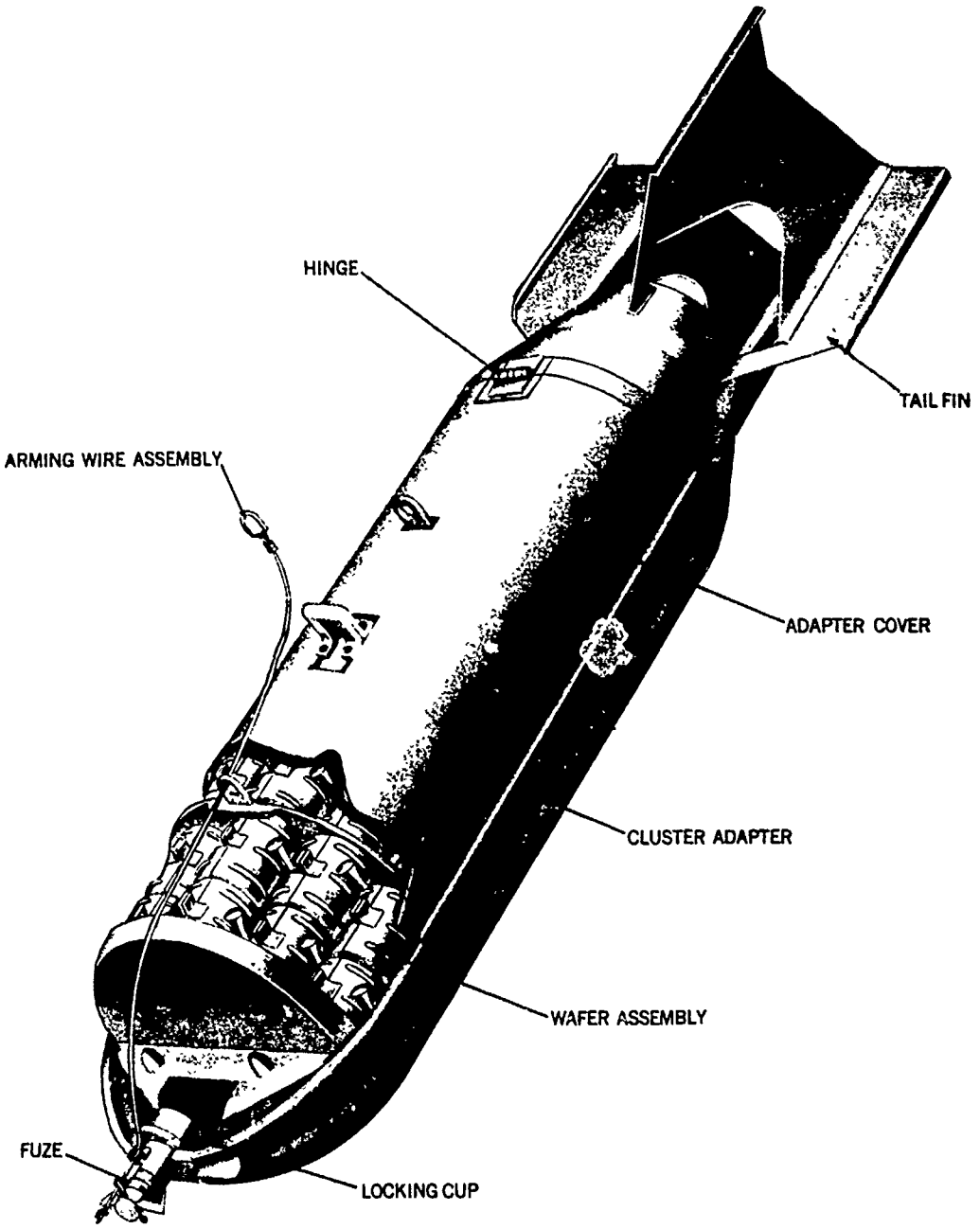


FIGURE 3-10. 500-lb Fragmentation Bomb Cluster M29A1, Cutaway View (Reference 7).

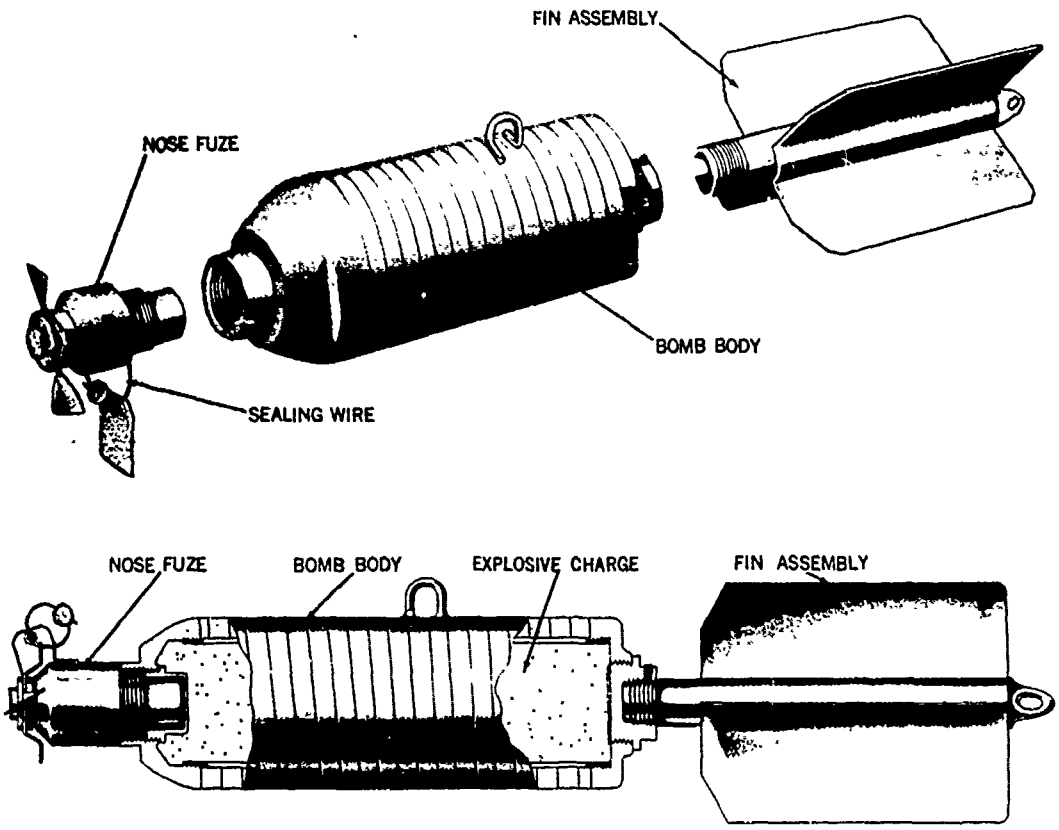
20-lb Fragmentation Bomb AN-M41, and 23-lb Parachute Fragmentation Bombs AN-M40 and M72

The 20- and 23-lb fragmentation bombs AN-M41, AN-M40, and M72 were constructed of spirally wound wire wrapped around a seamless steel inner tube that was threaded to hold the cast-steel nose and tail sections. The fin assembly for the 20-lb AN-M41 high-level fragmentation bomb was made of four rectangular sheet-steel vanes welded to a one inch cast iron pipe (Figure 3-11). The threaded end of the pipe was secured to the base filling plug of the bomb. The 23-lb AN-M40 and M72 low-level parachute fragmentation bombs were fitted with cylindrical sheet-steel parachute housings which had end caps at the rear and contained a white silk parachute unit, M3 for the M40 bomb and M4 for the M72 bomb. Both the 20-lb and 23-lb fragmentation bombs had a U-shaped steel eyebolt welded to the bomb case at the center of gravity for horizontal suspension. An eyebolt was welded to the tail of the AN-M41 for vertical suspension. Approximately 13% of the complete weight of the bombs was either Amatol 50-50 or TNT.

The 20-lb AN-M41 fragmentation bomb (Figure 3-11) was used in the 100-lb Fragmentation Bomb Cluster, MI, AN-M1A1, AN-M1A2, and 500-lb Fragmentation Bomb Cluster AN-M26, AN-M26A1, AN-M26A2 (Figures 3-12 and 3-13). The difference between the 100-lb AN-M1A1 and AN-M1A2 was in the cluster adapter. The AN-M1A2 cluster was the only one in the series that was issued unfuzed. The cluster adapter for the 500-lb M26A2 cluster was a "quick-opening frame" type adapter that held the AN-M41A1 fragmentation bombs in two banks of ten each. The M13A2 cluster adapter could be set for immediate or delayed action (5 to 92 seconds) after release of the bombs. A fuze was not required for immediate release since withdrawal of the arming wire opened the adapter. For delayed action, a mechanical time fuze (M155A1) was screwed into the fuze well in the center tube of the adapter. The fuze would function after a settable time delay following release of the cluster from the aircraft. The difference between the fragmentation bomb cluster M26A2 and M26A1 was in the adapters, fragmentation bombs, and fuzing components used. The M26A2 cluster was issued with 20 unfuzed, 20-lb AN-M41A1 fragmentation bombs assembled into an M13A2 cluster adapter. The M26A1 cluster was issued with 20 fuzed AN-M41 fragmentation bombs assembled into an M13A1 cluster adapter (see Figure 3-13).

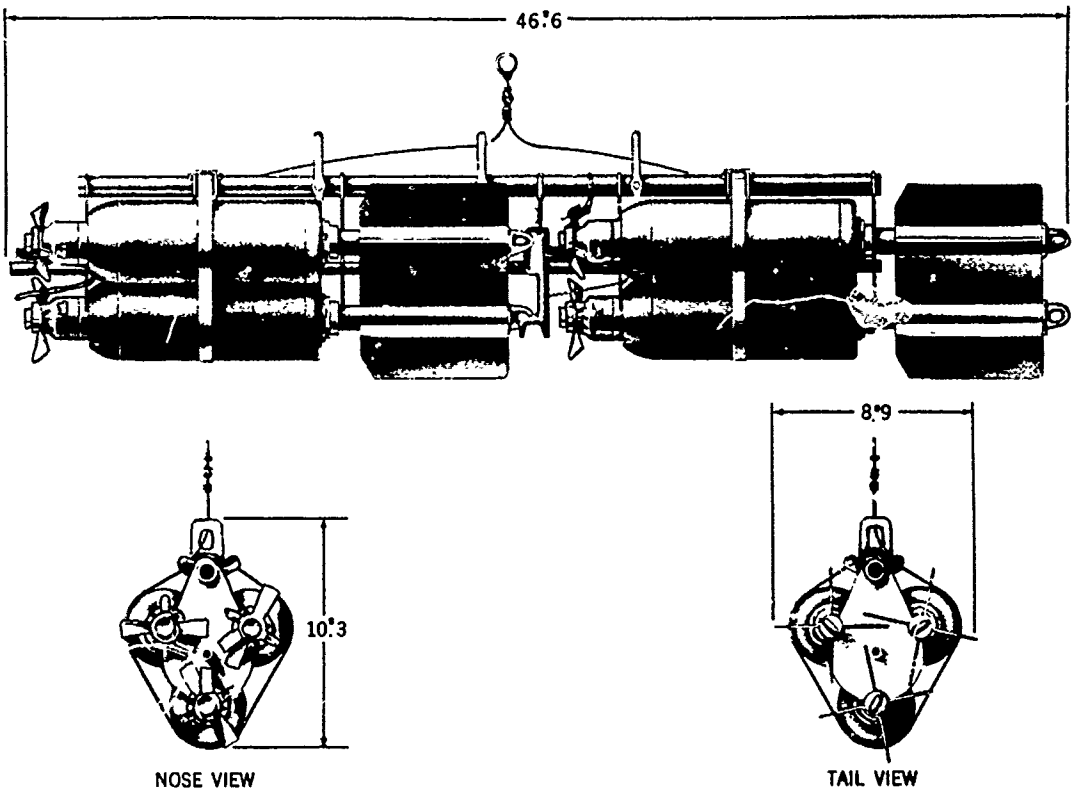
The 23-lb AN-M40 parachute fragmentation bombs were always clustered. Normally three AN-M40 bombs within the AN-M1A3 cluster adapter formed the fragmentation bomb cluster AN-M4 (see Figure 3-14).

The 23-lb M72 fragmentation bomb, a slightly modified version of the AN-M40, was adapted for individual vertical suspension in vertical cellular racks by several types of Army planes. Both the AN-M40 and M72 were used against ground targets flying at low altitudes, whereas the 20-lb AN-M41 was used against personnel, motor convoys, airplanes, on-the-ground targets, aboard ships, etc. The AN-M40 and M72 low-level bombs were designed to be dropped from a maximum altitude of 400 ft. The AN-M41 high-level bomb was designed to be dropped from a minimum altitude of 800 ft.



Model	AN-M41A1
Assembly drawing no.	82-0-39
Length of assembled bomb, inches	22.4
Body diameter, inches	3.64
Fin span, inches	5.13
Weight of explosive charge, lb	
Amatol 50-50	2.57
TNT	2.7
Weight of fin assembly, lb	1.6
Weight of assembled bomb, lb	
Loaded with Amatol 50-50	19.7
Loaded with TNT	19.8
Nose fuze	AN-M110A1, AN-M158
Bomb cluster	
100-lb size	AN-M1A2
500-lb size	M26A2
Cluster adapter	
100-lb size	AN-M1A3
500-lb size	M13A2

FIGURE 3-11. 20-lb Fragmentation Bomb AN-M41A1, Exploded View (top), Cutaway View (bottom) (Reference 7).



Model	AN-M1A2
Assembly drawing no.	82-0-69
Length of cluster, inches	46.6
Width of cluster, inches	8.9
Height of cluster, inches	10.3
Cluster adapter	
Model	AN-M1A3
Length, inches	38.25
Fragmentation bombs	
Model	AN-M41A1
Number required	6
Weight of each bomb, lb	20.0
Weight of cluster, lb	128.0
Nose fuzes	
Model	AN-M110A1 or AN-M158
Number required	6

FIGURE 3-12. 100-lb Fragmentation Cluster Bomb M1, AN-M1A1, and AN-M1A2 (Reference 7).

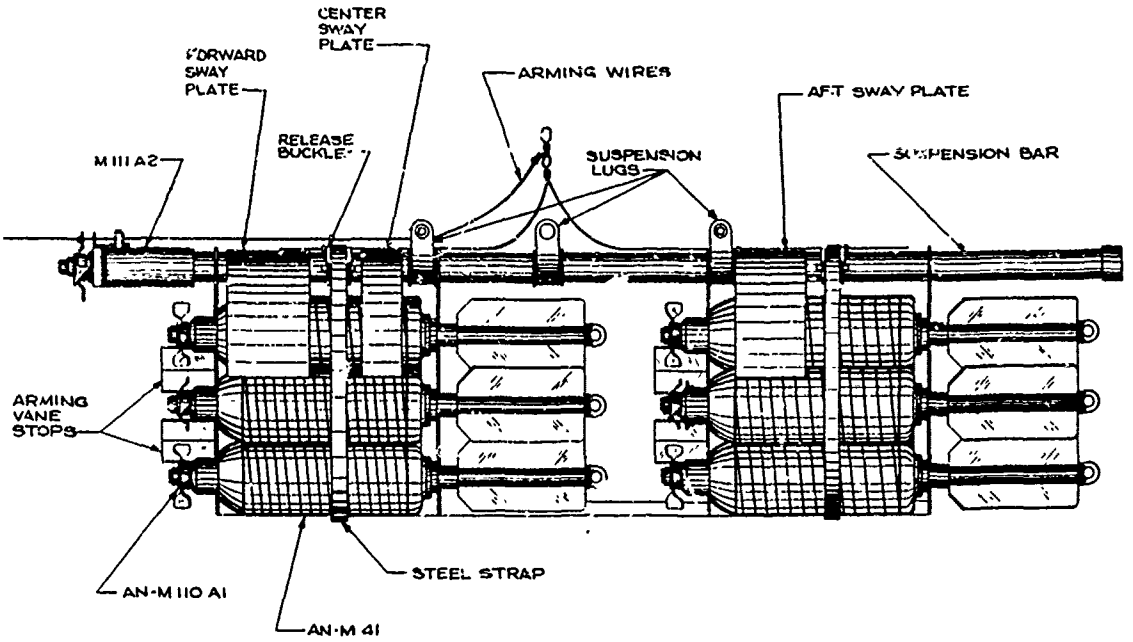


FIGURE 3-13. 500-lb Fragmentation Cluster Bomb AN-M26, AN-M26A1, AN-M26A2 (Consists of Twenty 20-lb Fragmentation Bombs AN-M41) (Reference 5).

The general performance characteristics of the 20-lb AN-M41 fragmentation bomb were typical of smaller-sized fragmentation bombs. The spirally wound outer case of the AN-M41 and AN-M41A1 was 0.44 inches in cross section and, upon detonation, broke up into 1000 to 1500 fragments. The average weight and general distribution of the fragments was between 0.2 and 0.3 ounces (87 to 131 grains) as seen in Figure 3-15. From Figure 3-16 it can be seen that approximately 80% of all fragments were projected within 72 deg on either side of the bomb's "equator". Within this 72-deg arc, there was a very dense spray of fragments in the region from the bomb's equator to about 6 deg towards the bomb tail. At a distance of 80 feet from the bomb, the density was about 12 fragments per square yard; at 60 feet, the density was about three fragments per square yard. The initial velocity of the fragments was 2800 to 2900 ft/sec, and some of the fragments projected as far as 50 yards. Penetration tests showed that about 65% of all the fragments would penetrate 0.125-inch thick mild steel plates at a distance of 60 feet from the bomb detonation. Additional details of the physical characteristics of the 20-lb AN-M41 and 23-lb AN-M40 and M72 fragmentation bombs are given in Table 3-5.

30-lb Fragmentation Bomb M5

The M5 fragmentation bomb body consisted of a seamless steel tube over which rings cut from cast-steel pipe were fitted. Threaded, cast-steel nose and base sections were

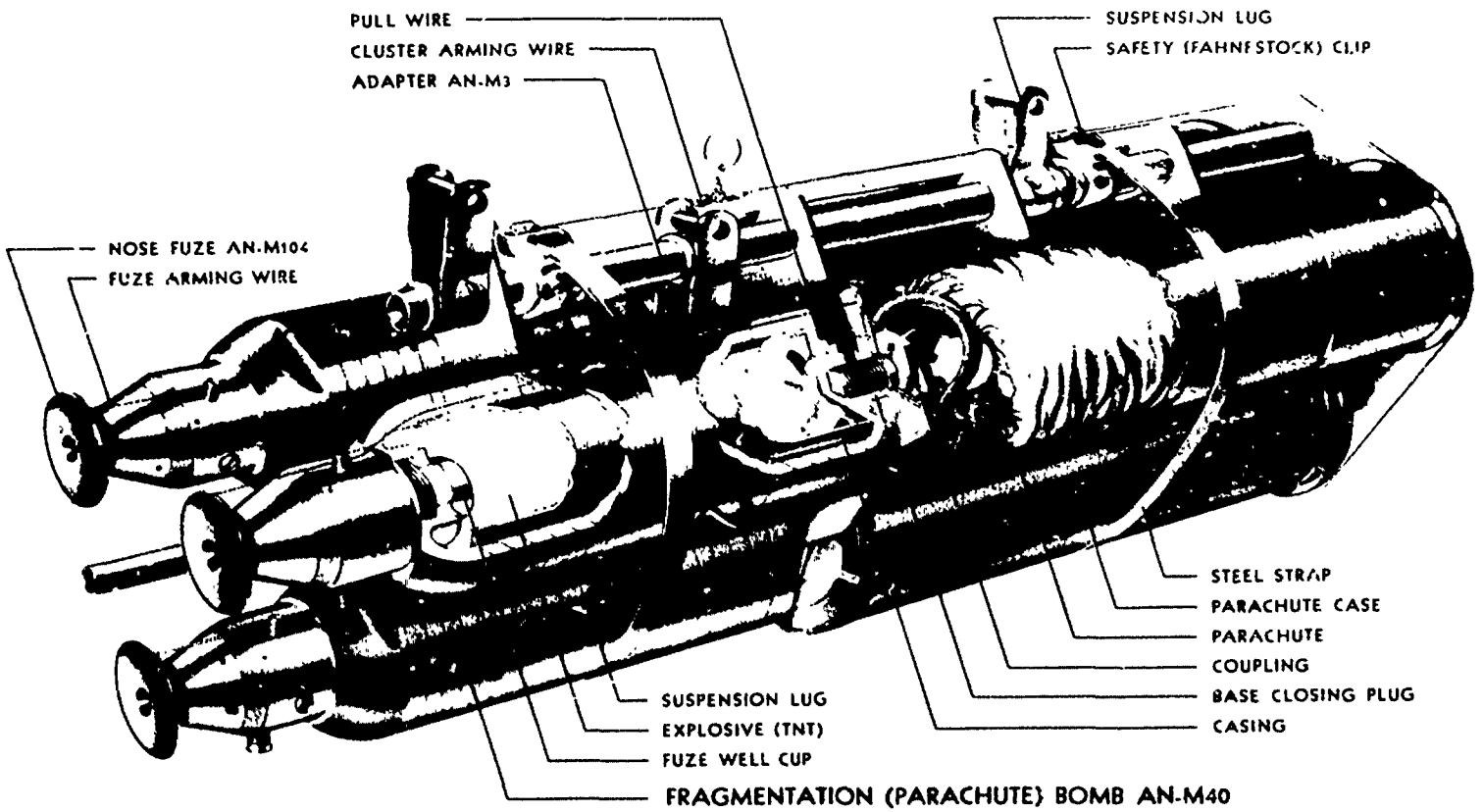


FIGURE 3-14. 100-lb Fragmentation Bomb Cluster AN-M4, AN-M4A1, AN-M4A2 (Reference 5).

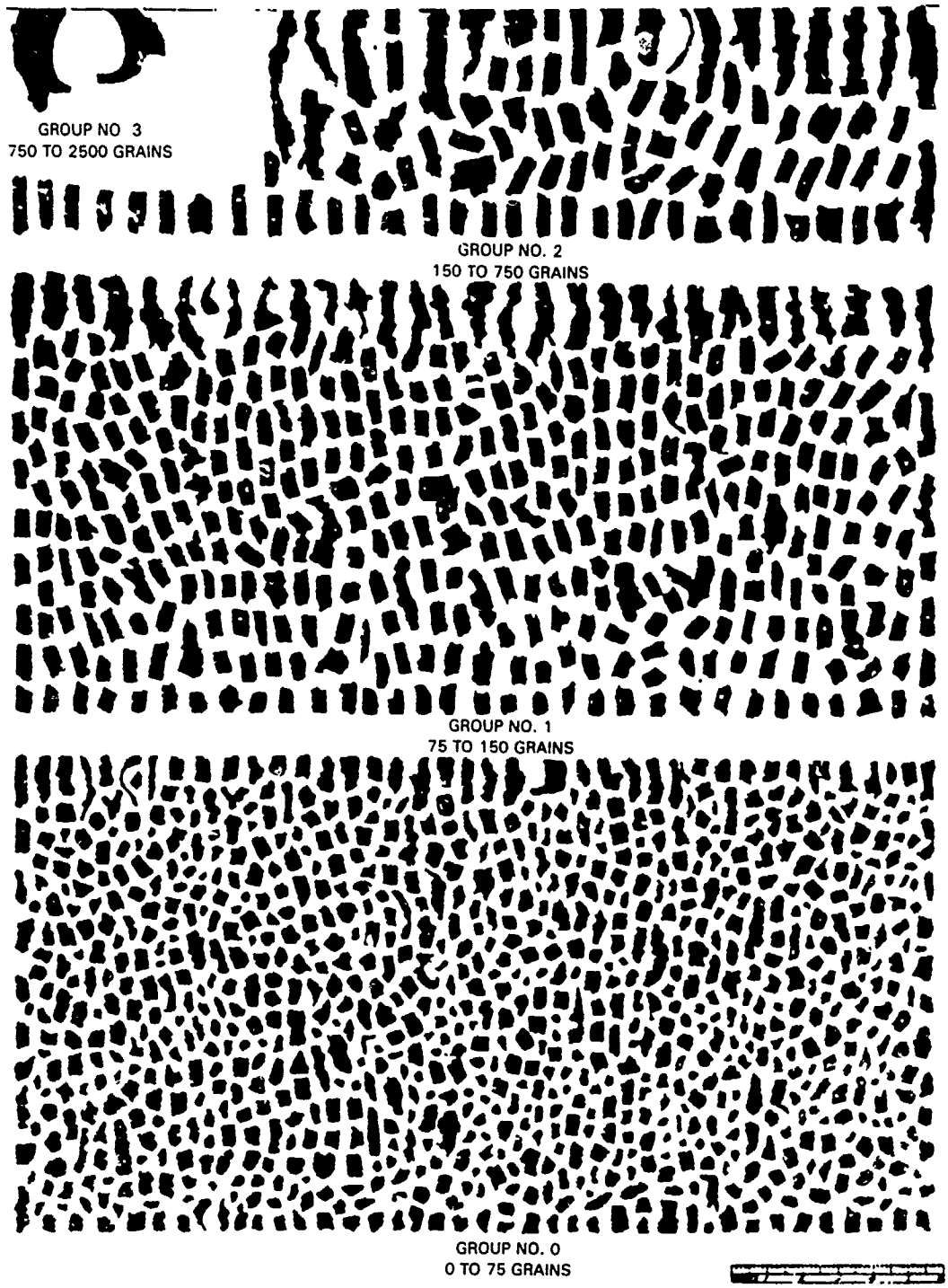


FIGURE 3-15. Typical Sample of Fragments from a 20-lb Fragmentation Bomb AN-M41 (Reference 7).

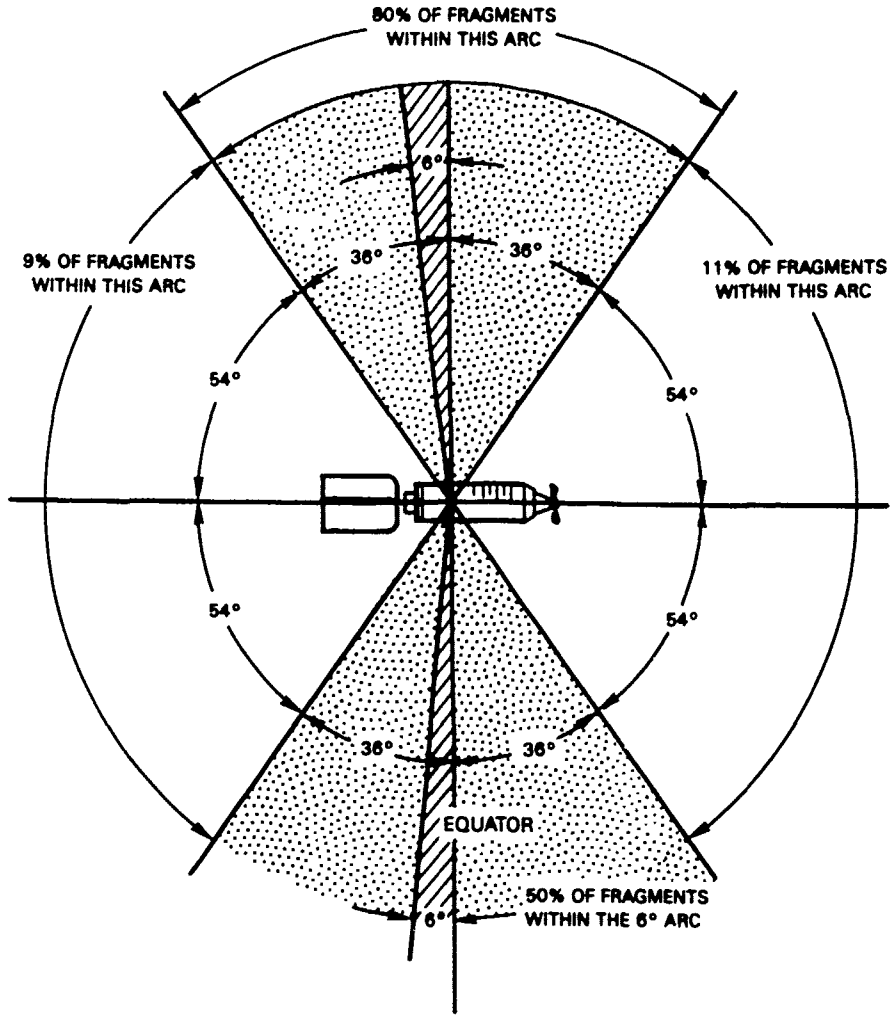
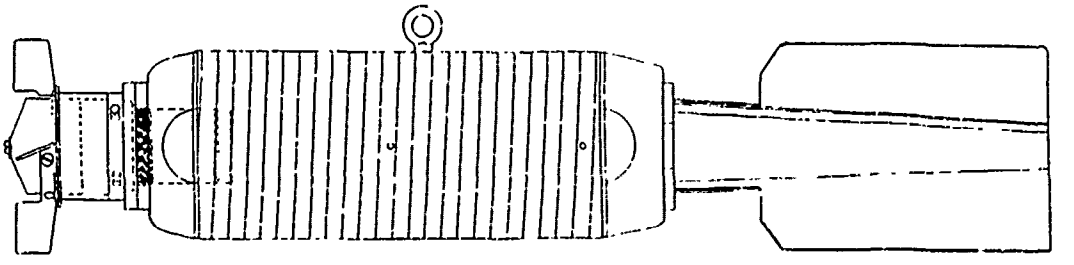


FIGURE 3-16. Fragment Pattern for 20- to 23-lb Fragmentation Bomb (Reference 7).

assembled to the center tube/cast iron pipe section. The bombs could be suspended horizontally, vertically, or in a cluster. Suspension lugs, U-shaped eyebolts, were welded to the bomb at the center of gravity and to the aft end of the tail section. Six 30-lb M5 fragmentation bombs were contained in the Fragmentation Bomb Cluster M3. The tail was constructed of four rectangular sheet-steel vanes that were welded to a length of one inch cast-iron pipe that screws into the base filling plug. Physical characteristics of the 30-lb fragmentation bomb M5 are included in Figure 3-17.

TABLE 3-5. Characteristics of 20-lb Fragmentation Bomb and 23-lb Parachute Fragmentation Bomb (Reference 5).

Characteristics	20-lb AN-M41	23-lb AN-M40 and M72
Overall length, inches	19.5	26.7
Body length, inches	11.3	11.3
Body diameter, inches	3.6	3.6
Wall thickness, inch	0.56	0.56
Tail length, inches	9.25	13.9
Tail width, inches	5.1	4.35
Tail weight, lb	1.6	5.3
Filling type	TNT	TNT
Weight of filling, lb	2.7	2.7
Total weight, lb	20.3	24.5
Charge/weight ratio, %	13.0	11 0
Fuzing	AN-M110A1, M110. M109	AN-M120, AN-M120A1, AN-M104



Overall length, inches 25 5
Body length, inches 13.05
Body diameter, inches 4.2
Wall thickness, inches 0.6
Tail width, inches 6.5
Type of filling ..... TNT
Weight of filling, lb 4.6
Total weight, lb 29.8
Charge/weight ratio 16.3%
Fuzing ..... Mk XIV

FIGURE 3-17. 30-lb Fragmentation Bomb M5 Mods 1, 2, and 3 (Reference 5).

90-lb Fragmentation Bomb M82

The 90-lb fragmentation bomb M82 was constructed similar to the 20- and 23-lb fragmentation bombs. Basically, a square helical steel spring was wrapped around a seamless cylindrical steel tube. A threaded opening was incorporated into the rounded cast-steel nose section to house the nose fuze. The tapered cast-steel section incorporated appropriate threaded interfaces to screw into the inner cylindrical steel tube, to hold an aft closure plug (following explosive loading) and for attachment of the box-type tail fin assembly by means of a fin lock nut (Figure 3-18).

The M82 bomb was designed for use in the fragmentation bomb cluster M27 (formerly T8) (Figure 3-19) and for single suspension by means of a lug welded to the outer steel casing. When adapted for single suspension, instantaneous or VT fuzes were used. The M27 cluster bomb could be adjusted to dispense six 90-lb M82 fragmentation bombs immediately after rack release or through the use of a mechanical time fuze, from 5 to 92 seconds after rack release. The mechanical time fuzes (M111A2, M155) required the addition of an adapter booster. Approximately 14% of the complete weight of the 90-lb M82 fragmentation bombs was explosive fill, either TNT or composition B. The immediate opening of the cluster (minimum altitude 1000 ft) provided an optimum impact pattern against parked aircraft, vehicles, and personnel, as well as sufficient fall time for the mechanical time fuze to arm.

Additional details of the physical characteristics of the M82 fragmentation bomb are shown in Table 3-6.

TABLE 3-6. Physical Characteristics of 90-lb Fragmentation Bomb M82 (Reference 5).

Overall length, inches 28.0	Fuzing: M103, AN-M103,
Body length, inches 19.8	AN-M103A1, M135, M135A1
Body diameter, inches.....6	M136, M136A1, M139,
Wall thickness, inch 0.94	AN-M139A1, M139,
Tail length, inches..... 9.3	AN-M139A1, M140,
Tail width, inches..... 8.1	AN-M140A1, M149, M163,
Tail weight, lb..... 2.8	M164, M165, M166, M166E1
Type of filling.....Composition B	M168, M188, T82.
Weight of filling, lb 12.0	
Total weight, lb.....91.6	
Charge/weight ratio 13.1%	

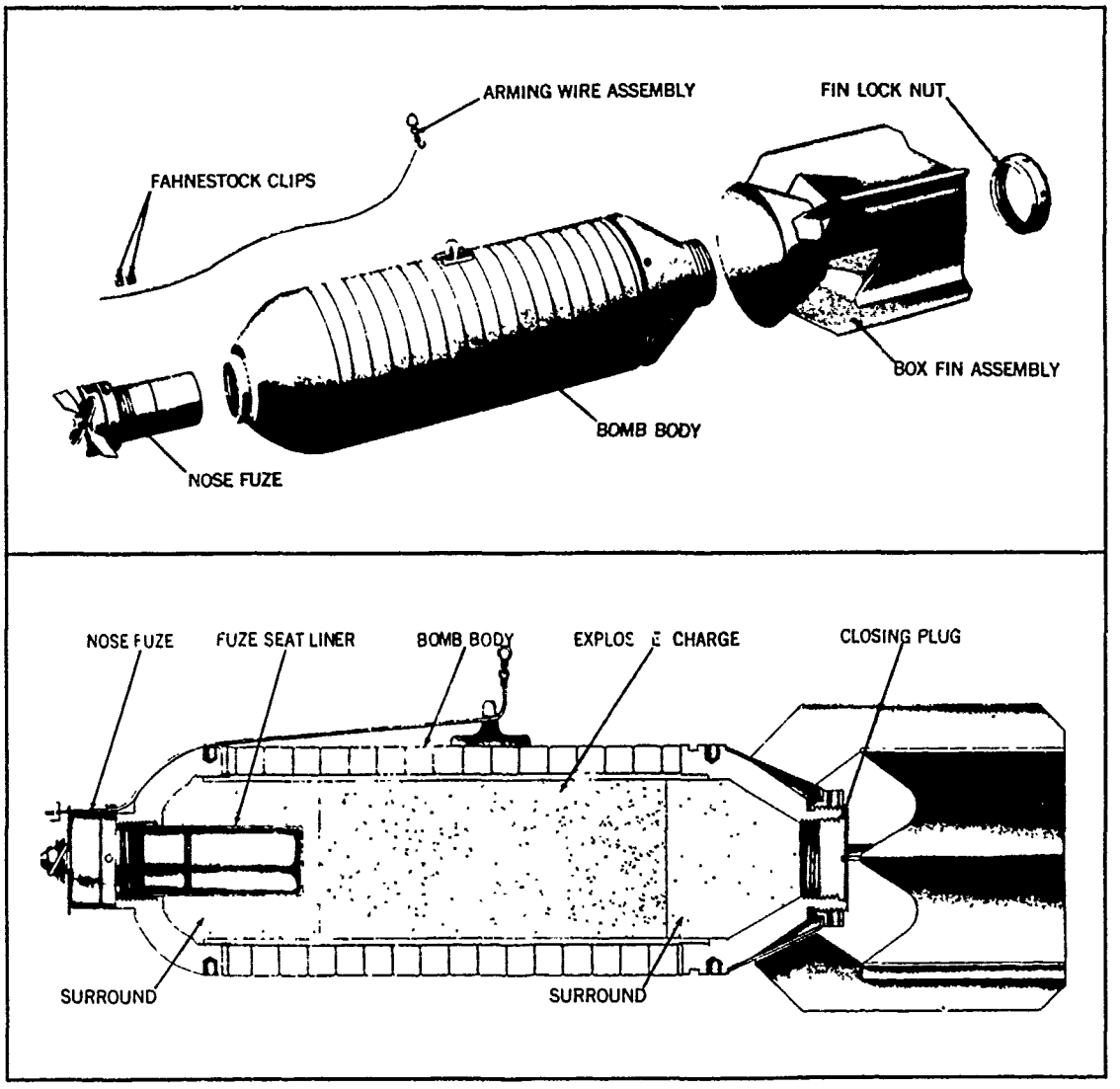
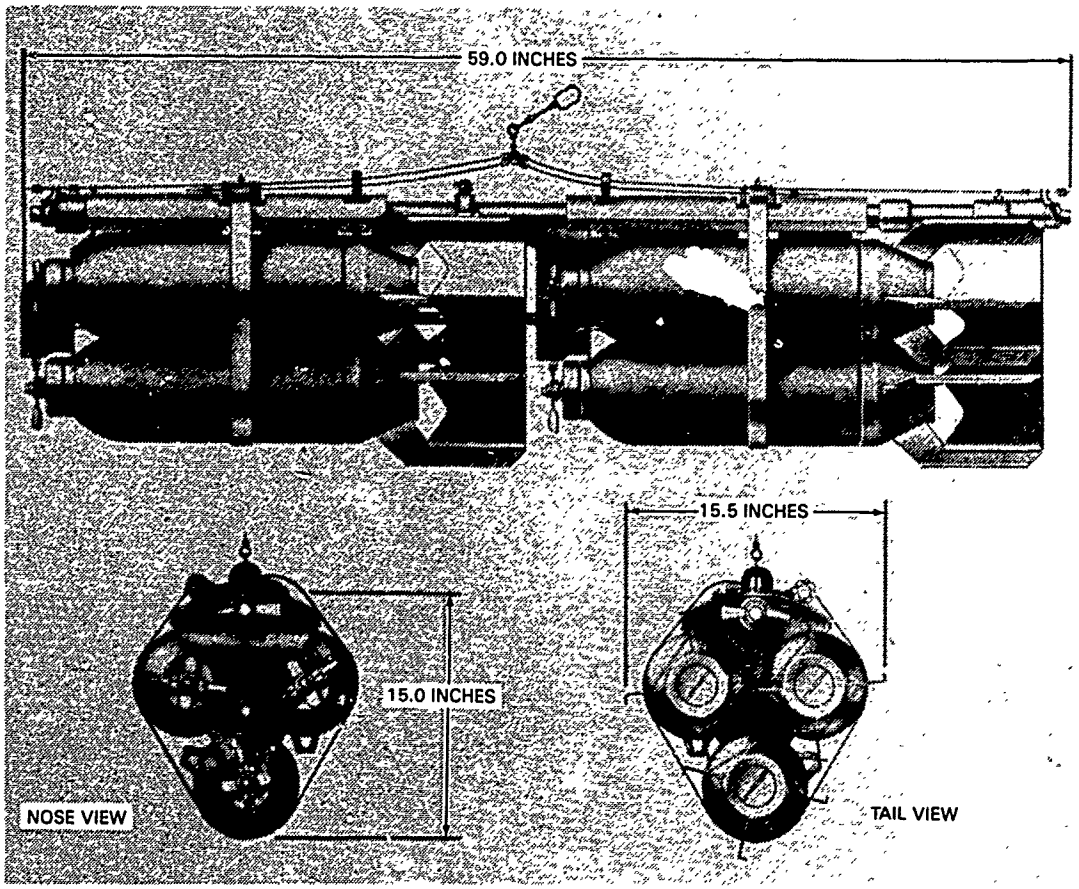


FIGURE 3-18. 90-lb Fragmentation Bomb M82; Exploded View (top) and Cross Section (bottom).

120-lb Parachute Fragmentation Bomb M86 (T13)

The M86 parachute fragmentation bomb consisted of the 90-lb M82 fragmentation bomb and the M5 parachute unit which was fastened to the base of the bomb body in place of the normal box-type tail fin assembly. Both units were issued separately and required assembly prior to use. The M5 parachute unit consisted of a cylindrical unit, 6.5



Model	M27A1
Assembly drawing no.	82-0-124
Length of cluster, inches	59.0
Width of cluster, inches	15.5
Cluster adapter	
Model	M14A1
Length, inches	55.33
Fragmentation bombs	
Model	M82
Number required	6
Weight of each bomb, lb	86.6
Weight of cluster, lb	585.0
Nose fuzes required	
For each bomb M82	AN-M103A1
For cluster adapter M14A1	M155A1

FIGURE 3-19. 500-lb Fragmentation Bomb Cluster M27A1, Now Obsolete (Reference 7).

inches in diameter and 35.5 inches long, that contained the parachute and shroud lines. The lid of the container was fastened by a latch, which was secured by an arming wire. The bomb was used on stations having the clearance for 500 lb and was suspended singly or as a two-bomb cluster with the M12 cluster adapter. One suspension lug was welded to the M82 bomb body at its center of gravity, and two suspension bands were issued with the M5 parachute unit. The larger of the suspension bands was used on the parachute unit, in conjunction with the suspension lug on the M82 bomb, and the smaller suspension band was secured to the bomb body. An arming wire, which was fastened to the bomb shackle and passed through the rear suspension band lug, secured the latch on the parachute container and prevented the parachute from opening until immediately after release of the bomb. Another shorter arming wire, that passed through the fuze, attached to an arming cord that was fastened to the parachute unit. On release, the primary arming wire was withdrawn from the latch on the container. As the bomb fell away from the aircraft, the air stream forced the lid from the aft end of the parachute container and allowed the parachute to be extracted and opened. The arming cord, which was attached to a shroud line, was pulled as the parachute opened, thereby permitting the fuze to arm. The bomb could use the instantaneous type AN-M120 or AN-M120A1 bomb fuzes via the M117 adapter booster (see Figure 3-20).

220-lb Fragmentation Bomb M88 and AN-M88

The initial production of this 220-lb fragmentation bomb utilized cast-steel nose and tail sections that were screwed into a central section of seamless steel tubing. A square helical steel coil was wrapped around the steel tubing. The nose and tail pieces were partially cut through to afford greater fragmentation (similar to the 90-lb bomb M82, except the M88 and AN-M88 incorporated the M104 auxiliary booster and tail fuzes). An alternate construction method (used for most of the units produced) consisted of a one-piece seamless steel tube around which was wrapped a helical steel coil (0.75-inch square for M88, 0.8125-inch square for AN-M88) for the entire length of the body (Figure 3-21).

The steel coil was forged at the nose and tail to form solid nose and tail sections. A box-type sheet-steel tail fin was secured to the aft end of the bomb by means of a fin lock nut. The nose and tail sections were threaded to accommodate respective fuzes. Two eyebolt-type suspension lugs were welded along the longitudinal axis of the bomb, 14 inches apart, on one side of the bomb body and a single eyebolt (lug) was similarly attached to the opposite side at the approximate center of gravity.

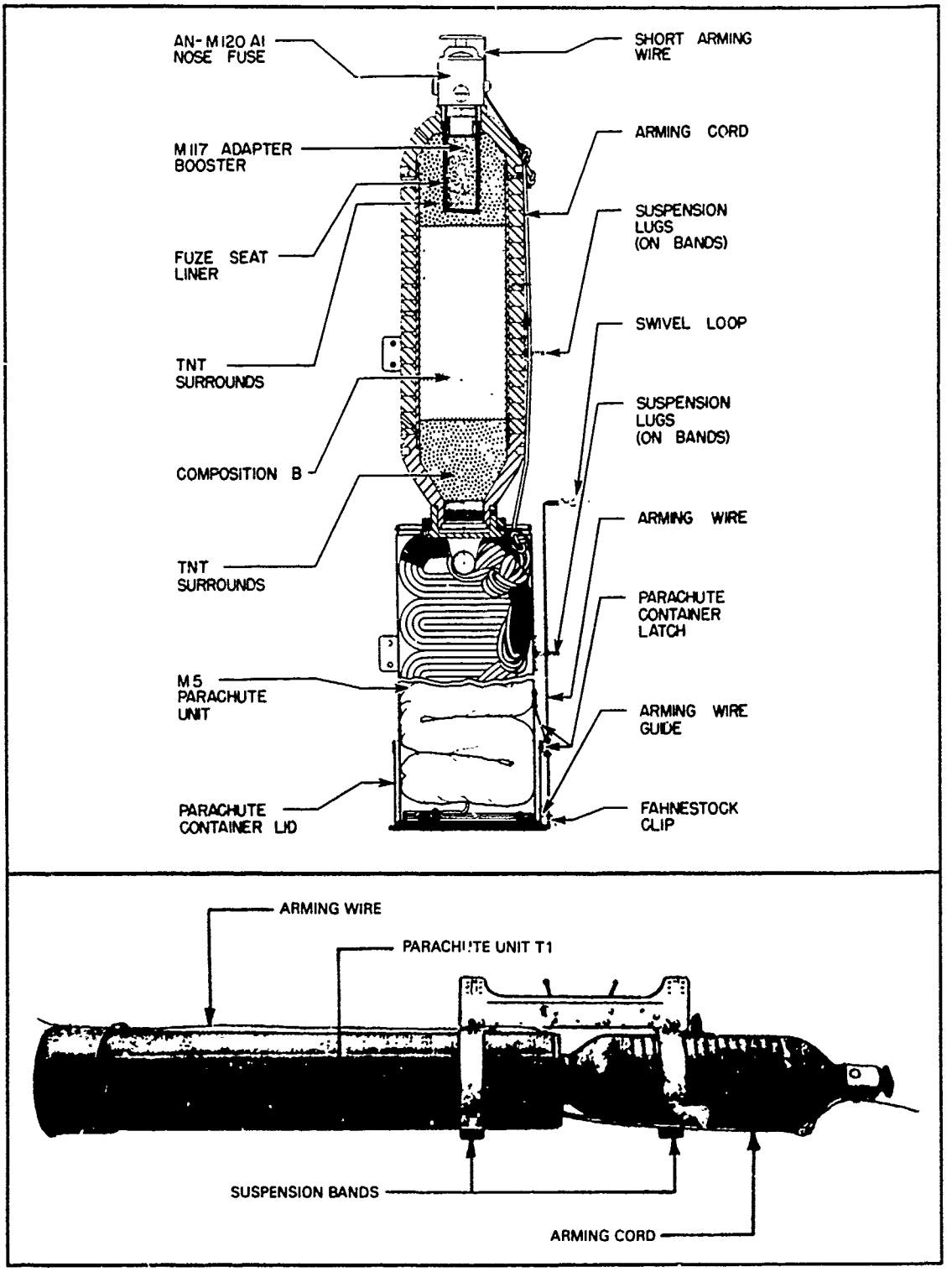


FIGURE 3-20. 120-lb Fragmentation Bomb M86 Parachute Type; Cross Section (top), Exterior View (bottom).

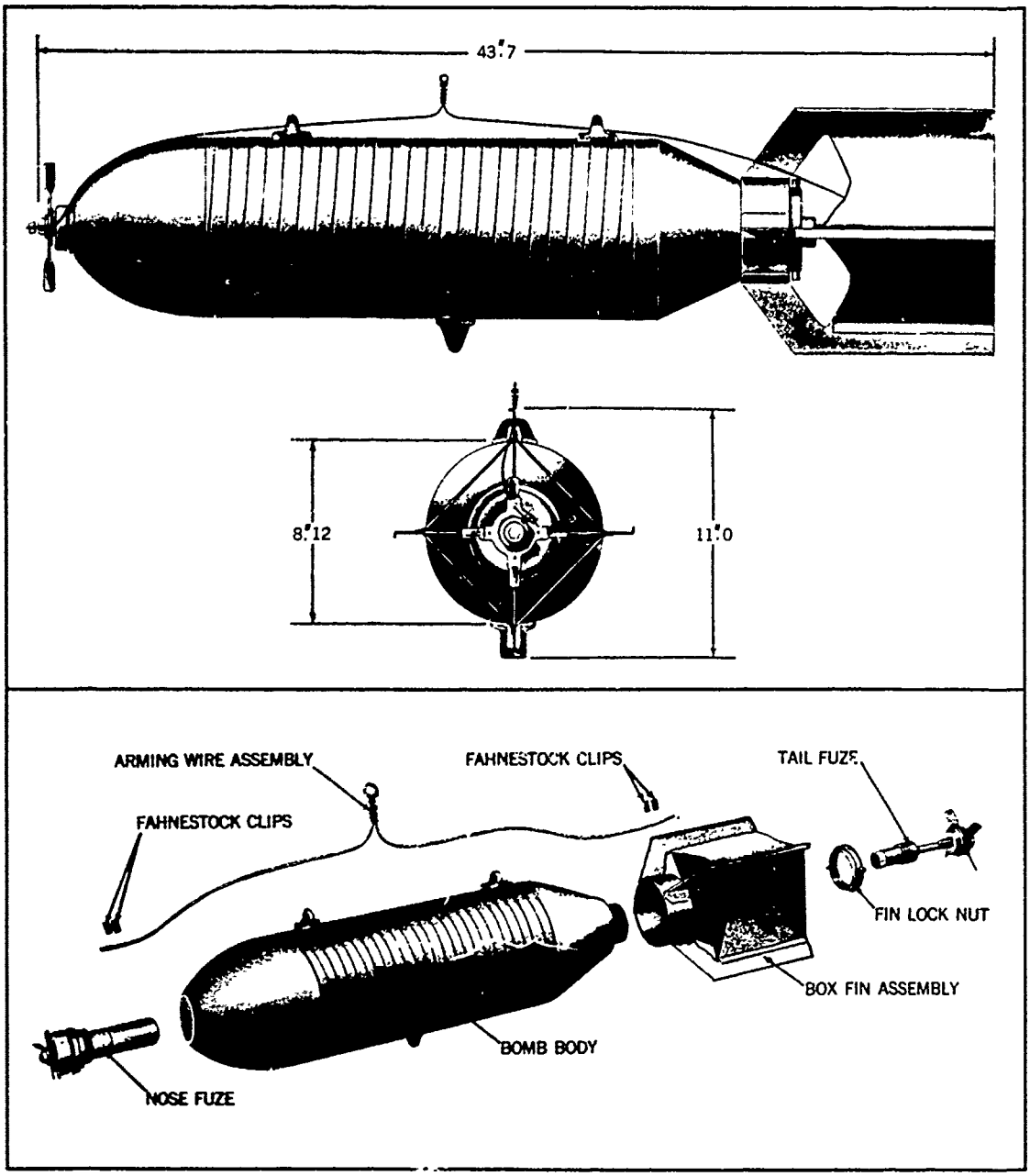


FIGURE 3-21. 220-lb Fragmentation Bomb AN-M88 with Fin Assembly AN-M103A1; Exterior View (top), Exploded View (bottom) (Reference 7).

Nose fuzing for the M88 and AN-M88 bombs included the AN-M103, AN-M130A1, 139, M139A1, M140, and M140A1 (all instantaneous); and M135, M135A1, M136, and M136A1 (all mechanical time airburst 5 to 92 seconds delay or impact instantaneous). Tail fuzing included the AN-M100A1 and AN-M100A2 (mechanical time, impact instantaneous, 0.01 to 0.24 second delay). The tail fuzes required a non-delay M14 primer detonator.

Older issues of the AN-M88 fragmentation bomb had yellow bands on the nose and aft end of the bomb body to identify its high-explosive filler of Composition B, Ednatol or TNT (see Figure 3-22). When filled with Composition B, nose and tail surrounds of TNT were used. Identifying nomenclature was stenciled in black on the olive-drab-colored bomb casing. Later issues of the bomb had olive-drab bodies, and yellow bands and marking.

When equipped with the M135 conical fin assembly, the 220-lb AN-M88 fragmentation bomb used the standard AN-M88 bomb body. This elongated conical fin assembly lengthened and streamlined the bomb, improving its aerodynamic performance and accuracy. The M135 fin assembly consisted of an elongated cone with four integral blades spaced at equal distances. A support tube ran through the center of the cone; the fin assembly was secured to the bomb body by means of support tube, a locking web, and a lock nut. Installation of the M135 conical fin assembly required the use of a long-stem tail fuze to locate the arming vane effectively in the air stream (Figure 3-23).

Additional details of the physical characteristics of the M88/AN-M88 fragmentation bomb are included in Figure 3-23.

260-lb Fragmentation Bomb AN-M81

The 260-lb AN-M81 bomb was an early modification of the 220-lb AN-M88 bomb. It was heavier because of its use of a larger square helical steel coil (1.0 inch as opposed to 0.8125 and 0.75 inch). Both bombs had the same outside diameter; however, the larger explosive cavity of the AN-M88 contained about 5 lb more explosive filler. The physical characteristics of the two bombs are otherwise similar (Figures 3-24, 3-25, and 3-26).

Similar to the 220-lb fragmentation bomb AN-M88, the 260-lb fragmentation bomb AN-M81 used its standard AN-M81 bomb body when equipped with the M135 conical tail fin assembly. For details on the M135 conical fin assembly, see Figure 3-26.

The 260-lb bomb was more effective for fragmentation than an equivalent bomb station loaded with 100- or 500-lb GP bombs or 20-lb fragmentation bombs, except for the

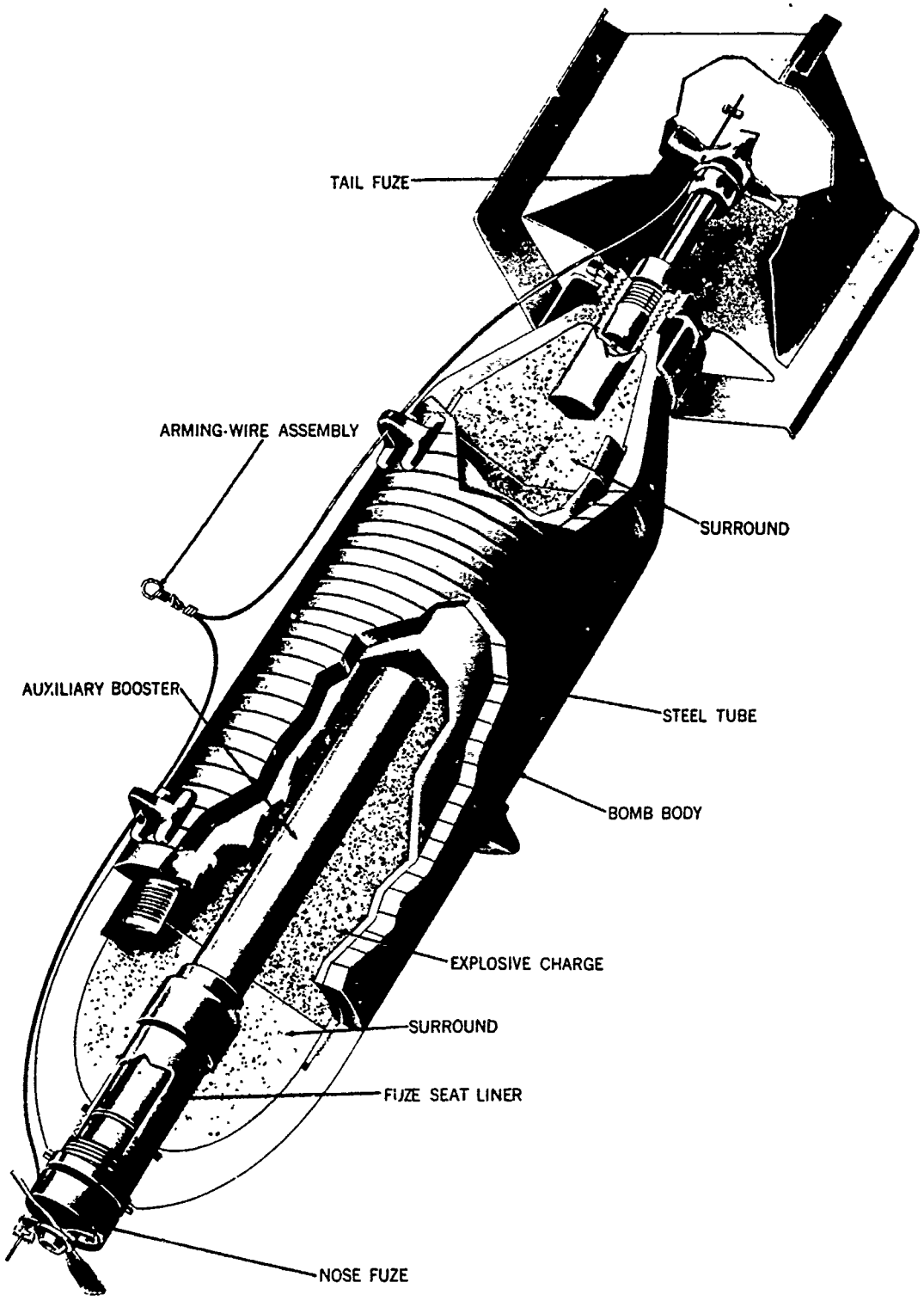


FIGURE 3-22. 220-lb Fragmentation Bomb AN-M88 with Fin Assembly AN-M103A1; Cutaway View (Reference 7).

220-lb AN-M88 Bomb Characteristics	With Fin Assembly AN-M103A1	With Fin Assembly M135
Model	AN-M88	AN-M88.
Assembly Drawing No	82-0-132.	
Fin Assembly Drawing No	82-3-437	82-3-773.
Length of Assembled Bomb (in.)	43.7	58.0.
Body Diameter (in.)	8.12	8.12.
Fin Span (in.)	11.0	11.19.
Weight of Explosive Charge (lb):		
Composition B	41.4	41.4.
Ednatol	41.2	41.2.
TNT	41.2	41.2.
Weight of Fin Assembly (lb)	4.1	17.5.
Weight of Assembled Bomb (lb):		
Loaded with Composition B	216.2	229.6.
Loaded with Ednatol	217.7	231.1.
Loaded with TNT	217.7	231.1.
Fin Locknut	M1 or Mk 2 Mod 0	Sk 329153.
Fin Locking Web	Not Used	Dwg 1350522.
Arming-Wire Assembly	Mk 1 or AN-M6A2	Mk 1 or AN-M6A2, and M13.
Nose Fuze	AN-M103A1, AN-M139A1, AN-M140A1, AN-Mk 219 [1] Mods 3, 4; AN-M166 (VT), AN-M168 (VT).	AN-M103A1, AN-M139A1, AN-M140A1, AN-Mk 219 [1] Mods 3, 4; AN-M166 (VT), AN-M168 (VT).
Tail Fuze	AN-M100A2 (with Primer-Detonator M14 (nondelay)).	M172, AN-M175.

[1] Requires Adapter Ring (dwg 294376-2 and Auxiliary Booster Mk 4.

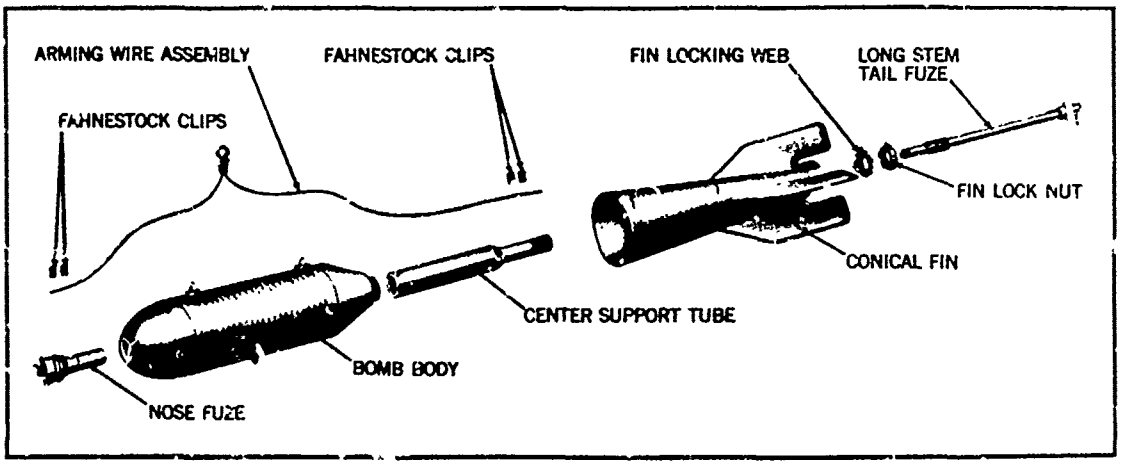
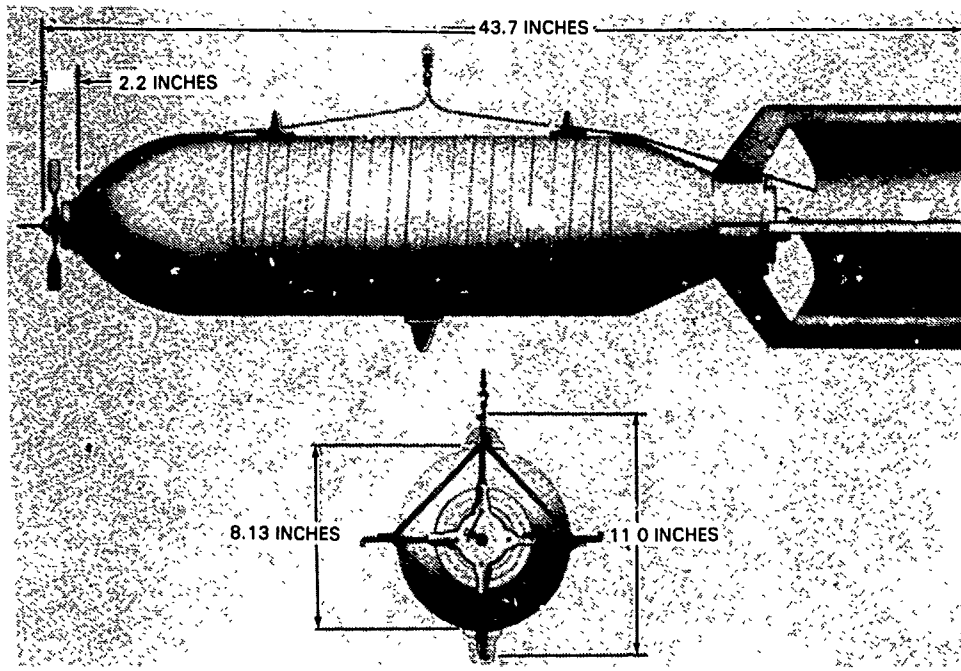


FIGURE 3-23. 220-lb Fragmentation Bomb AN-M88 with Fin Assembly M135, Exploded View (Reference 7).



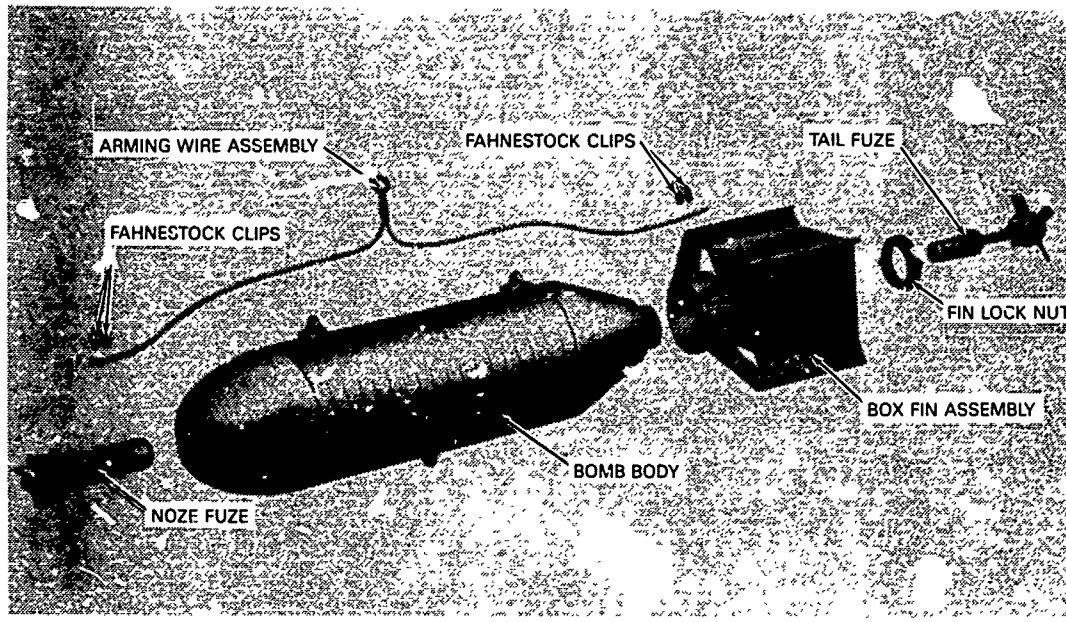


FIGURE 3-24. 260-lb Fragmentation Bomb AN-M81 with Fin Assembly AN-M103A1; Exterior View (top), Exploded View (bottom) (Reference 7).

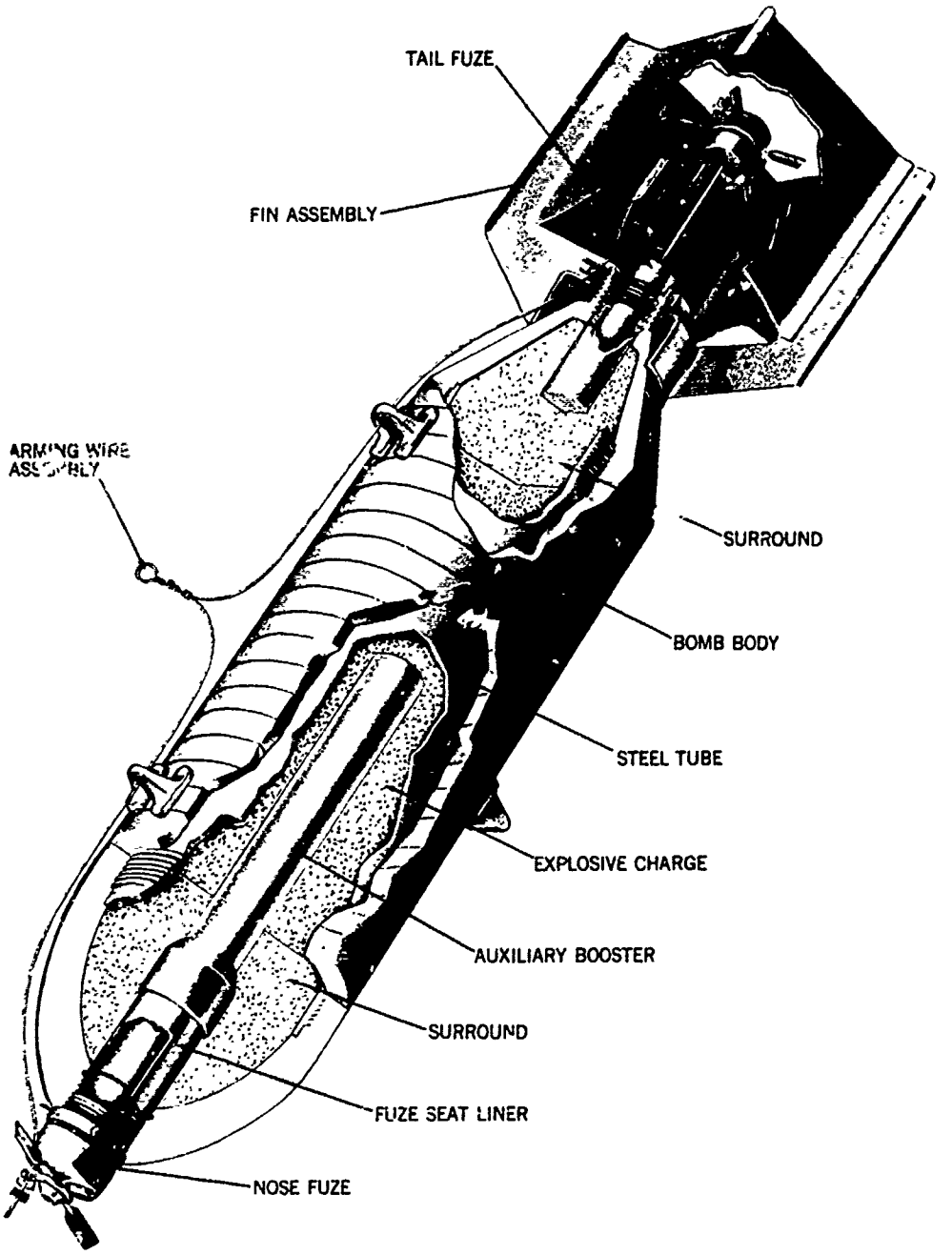


FIGURE 3-25. 260-lb Fragmentation Bomb AN-M81 with Fin Assembly AN-M103A1, Cutaway View.

260-lb AN-M81 Bomb Characteristics	With Fin Assembly AN-M103A1	With Fin Assembly M135
Model	AN-M81	AN-M81.
Assembly Drawing No.	82-0-102.	
Fin Assembly Drawing No.	82-3-437	82-3-778.
Length of Assembled Bomb (in.)	43.7	58.0.
Bomb Diameter (in.)	8.13	8.13.
Fin Span (in.)	11.0	11.19.
Weight of Fin Assembly (lb)	4.1	17.5.
Weight of Explosive Charge (lb):		
Composition B	36.2	36.0.
TNT	34.5	34.5.
Weight of Assembled Bomb (lb):		
Loaded with Composition B	263.0	276.5.
Loaded with TNT	261.5	275.0.
Fin Locknut	M1 or Mk 2 Mod 0	Sk 329153.
Fin Locking Web	Not Used	Dwg 1359522.
Arming-Wire Assembly	Mk 2	Mk 2.
Nose Fuze	AN-M103A1, AN-M145,[1] AN-M166 (VT), AN-M168 (VT).	AN-M103A1, AN-M145,[1] AN-M166 (VT), AN-M168 (VT).
Tail Fuze	AN-M100A2 (with Primer-Detonator M14 (nondelay)).	M172 or AN-M175 (with Primer-Detonator M14 (nondelay)).

[1] Requires Adapter Booster M117

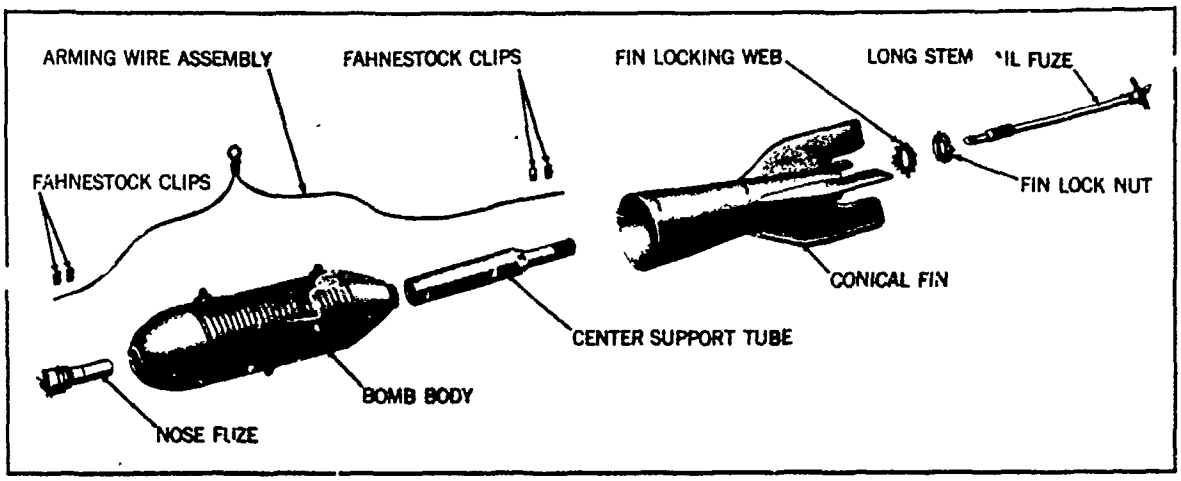


FIGURE 3-26. 260-lb Fragmentation Bomb AN-M81 with Fin Assembly M135, Exploded View.

casualty effect on unprotected personnel by 20-lb fragmentation bombs when released from high altitudes. However, the 220-lb AN-M88 fragmentation bomb provided an overall increase in fragmentation effectiveness under all conditions.

The bomb case of the AN-M81, when detonated, broke up into about 6000 to 7000 fragments. The average distribution from this bomb was similar to that for the 20- and 23-lb fragmentation bombs. The fragments of the AN-M81 fragmentation bombs were heavier on the average than those of the 20-lb bombs, as evident from a comparison of Figures 3-15 and 3-27. It should be noted that the fragments shown in Figure 3-27 do not represent the total number of fragments from the AN-M81 bomb, but consisted of a sample lot representative of the various weights of fragments recovered.

Fragmentation Cluster and Adapter

M1/M1A2 Cluster–AN-M1A3 Adapter. This 100-lb class cluster held six 20-lb AN-M41 fragmentation bombs. The cluster was 46.6 inches long and weighed 125 lb. It had lugs for double-hook suspension only. The release mechanism operated by means of a cartridge and firing device (Figures 3-12, 3-28, and 3-29).

M27/M27A1 Cluster–M14/M14A1 Adapter. These 500-lb class clusters held six 90-lb M82 fragmentation bombs. The M14A1 adapter (Figure 3-30) consisted of two longitudinal tubes, 56-inches long, to which were welded four steel plates forming a support for six bombs. The lower tube served as the backbone of the cluster while the upper tube carried the suspension lugs, buckles for the releasing straps, and the adapters for both nose and tail fuzes. The M111A2 or M155 nose fuzes were used, but there was no mechanical time fuze in the tail (see Figures 3-18 and 3-19). If an immediate release was required, the shear wire was cut after the arming wire was installed and no fuze was used. Immediate opening of the cluster produced the optimum impact pattern on the ground; however, this was constrained to altitudes above 1000 ft (minimum in order for the bomb fuze to arm).

M28 Cluster–M15 Adapter. This 100-lb class cluster weapon held 24 of the 4-lb M83 fragmentation bombs. The cylindrical sheet metal adapter opened longitudinally, being hinged at the rear and closed at the front end by means of a nose cup. It was 47.48 inches long, 8 inches in diameter, and weighed 155 lb loaded. It used an M155 or AN-M146 nose fuze. These clusters were released from altitudes of not less than 3000 feet and not more than 5000 feet. Fuze settings for functioning after release varied from 5 seconds at minimum release altitude to 8 seconds at maximum release altitude. When the fuze functioned (fired), it released the nose closure cup, allowing the clamshell-like adapter (Figure 3-31) to open and release the bombs, which formed a pattern covering an area approximately 200 by 300 feet.

FIGURE 3-27. Typical Sample of Fragments from 260-lb Fragmentation Bomb AN-M81 (Reference 7).

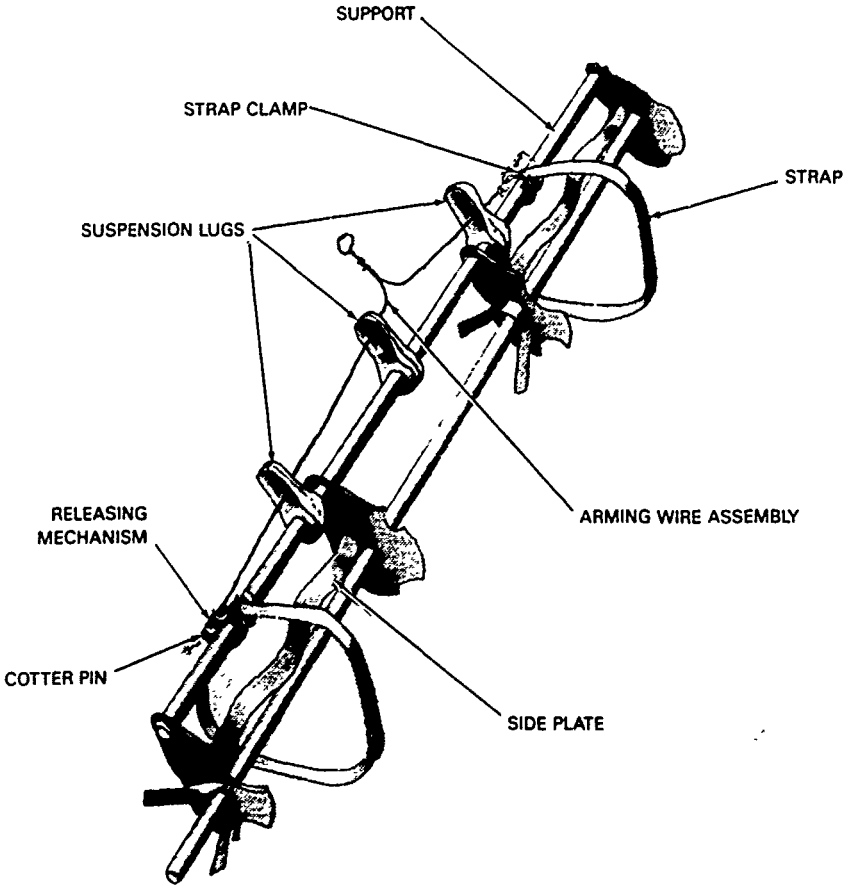


FIGURE 3-28. 100-lb Fragmentation Bomb Cluster AN-M1A2, Perspective View (Reference 7).

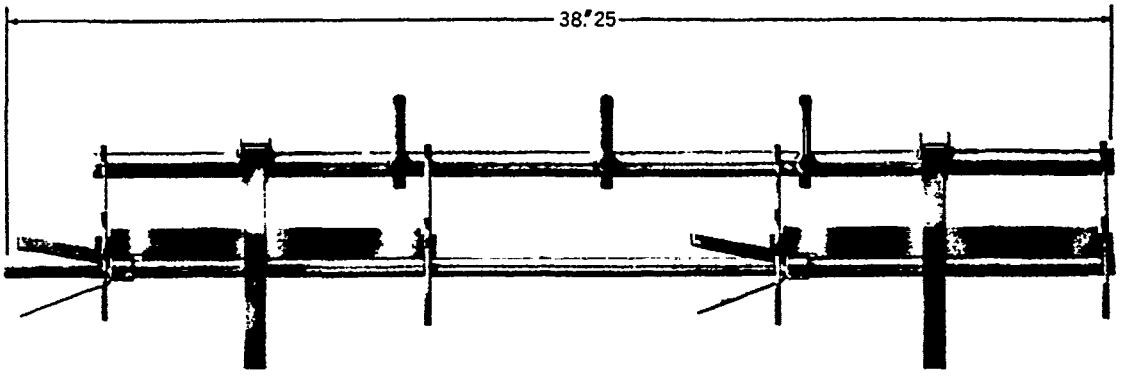


FIGURE 3-29. 100-lb Cluster Adapter AN-M1A3.

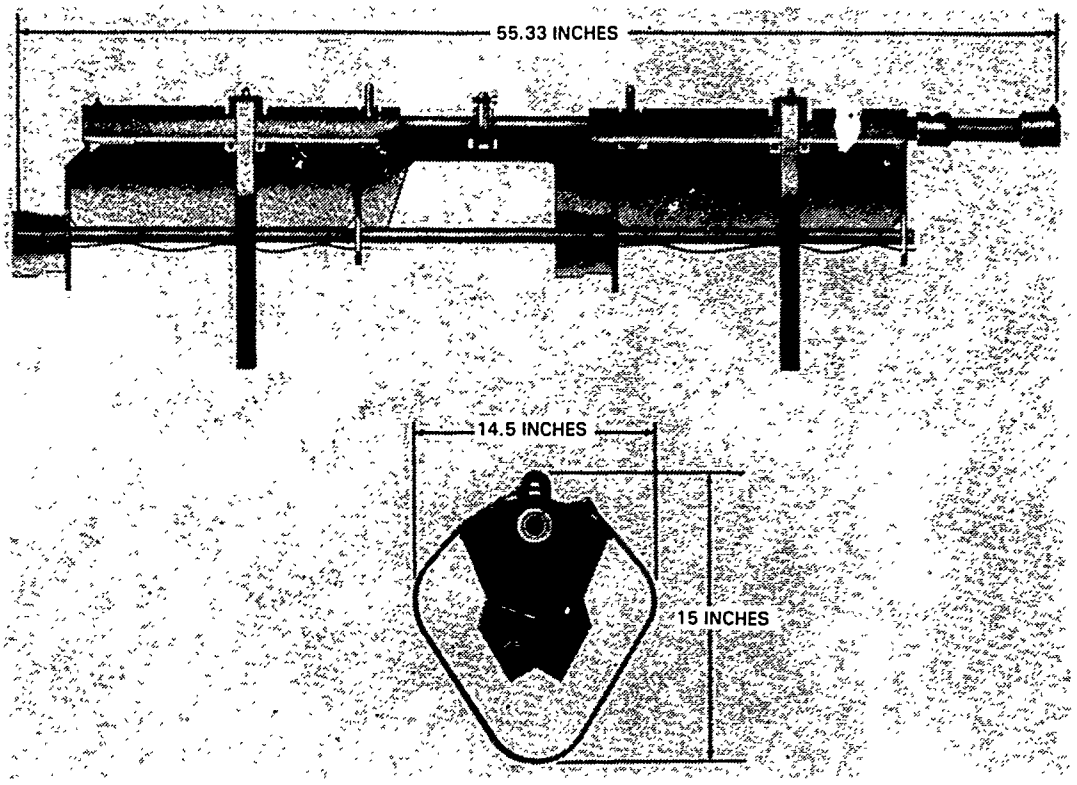


FIGURE 3-30. 500-lb Cluster Adapter AN-M14A1.

FIGURE 3-31. 100-lb M28 Fragmentation Cluster–M15 Cluster Adapter.

M28A1 Cluster–M15A1 Adapter. The 100-lb M28A1 cluster was the same as the M28 cluster except that it incorporated a spoiler ring around the nose and a drag plate secured to the tail by four screws (see Figure 3-32). These two devices were added because the release altitude for the M28 cluster was limited by the high velocity attained by the cluster at high altitude, resulting in damage to the fragmentation bombs when the cluster opened. When drag plates and spoiler rings were used, the recommended release altitude was 1500 feet with a 6-second fuze setting or any higher altitude that would open the cluster at altitudes between 1000 and 2500 feet.

FIGURE 3-32. 100-lb M28A1 Fragmentation Cluster with Spoiler Ring and Drag Plate.

M28A2 Cluster–M15A2 Adapter. The A2 modification consisted of a new case-locking cup and bushing, which was secured to the adapter by slotted screws. The M15A2 adapter also incorporated the spoiler ring and drag plate.

M29 Cluster–M16A1 Adapter. The 500-lb class M29 cluster weapon (Figure 3-33) held ninety 4-lb M83 fragmentation bombs. The container was similar to the M15 except for size. In the M16 Adapter, the M83 fragmentation bombs were loaded in "wafer" assemblies (Figure 3-34). The cluster had a third single lug for British aircraft suspension systems (Figures 3-35).

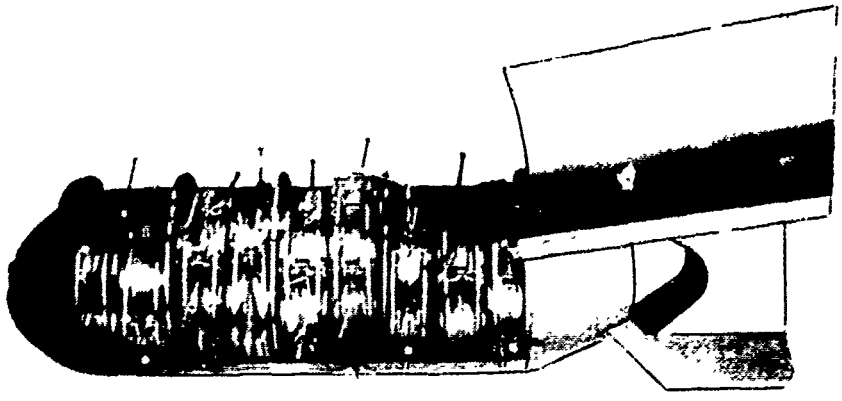


FIGURE 3-33. 500-lb M29 Fragmentation Cluster–M16 Cluster Adapter.

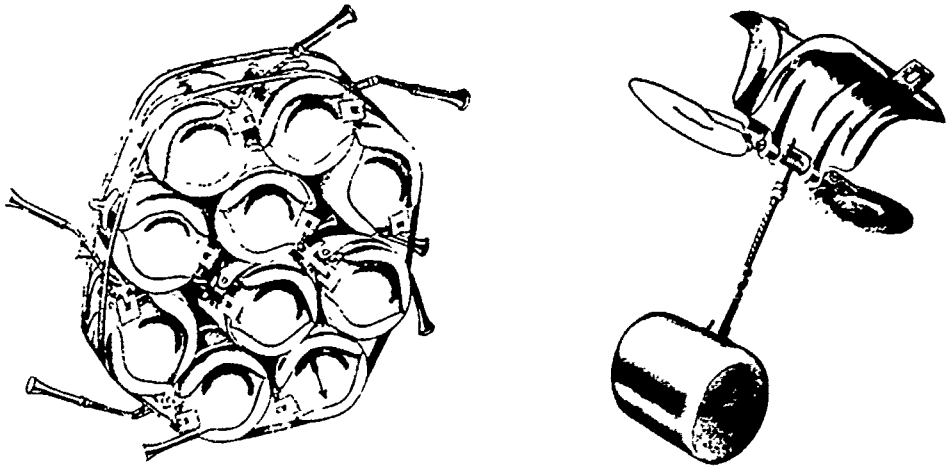


FIGURE 3-34. 4-lb Fragmentation Cluster M83 and Wafer Assembly.

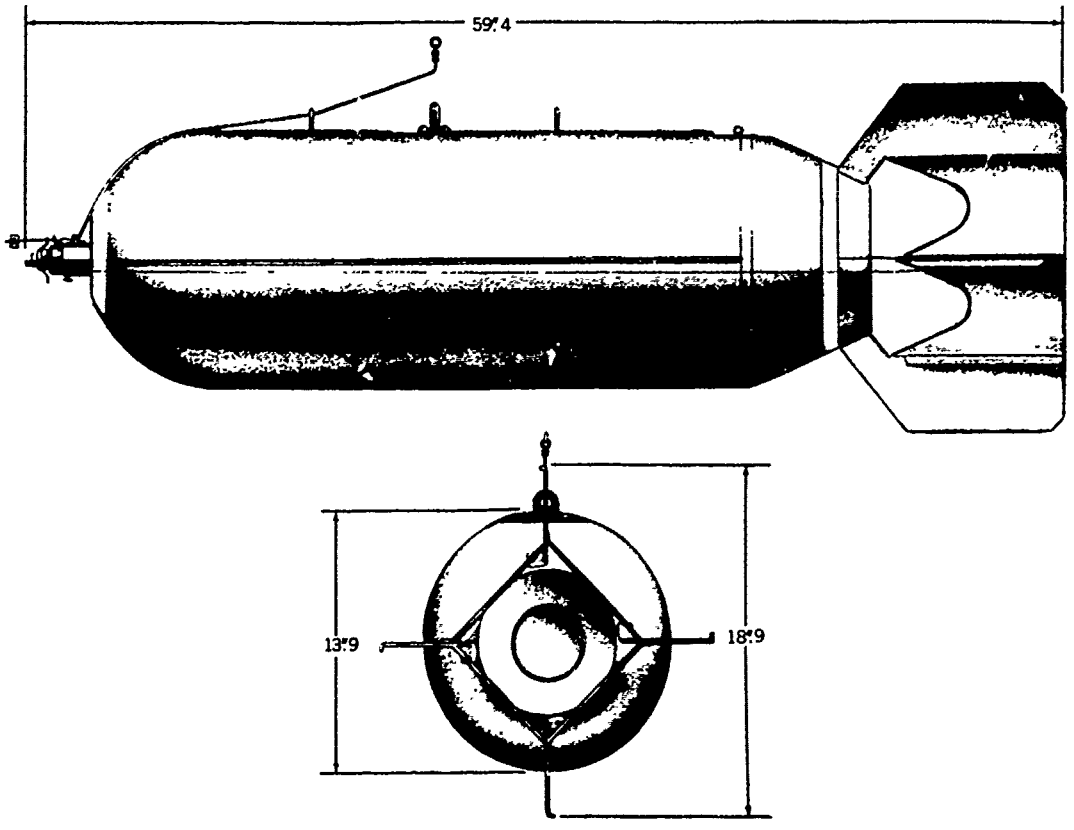


FIGURE 3-35. 500-lb M29 Fragmentation Cluster Bombs M29A1.

M29A1 Cluster–M16A2 Adapter. The A1 modification had the new nose-locking cup and bushing, which was secured to the adapter by two slotted screws. Otherwise it was the same as the M29 cluster. For Navy usage, the Bureau of Ordnance recommended that the case-locking bushing be used with all "Butterfly" fragmentation clusters, including the M28, M28A1, M28A2, M29, and M29A1. One end of the bushing screwed into the fuze adapter and the other end was internally threaded to receive the fuze. The locking cup was positively retained by a safety wire which passed through a hole in the locking-cup tab and around a cotter pin in the bushing. When the fuze fired, the locking cup was blown into the cluster, shearing the safety wire and allowing the adapter to open.

Innovative Fragmentation Bomb Cluster Design Features

In addition to incorporating [illegible] tabs on all the short length, box-shaped tail fin assemblies (most likely to both strengthen the fin and induce bomb rotation), the fins did not extend beyond any part of a square circumscribing the maximum bomb body diameter. This latter feature permitted maximum volumetric efficiency for magazine storage, logistic supportability, and aircraft loadout both for external and internal carriage. Also, to the writer's knowledge, the M28A1 and M28A2 Fragmentation Bomb Clusters were the first to incorporate a spoiler ring around the nose (boundary layer trip) as well as a drag plate (decelerator) to both improve the aerodynamic performance and retard the descent of a free-fall weapon system.

U.S. NAVY "MK" SERIES BOMBS

These Navy-designed "Mk" series bombs were similar to Army bombs of the same class. However, after the formation of the Army-Navy Standard Board early in 1941, the Navy concentrated on designing bombs for primarily naval targets and for aircraft carrier handling, and left the other types of bombs to Army designers.

GENERAL-PURPOSE BOMB CLASSES

There were three classes of general-purpose bombs included in the Navy "Mk" series, namely: (1) the 100-lb GP bomb—Mk I Mods 2 and 3, and Mk 4 Mods 1 and 4; (2) the 500-lb GP bomb—Mk 3 Mod 1, Mk 9, and Mk 12 Mods 0, 2, and 3; and (3) the 1000-lb GP bomb—Mk 13 Mods 0 and 2, Mk 3, Mk 5, Mk, 9 and Mk 36. (See Figures 3-36, 3-37, 3-38, and 3-39). All of these bombs were filled with TNT, with charge-to-weight ratios ranging from 50% to 56%.

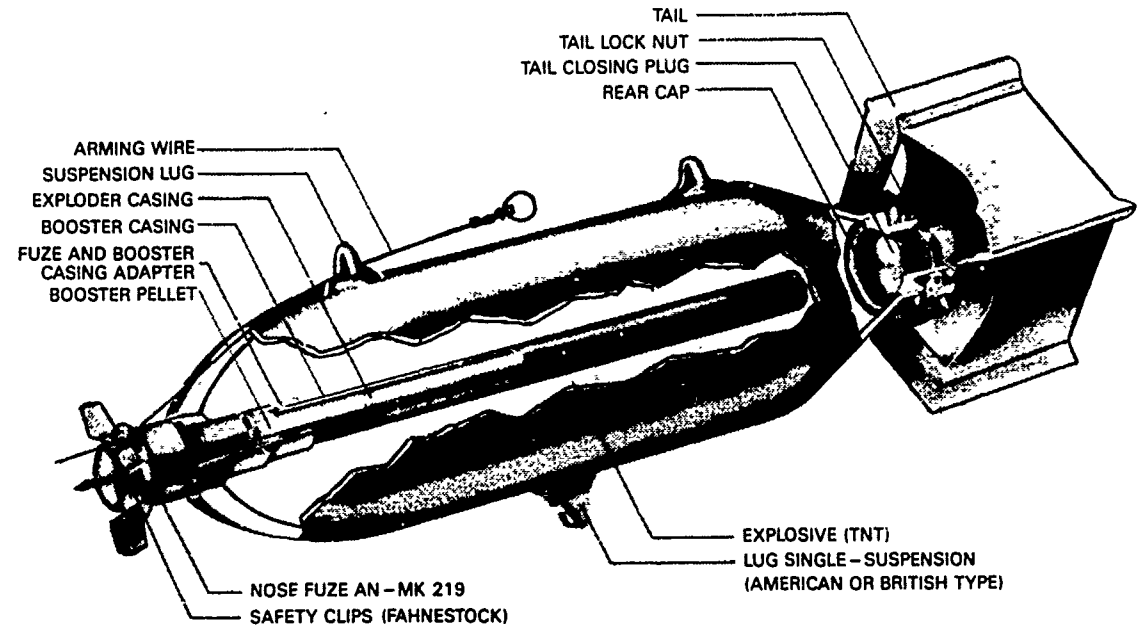


FIGURE 3-36. 100-lb GP Bomb Mk 4 Mod 4.

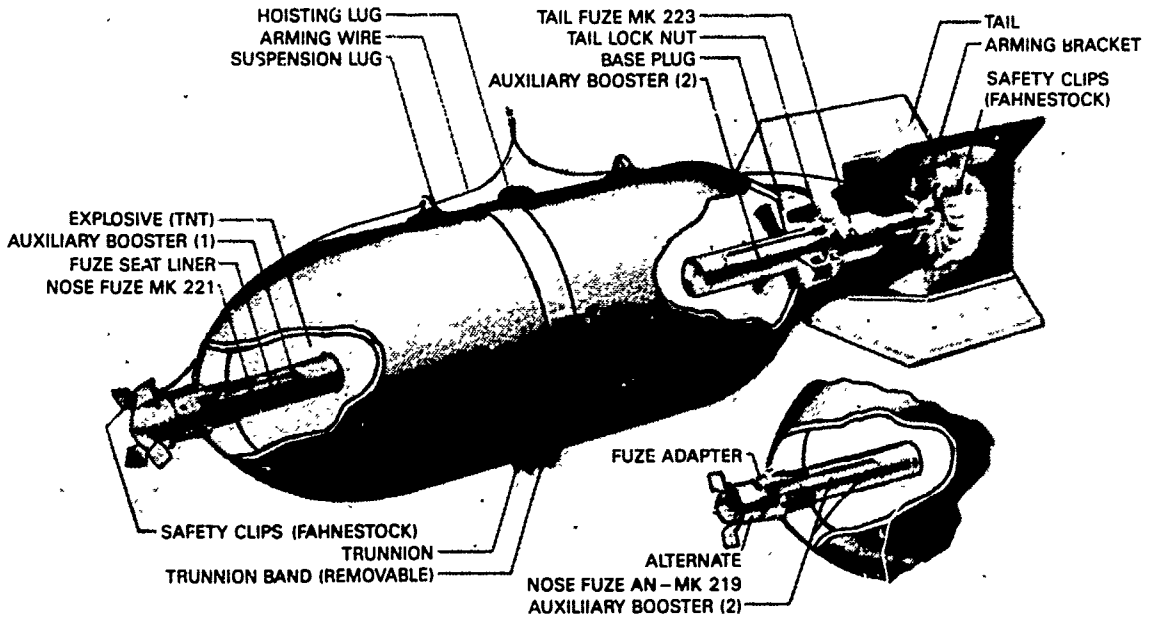


FIGURE 3-37. 500-lb GP Bomb Mk 12 Mod 2.

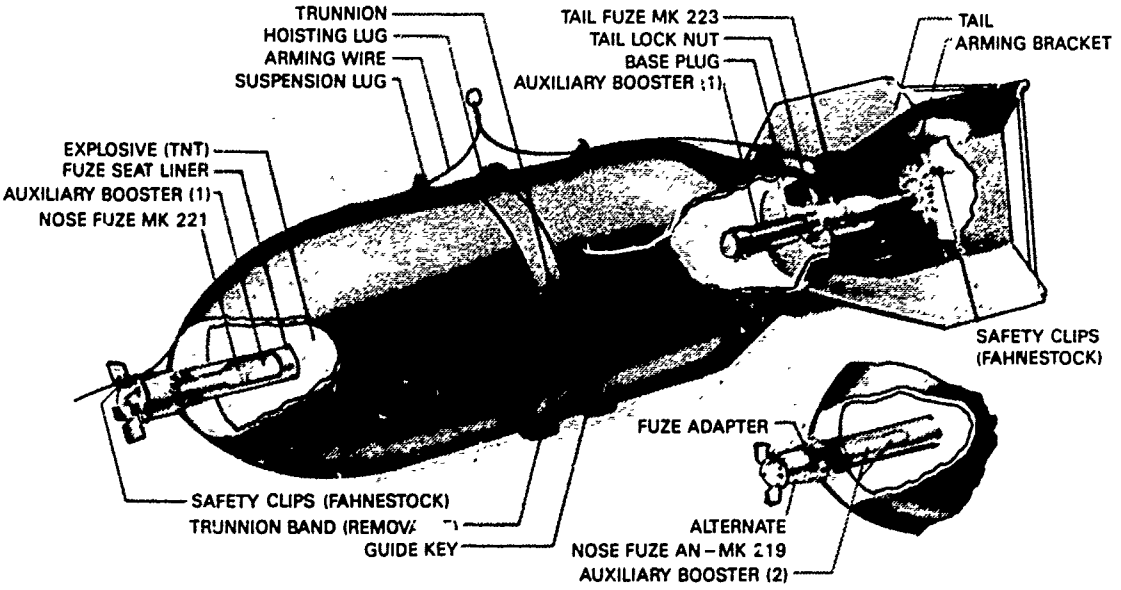


FIGURE 3-38. 1000-lb GP Bomb Mk 13 Mod 2.

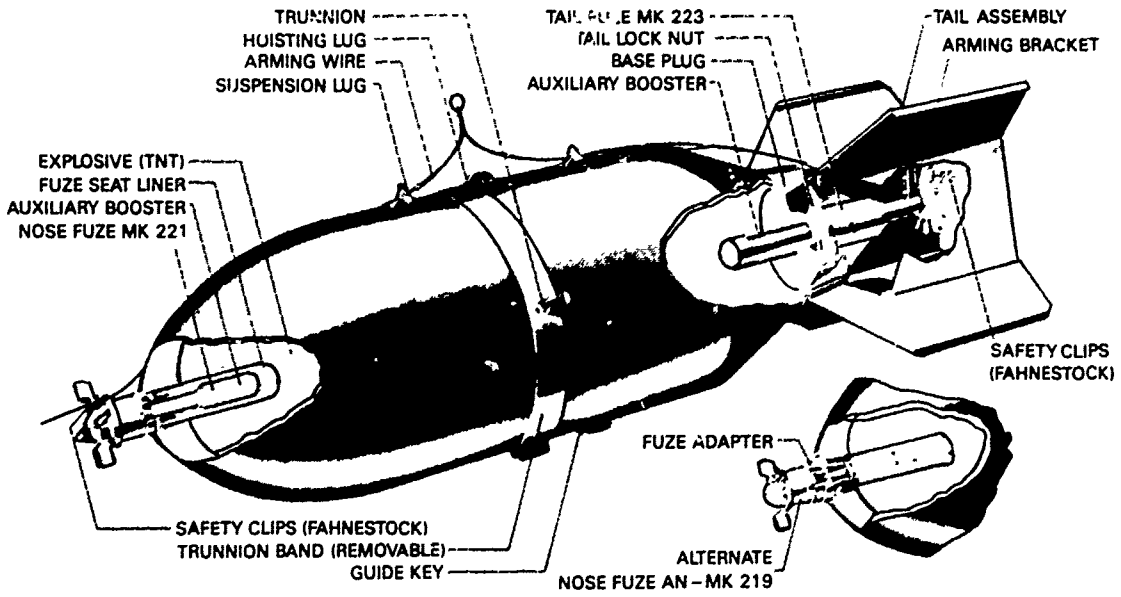


FIGURE 3-39. 1000-lb GP Bomb Mk 36.

Bomb Body Construction

The 100-lb Mk I bomb was constructed from two steel castings welded together to from a "tear-drop" shape. The Mk 4 version was a single-piece steel forging, cylindrical with an ogival nose. The 500-lb and 1000-lb GP bombs were also "tear drop" in shape, constructed from one-piece steel forged or drawn, cylindrical with an ogival nose. Both the 500-lb and 1000-lb bombs (except the Mk 36) incorporated a female base plate and a right-angle fin sleeve instead of the conical type. The 1000-lb demolition bomb Mk 36 was a modified version of the 1000-lb GP bomb AN-M44. The Mk 36 permitted the use of nose fuzes AN-Mk 219 or Mk 221, tail fuzes Mk 223 or hydrostatic Mk 229 Mod 3, a Navy-type hoisting lug and guide key, trunnions for use in dive bombing by means of a trunnion band, and TNT rather than 50-50 Amatol explosive fill.

Suspension System

All of these GP bombs had two suspension lugs welded 14 inches apart to the bomb body for suspension from double-hook racks or shackles. They also had a single lug or a band around the body with trunnions for dive bombing. A pressed steel guide key was welded to the bomb to permit suspension in torpedo slings.

Tail Construction

The box-shaped tail consisted of four fins or vanes that slipped down over the bomb body and were welded to a tail cone. The vanes were fastened to the body of the bomb by screws and braced with two sets of bar struts riveted to the vanes. A later change incorporated a locking nut (which surrounded the fuze) instead of using screws to secure the vanes to the bomb body.

Fuze Systems

The fuze systems used in the Mk Series Bombs were as follows:

1. Nose fuzes included the AN-Mk 219 (instantaneous), which required an adapter ring and one additional auxiliary booster Mk I, the Mk 221 (0.01-second delay), the Mk 243 Mod 0, the Mk 244 Mods 0-1, and the Mk 239.

2. Tail fuzes, for the 500-lb and 100-lb classes only, included the Mk 223 (0.01-second delay) the Mk 229, and the Mk 229 Mod 3. To permit a wider selection of possible tail fuzes, an adapter booster (M102) with a 0.047-inch spacer ring was used enabling the installation of the AN-M101A1, M113A1, M114A1, M116, or M117 fuzes.

AIRCRAFT DEPTH BOMBS

Basically, depth bombs were designed to be light-case or high-capacity type weapons to maximize the amount of explosive charge to weapon weight ratio and thereby achieve the desired levels of underwater explosive effects (combination of shock and bubble energy). Because survival of water impact only, at the severest tactical delivery condition, was the major warhead design objective, characteristically, thin-walled, large-diameter cases (larger than other types of bombs of the same weight) were used, resulting in charge-to-weight ratios of approximately 70%. Depth bombs normally used hydrostatic fuzes that could be preset to initiate the warhead at any desired depth; however, these bombs could have instantaneous-type nose fuzes installed for use against a wide variety of blast-sensitive surface targets. One interesting design feature of the 325-lb, 350-lb, 650-lb, and 700-lb depth bombs was the use of the hydrostatic fuzes AN-Mk 224 or AN-Mk 234 in an "athwartship" or "midship tube", along with an impact-type nose fuze and a hydrostatic tail fuze. To prevent ricochet of bombs on striking water when they were dropped from low altitudes and also to improve the underwater trajectories, blunt-nose shapes were adapted to most depth bombs. Lessons learned from earlier round-nose-shape depth bombs, with their ricochet and underwater trajectory problems, initiated near-term quick fixes (flat-false-nose attachments) and longer term improvements (blunt-nose shapes) in follow-on production versions.

The target spectrum for these aircraft depth bombs were submarines or light surface ships or as light case (high capacity) demolition bombs for general bombardment against land targets.

The specific aircraft depth bombs included in the "Mk" series are described in the following descussions.

100-lb Aircraft Depth Bomb Mk 52

The Mk 52 depth bomb was a light-case, fast-sinking, round-nose bomb for use by airship. It was carried in a Mk 53 bomb rack and accordingly had no trunnions, trunnion bands, or suspension lugs. A cylindrical shroud was fastened to the tail section by

four vanes. The entire tail assembly was fastened to the rear of the bomb body by six flat-head machine screws. A cast-iron nose shape, secured to the front of the bomb body, housed the Mk 140 nose fuze (instantaneous or 0.025-second delay), the fuze booster, and two auxiliary boosters. See Table 3-7 and Figure 3-40 for additional details on physical characteristics. The nose fuze would function on impact with a solid object below the surface of the water, but would also function upon striking the water at any velocity greater than 300 ft/sec (approximately). This velocity was attainable in free-fall from a vertical height of 1400 feet.

TABLE 3-7. 100-lb Aircraft Depth Bomb Mk 52.

Overall length, in.	45.9		
Body length, in.	7.0		
Filling	TNT	or	Torpex
Weight of filling, lb	45.3		50.3
Total weight, lb	99		104
Charge/weight ratio	46%		49%

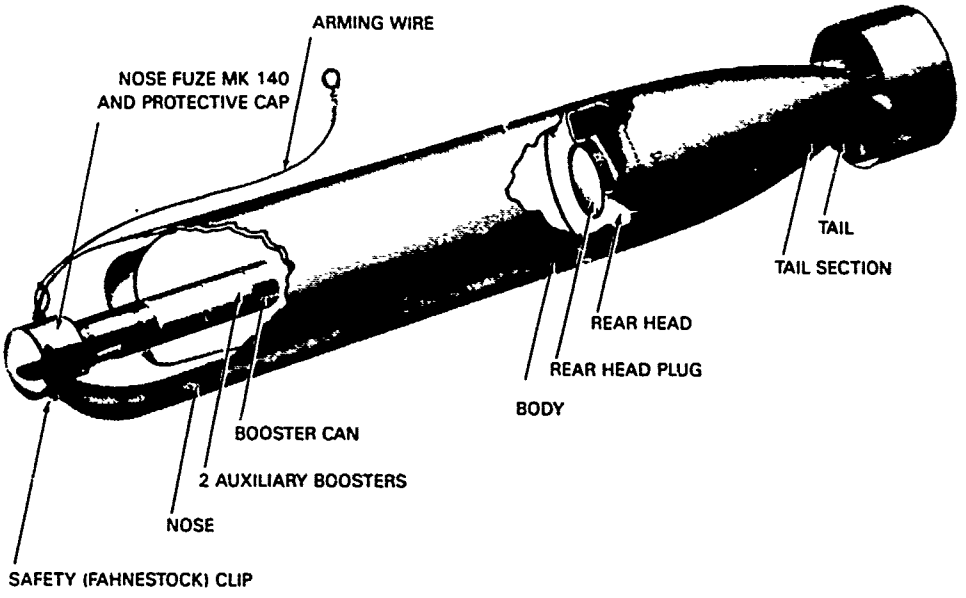


FIGURE 3-40. 7.0-Inch 100-lb Depth Bomb Mk 52.

325/350-lb Aircraft Depth Bomb Mk 17 and Mk 44

The Mk 17 and Mk 44 TNT- or Torpex-filled depth bombs were light-case, high-capacity bombs, that had charge-to-weight ratios of approximately 70%. The bombs were made with round noses welded to thin cylindrical steel tubes. To reinforce the body and nose area, steel strips and a steel strengthening disc were welded along the suspension lugs and nose section, respectively. A transverse or athwartship fuze was located approximately 12 inches aft of the nose (Figure 3-41). An impact nose fuze allowed the bomb to be used as a blast or demolition bomb. The use of a delay function in the nose fuze was not recommended because of the likelihood of bomb-case breakup before the fuze could function. When it was found that round-nose depth bombs tended to ricochet when impacting the water at angles of between 15 and 20 deg, and that ricochet was certain at angles less then 15 deg, an antiricochet flat-nose attachment was provided for those bombs that did not have an integral flat-nose shape. Another purpose of the flat-nose attachment was to improve underwater trajectories. After attachment of the bucket-shaped, antiricochet flat-nose device, the intervening space was filled with plaster or cement, increasing the 325-lb class depth bombs by 44 lb and the 650-lb class by 72 lb.

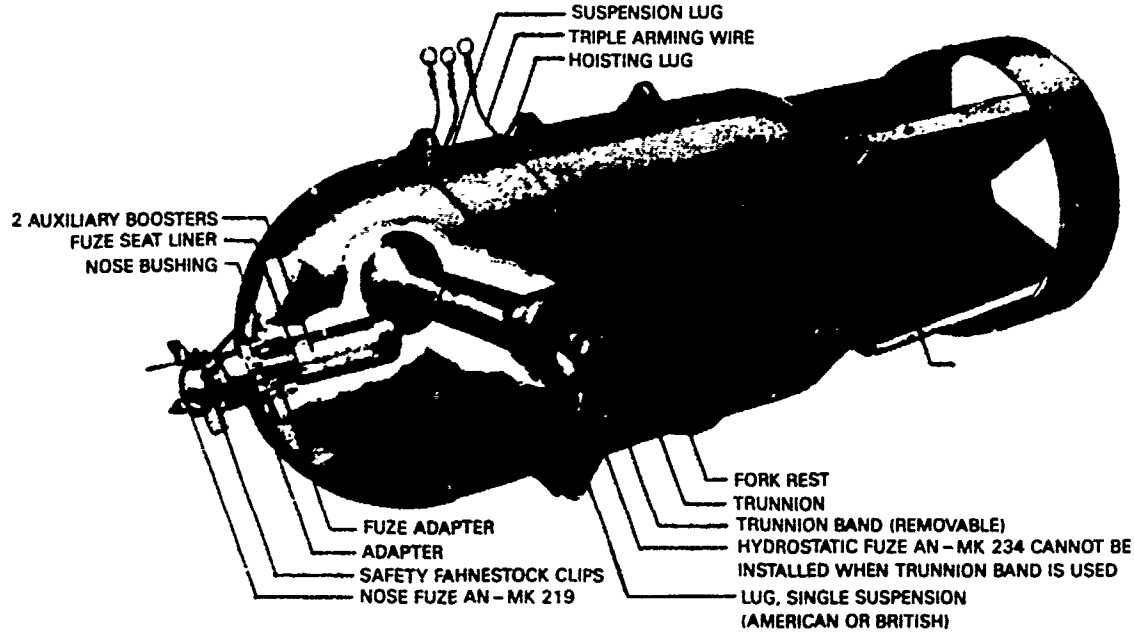


FIGURE 3-41. 325/350-lb Aircraft Depth Bomb AN-Mk 17 Mod 2 (TNT-Loaded), AN-Mk 44 (Torpex-Loaded).

325/350-lb Aircraft Depth Bomb Mk 41 and Mk 47

The Mk 41 and Mk 47 aircraft depth bombs were also TNT- or Torpex-filled light-case, high-capacity bombs, constructed with flat noses. There was a slight taper from the walls of the cylinder to the nose section. The bomb body was constructed from three sections. The midsection was tubular, with a transverse or athwartship fuze pocket tube (well) welded in place approximately 15 inches aft of the nose (see Figure 3-42).

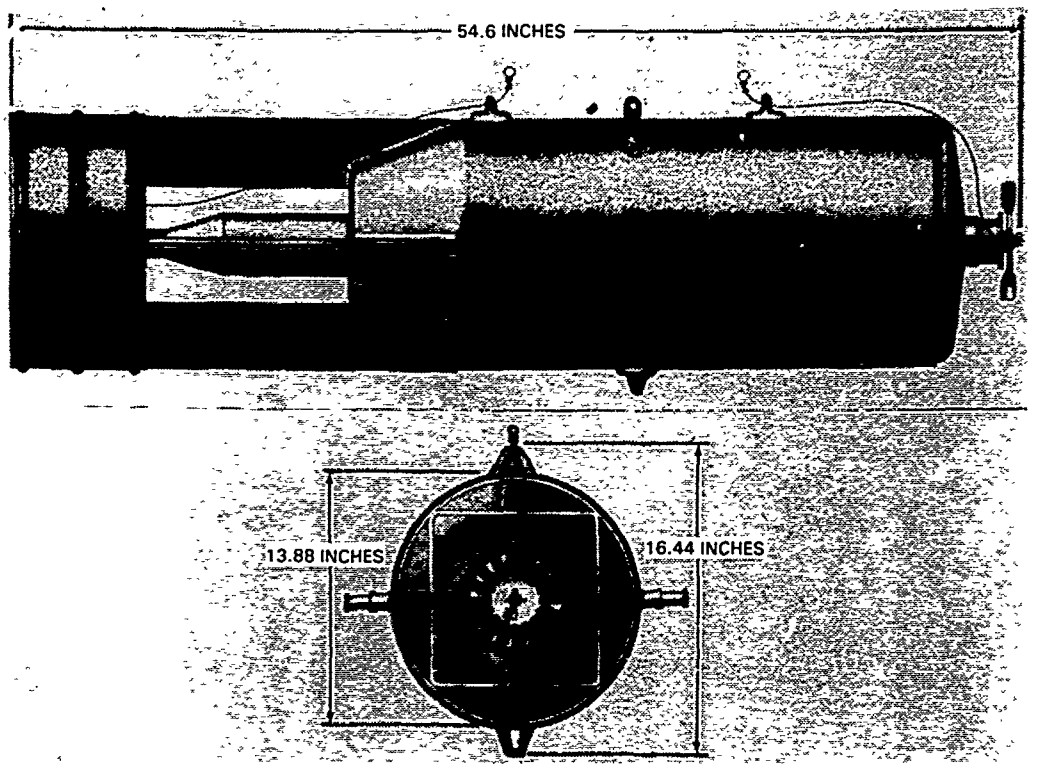


FIGURE 3-42. 325/350-lb Aircraft Depth Bomb AN-Mk 41 (TNT-Loaded), AN-Mk 47 (Torpex-Loaded).

The suspension system for the 325-lb depth bombs incorporated both single and dual lugs that were welded to the bomb case. The single lug was more of a bracket than a lug. Trunnions and trunnion bands were attached to the bombs for dive-bombing requirements. The bombs used a circular, drum-type tail fin assembly instead of the usual box-type tails, with four internal fins (vanes) at right angles to each other. The fins were welded to both the tail cone and the circular drum shroud. The tail assembly was secured to the bomb body aft-closure plate by four bolts.

Additional details on the 325-lb Depth bombs Mk 17, Mk 41, Mk 44, and Mk 47 see are presented in Table 3-8.

TABLE 3-8. 325/350-lb Depth Bomb AN-Mk 17, AN-Mk 44, AN-Mk 41, AN-Mk 47 Comparison.

Physical characteristics	AN-Mk 17-2 AN-Mk 44		AN-Mk 41 AN-Mk 47	
Overall length, in.	52.5		49.9	
Body length, in.	31.1		27.8	
Body diameter, in.	15.0		15.0	
Wall thickness, in.	0.06		0.06	
Tail length, in.	20.2		24.6	
Tail width, in.	20.6		15.4	
Nose shape	Round[a]		Flat	
Filling, type	TNT	Torpex	TNT	Torpex
Filling weight, lb	224	249	227	252
Total weight, lb	325	350	330	355
Tail fuzing:				
AN-Mk 230 or AN-Mk 230-4				
Nose Fuzing:				
AN-Mk 219; will not arm if dropped from below 2500 ft when used on bomb with flat nose or flat nose attachment. Requires a Mk 219 adapter ring. Gives instantaneous action.				
Mk 221; delay of 0.01 sec. Will not arm on flat nose if dropped below 2500 ft.				
AN-M103/M103A; instantaneous only. Special vanes for flat-nose bombs.				
Athwartships:				
AN-Mk 224 and AN-Mk 234; hydrostatic fuzes; settable to function at 25, 50, 75, 100, or 125 ft.				

[a]Can use a flat-nose attachment.

325/350-lb Aircraft Depth Bombs Mk 53 and Mk 54

The 325-lb TNT-filled Mk 53 and 350-lb Torpex-filled Mk 54 aircraft depth bombs were very similar to the Mk 41 and Mk 47 bombs in configuration and construction--basically a cylindrical, welded-sheet-steel body with a flat nose (Figures 3-43 and 3-44). An aft closure plate was secured to the back end of the bomb body by four bolts. The bombs were suspended vertically by two lugs seven inches on either side of the center

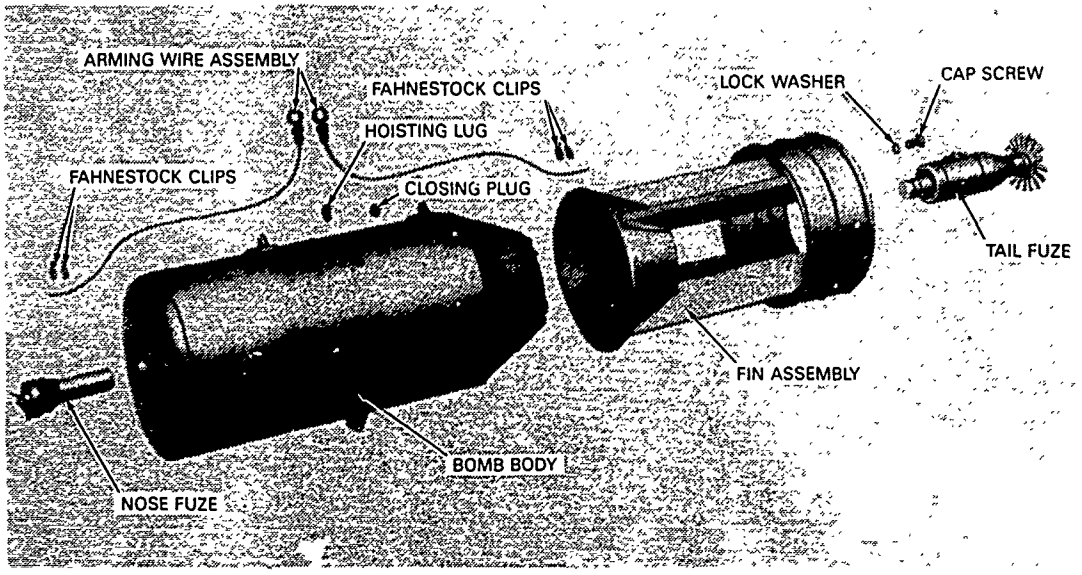
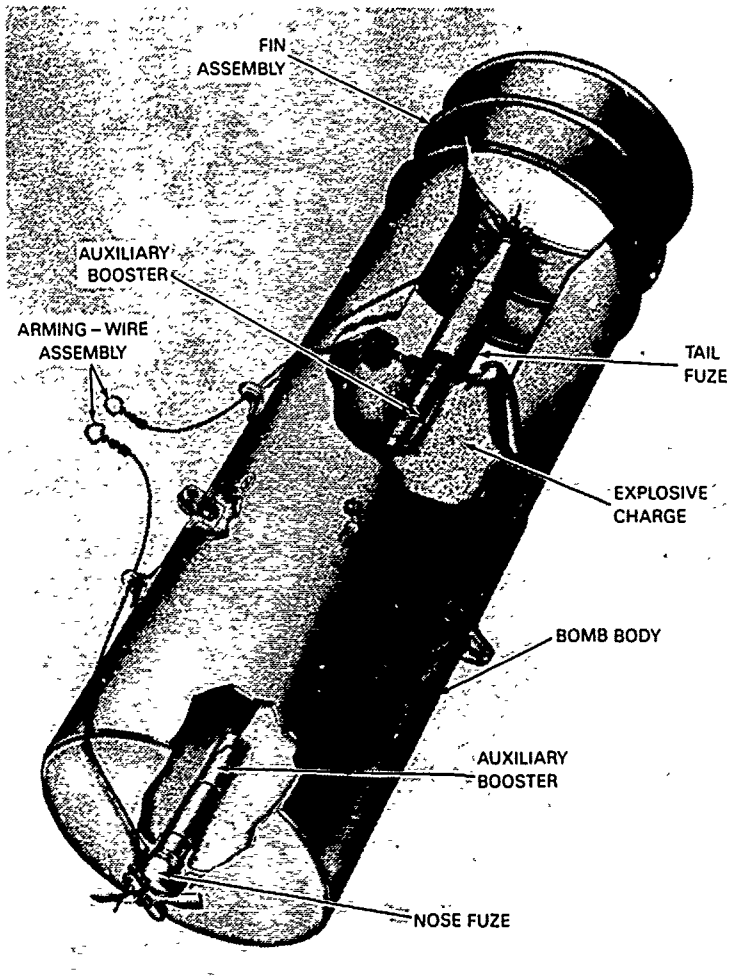


FIGURE 3-43. 325-lb Aircraft Depth Bomb AN-Mk 53 Mod 1, Exploded View.

of gravity, or by a single lug at the center of gravity, 180 deg removed from the other lugs. The bomb cases were strengthened by internal bands secured at the center of gravity. Trunnions for dive bombing were threaded into the case and internal strengthening band. The tail construction consisted of four fins (vanes) welded to the tail cone. The fins were strengthened by interior box-type struts and an exterior wide ring strut. The tail fin assembly was secured to the bomb body base-closure plate with four bolts.

The Mk 53 and Mk 54 bombs were designed to replace the previous 325-lb depth bombs that used the athwartship hydrostatic fuzes, since difficulties were encountered with the AN-Mk 224 and AN-M234 hydrostatic fuzes. Specifically, on numerous instances in water crash landings, depth bombs exploded when fuzed with the transverse or athwartship hydrostatic fuzes. These fuzes were suspended from use as was the use of the transverse fuze well. The Mk 53 and Mk 54 depth bombs used the AN-230 hydrostatic tail fuze and an impact type nose fuze. Neither bomb body had provisions for a transverse or athwartship fuze.

All of the 325-lb and 350-lb depth bombs, except the Mk 17 Mod 1 were later assigned Army, Navy (AN) Standard designations.



Overall length, in.	54.6
Body diameter, in.	13.5
Wall thickness, in.	0.06
Tail length, in.	24.5
Tail width, in.	13.9
Type of filler:	
Mk 53	TNT
Mk 54	Torpex
AN-Mk 54-1	HBX
Loading factor, %	(approx.) 70%
Fuzing:	AN-Mk 230 hydrostatic tail fuze and impact type nose fuze

FIGURE 3-44. 350-lb Aircraft Depth Bomb AN-Mk 54 Mod 1, Cutaway View.

650/700-lb Aircraft Depth Bombs Mk 29, Mk 37, Mk 38, and Mk 49

All of the 650-lb and 700-lb depth bombs were constructed from three steel sections, in which a hemispherical nose piece (reinforced with a steel disc) for the 600-lb Mk 29 and Mk 37 and a flat nose piece for the 600-lb Mk 38 and the 700-lb Mk 49, were welded to a cylindrical center section. To complete the construction of the bomb body, a conical tail with a circular shroud around the four vanes was welded to the base of the cylindrical center section. The suspension lugs were reinforced with steel strips, and threaded holes were provided in both sides, 90 deg removed from the lugs, to receive trunnion lugs for suspension when used in dive-bombing deliveries. A flat nose attachment in the shape of a bucket was fitted down under the round nose of the Mk 29 and Mk 37 bombs to minimize ricochet and to improve underwater trajectories. The tail sections of the Mk 37, Mk 38, and Mk 49 were 7 inches shorter than the Mk 29 so that the Mk 229 tail fuze could arm more readily (Figures 3-45 and 3-46). The three 650-lb depth bombs and the one 700-lb Mk 49 (a Torpex-filled version of the Mk 38) all used a nose impact fuze, an athwartship or transverse hydrostatic fuze, and a hydrostatic tail fuze. The same precautions noted for the 325/350-lb Mk 17 and Mk 44 depth bombs (p. 98), relative to using a delay function in the nose fuze, applied to the 650-lb and 700-lb depth bombs. See Table 3-9 for more details on these bombs.

TABLE 3-9. Physical Characteristics of 650/700-lb Aircraft Depth Bombs.

Characteristics	Mk 29	Mk 37	Mk 38	Mk 49
Overall length, in.	70.0	63.0	58.5	58.5
Body length, in.	41.0	41.0	36.4	36.4
Body diameter, in.	17.7	17.7	17.7	17.7
Wall thickness, in.	0.12	0.12	0.12	0.12
Tail length, in.	36.0	29.0	29.0	29.0
Tail width, in.	17.7	17.7	17.7	17.7
Filler:				
Type	TNT	TNT	TNT	Torpex
Weight, lb	464	464	425	472
Total weight, lb	657	659	634	681
Charge-to-weight ratio	70%	70%	67%	69%

Fuzing: AN-M103/M103A1 and AN-Mk 219 nose fuzes.
AN-Mk 224 or AN-Mk 234, athwartship fuzes.
Mk 229/Mk 229 Mod 3, tail fuzes.

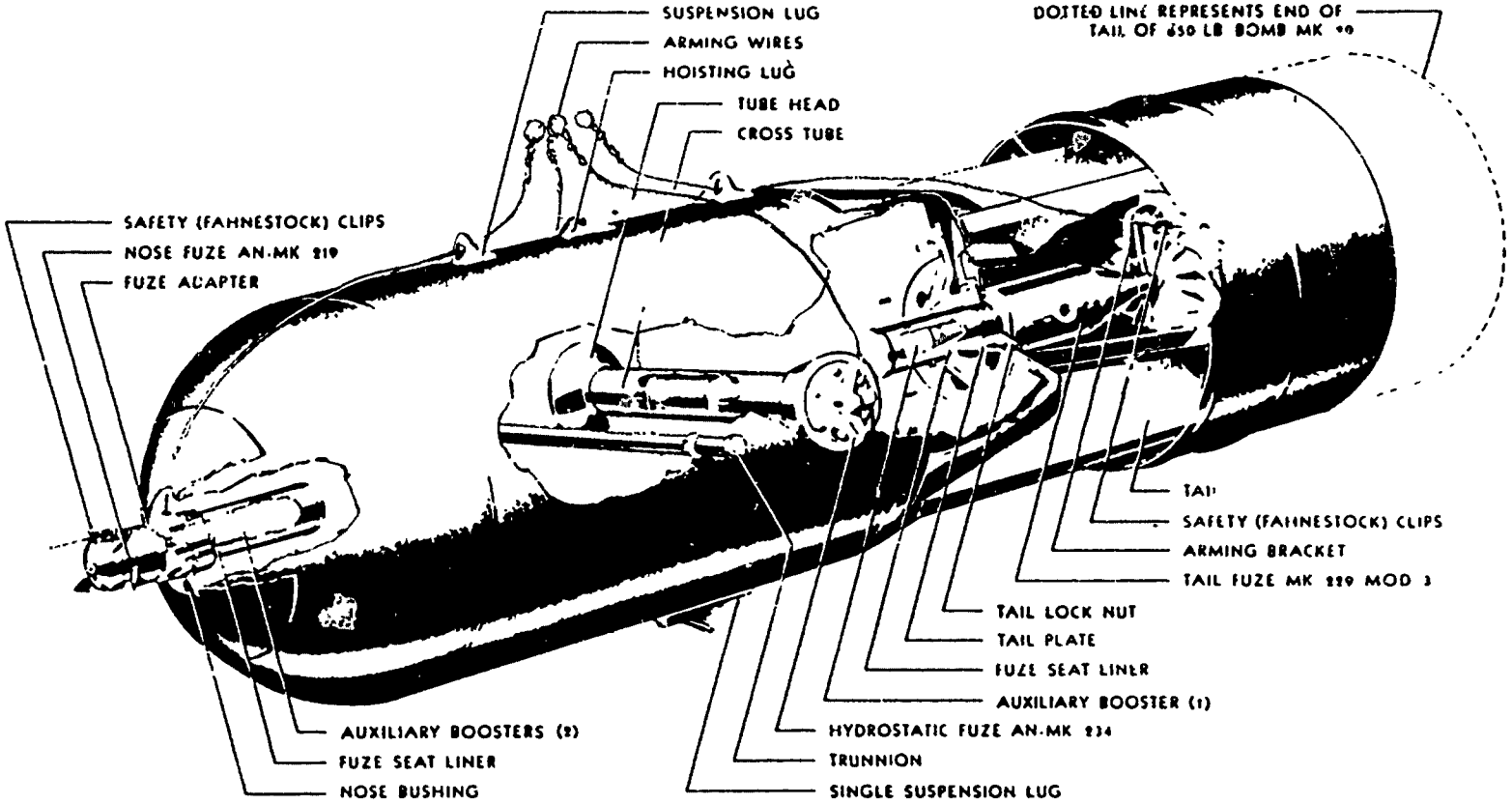


FIGURE 3-45. 650-lb Depth Bombs Mk 29 and Mk 37.

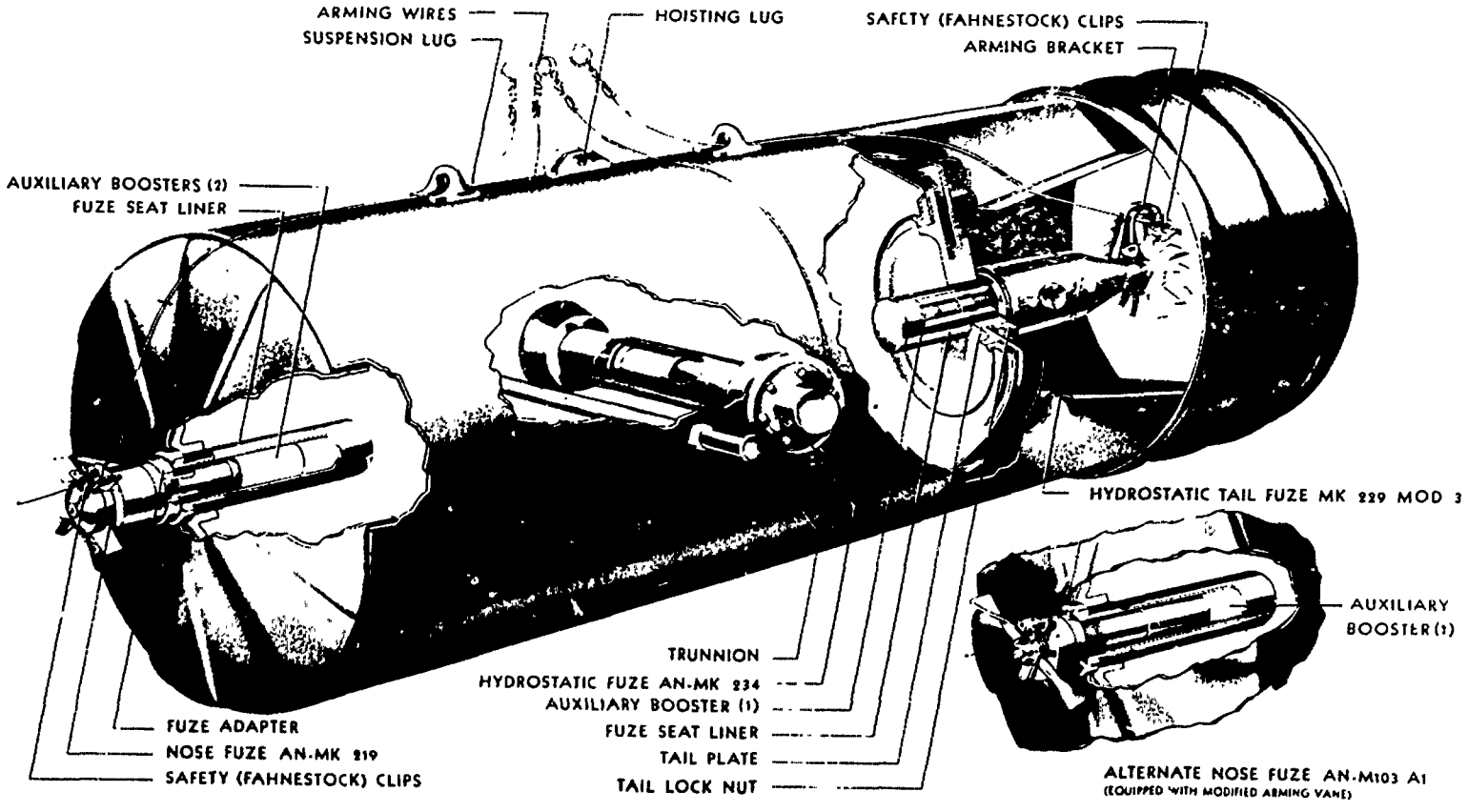
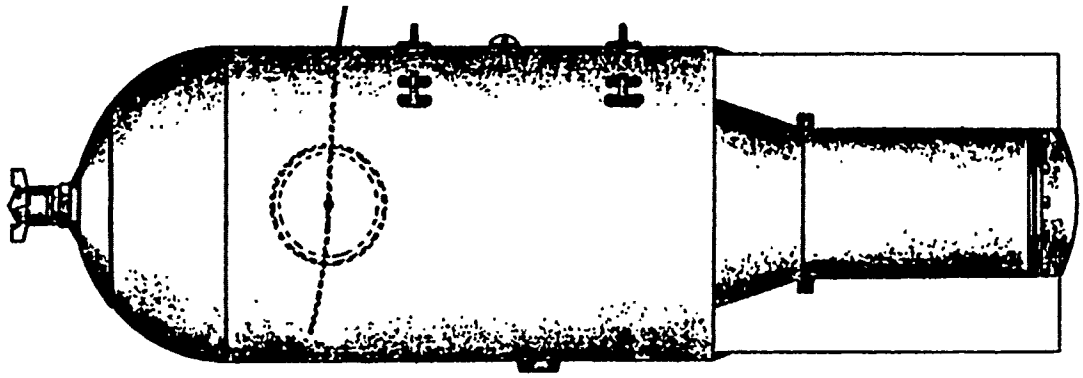


FIGURE 3-46. 650-lb Aircraft Depth Bomb Mk 38 (TNT).

AIRCRAFT MINES

1000-lb Aircraft Mine Mk 13 Mods 0, 4, and 5

This heavy-charge aircraft mine consisted of three steel sections welded together, a hemispherical nose, a tubular or cylindrical body, and a somewhat tapered tail section. Four sheet-metal vanes or fins, folded longitudinally in a "V" shape, were welded to the tail section, which in turn was welded to the mine case. The suspension system consisted of three sets of double lugs, placed 45 deg apart from each other (Figure 3-47). When used as a mine, a Mk 229, Mod 3 mechanical arming hydrostatic firing tail fuze or a magnetic induction type fuze was used in Mods 0 and 4, and an acoustic type fuze in Mod 5. When used as a demolition bomb, the AN-Mk 219 or AN-M103 mechanical impact fuzes (rotor system arming) were used. It should be noted that the Mk 13 was basically a ground mine and was not designed to function in water depths over 15 fathoms deep. The clock in this mine was started by a hydrostatic clock starter after the mine reached a depth of 15 feet in water, which armed the magnetic-influenced firing mechanism in about 15 minutes.

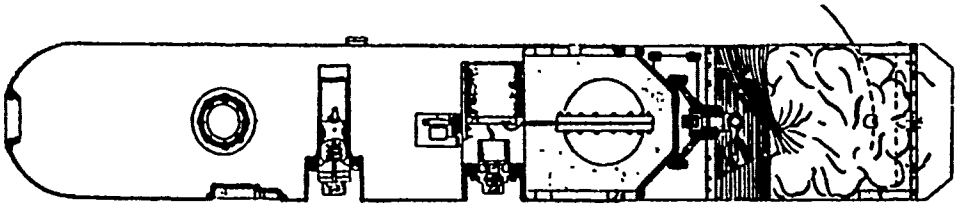


Overall length, in.	67.6
Body diameter, in.	19.9
Wall thickness, in.	0.11
Tail length, in.	24.25
Tail width, in.	25.25
Filling, type	TNT
Filling, weight, lb	675
Total weight, lb	1026
Charge/weight ratio	65%

FIGURE 3-47. 1000-lb Aircraft Mine Mk 13.

1600-lb Aircraft Mine Mk 12 Mods 1 and 4

The 1600-lb aircraft mine was very similar to the 1000-lb Mk 13 aircraft mine, except it employed a high-drag-only parachute system to retard the rate of descent. A sling-type suspension system was used instead of lugs (Figure 3-48). The weight of the heavy-charge Mk 12 mine varied from a minimum of 1565 lb (Mod 4 with 1065 lb of TNT) to a maximum of 1725 lb (Mod 1 with 1225 lb of Torpex). TNT or Torpex was used in both Mods of the Mk 12 aircraft mine.



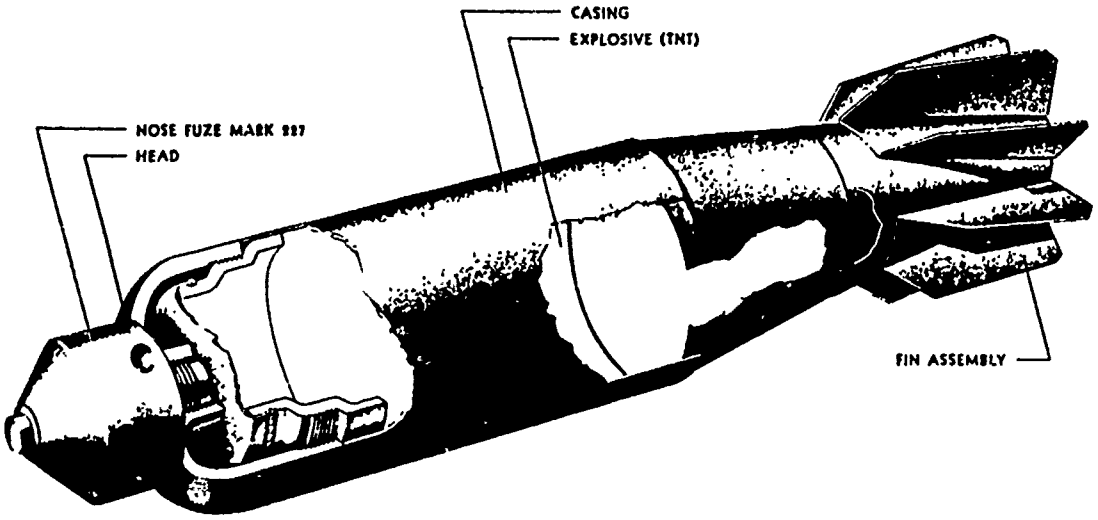
Overall length, in.	130.9
Body diameter, in.	20.9
Wall thickness, in.	0.11
Tail construction	Aluminum alloy
Tail width, in.	Parachute container
Filling, type	TNT or Torpex
Filling, weight, lb	1065-1095 1190-1225
Total weight, lb	1565-1595 1690-1725
Charge/weight ratio	69% 71%

FIGURE 3-48. 1600-lb Aircraft Mine Mk 12 Mods 1, 4.

ANTIAIRCRAFT BOMBS

The 5-lb antiaircraft bomb Mk 34 was constructed from a three-piece reinforced-steel nose piece and a tapered tail section, both welded to a cylindrical steel body. The tail section consisted of four U-shaped sheet steel vanes or fins welded to a steel cone shaped section. The fins were welded on the cone at ten-deg angles from the longitudinal axis, to induce bomb rotation (Figure 3-49). The bomb was normally clustered in a static-dispenser-type container that held 20 units. Either the 175-lb Mk 3 or Mk 3 Mod 1 container (Figure 3-50) was used to dispense the bombs. These bombs were used against enemy aircraft in flight or on the ground. The bomb had a unique Mk 227 mechanical impact fuze that used centrifugal force as its arming device. The rotational velocity required to arm the fuze was acquired by the offset tail fins.

The Mk 34 bomb and the Mk 227 fuze were designed for air-to-air bombing, but did not prove successful in this application. It had limited use against parked aircraft and was dropped for its nuisance value on night raids during the early stages of World War II in the Pacific Theatre.



Overall length, in.	15.0
Body length, in.	12.0
Body diameter, in.	3.0
Wall thickness, in.	0.05
Tail length, in.	3.0
Tail width, in.	3.0
Weight and type of explosive fill, lb	1.9 TNT
Total weight, lb	5.5
Charge/weight ratio	34.5%

FIGURE 3-49. 5-lb Antiaircraft Bomb Mk 34.

There also was a smaller version of this antiaircraft bomb, the 3-lb type C (Mk XXXII), introduced in World War II. However, as noted in Reference 5, this bomb ceased to be used after June 1944.

U.S. ARMY-NAVY "AN" SERIES BOMBS

The creation of the Army-Navy Standardization Board resulted in the standardization of bombs of these two services into the "AN" series. This series was very similar to the "M" series except for these modifications:

1. A third suspension lug was added at the center of gravity and diametrically opposite the dual suspension lugs to fit British release devices.

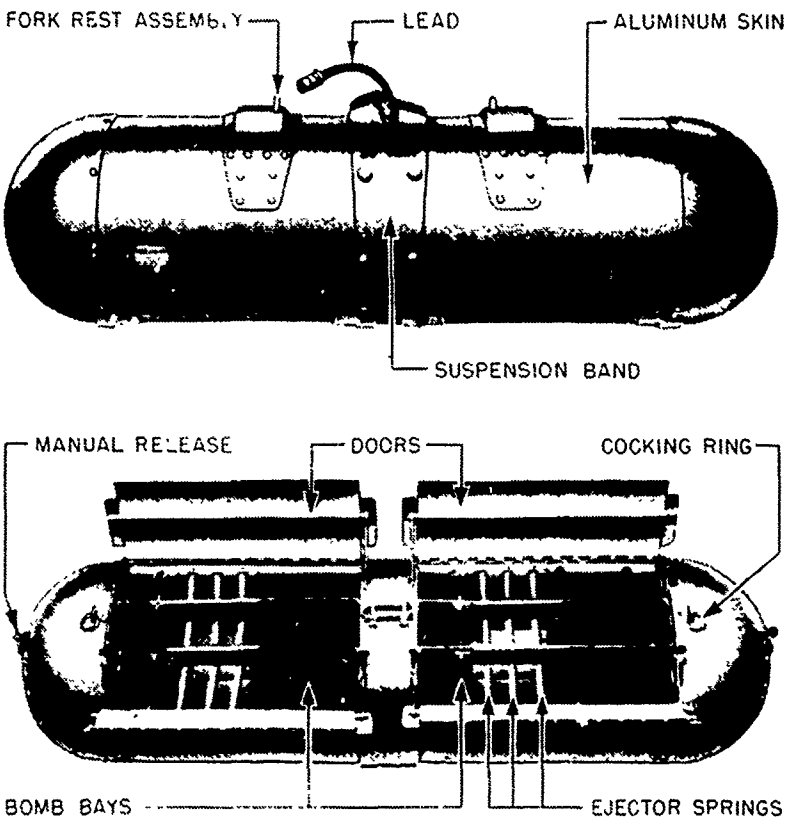


FIGURE 3-50. Bomb Container Mk 3 Mod 1 (Reference 6).

2. The base plate was changed to a male plug to increase the strength on low-angle penetration of targets.

3. The bombs were painted an overall olive drab with 1-inch yellow bands around the nose and base and a 0.25-inch yellow band around the center of gravity.

The bombs in the "AN" series included the following weight classes: 100-lb AN-M30, 250-lb AN-M57, 500-lb AN-M43, 1000-lb AN-M44, and 2000-lb AN-M34. These bombs were all high-capacity (charge-to-weight ratios ranging from 48 to 56%), high-explosive general purpose bombs (Figures 3-51, 3-52, 3-53, 3-54, and 3-55).

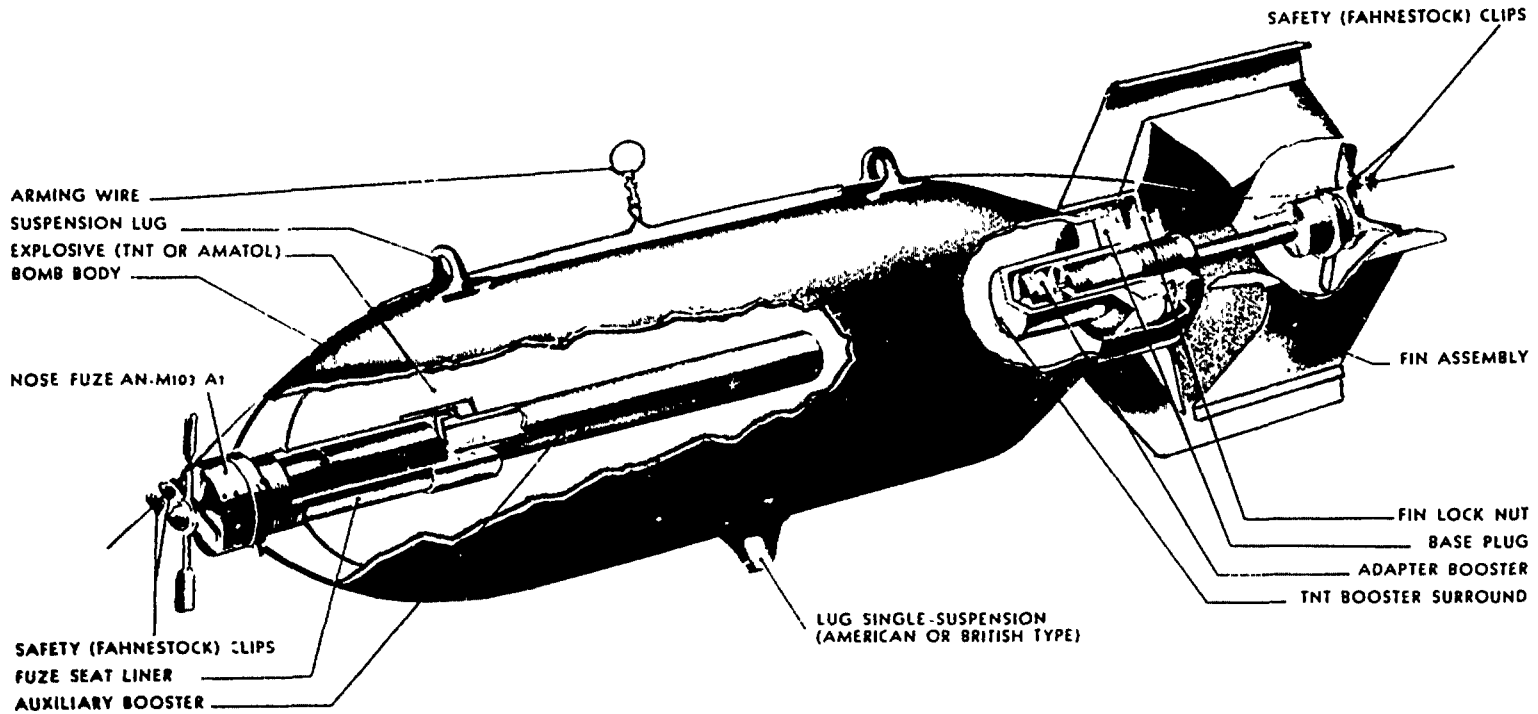


FIGURE 3-51. 100-lb GP Bomb AN-M30.

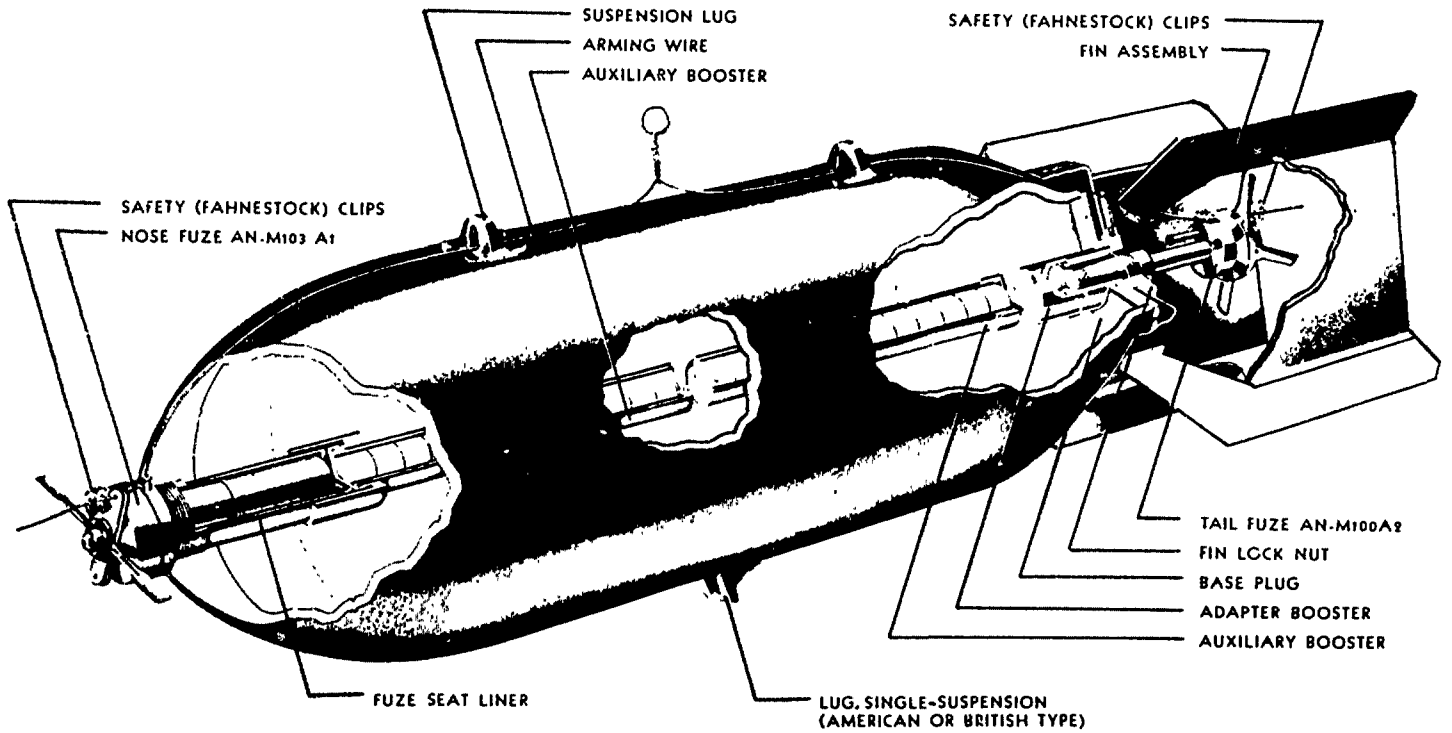


FIGURE 3-52. 250-lb GP Bomb AN-M57.

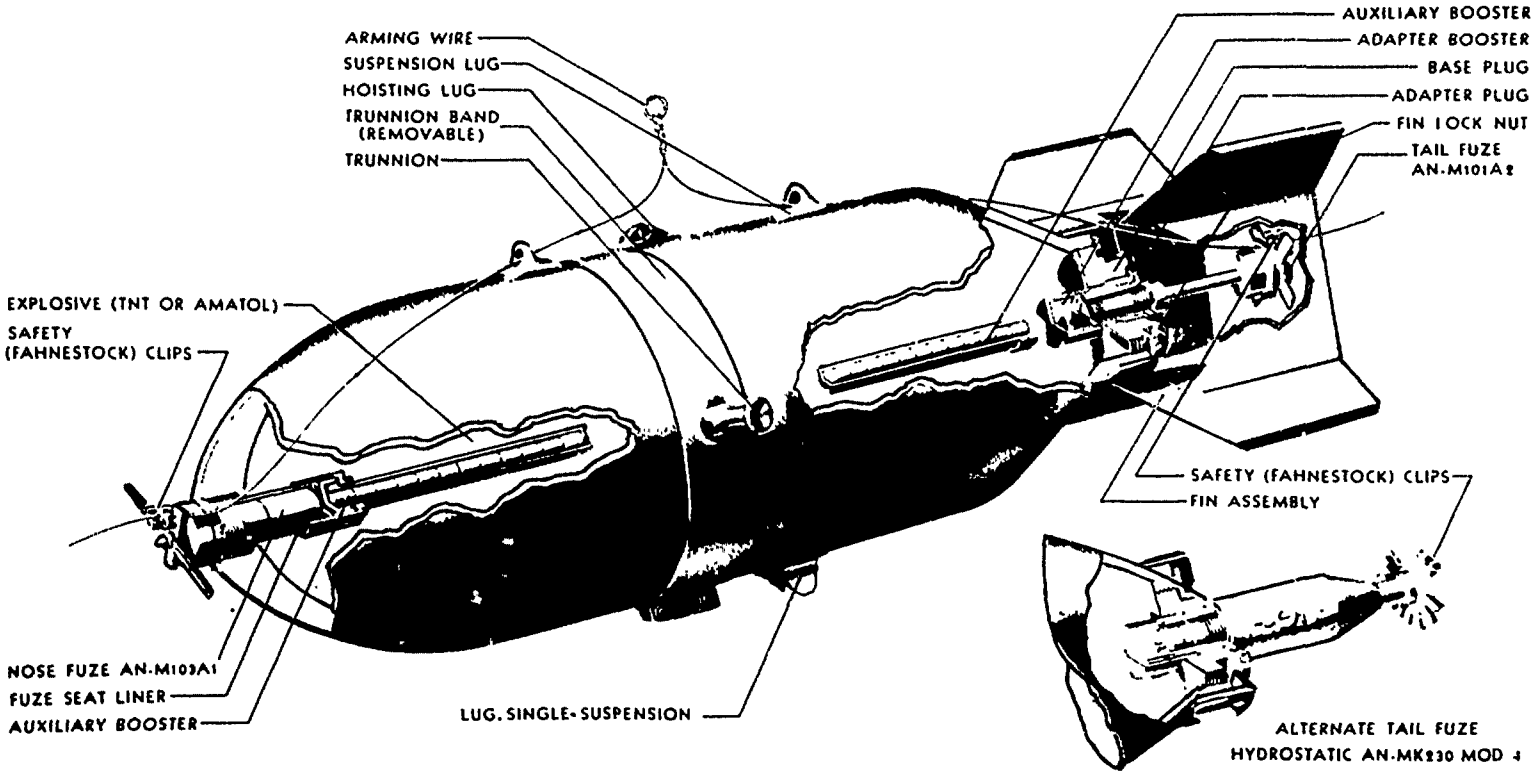


FIGURE 3-53. 500-lb GP Bomb AN-M43 and AN-M64.

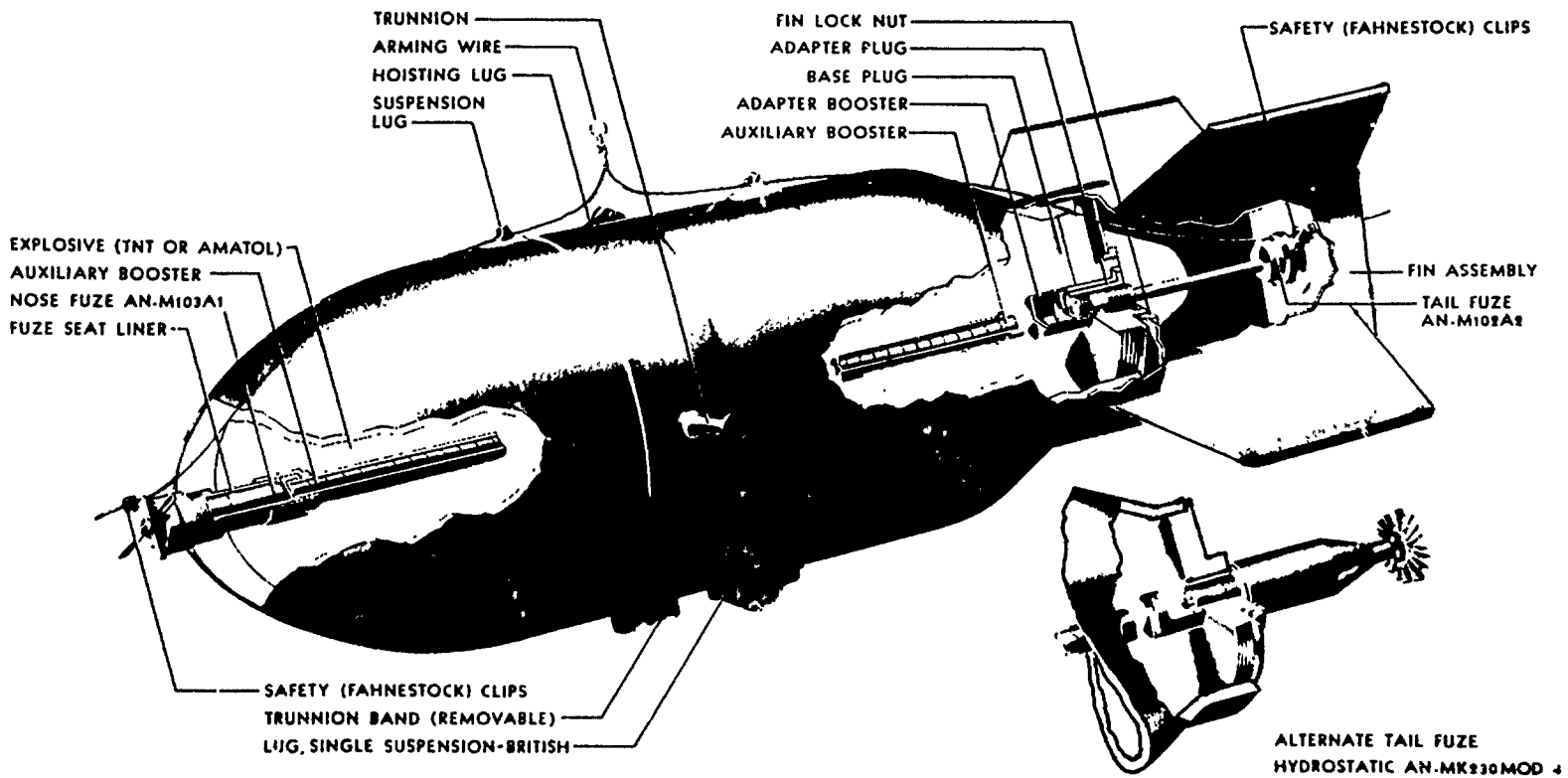


FIGURE 3-54. 1000-lb GP Bomb AN-M44 and AN-M65.

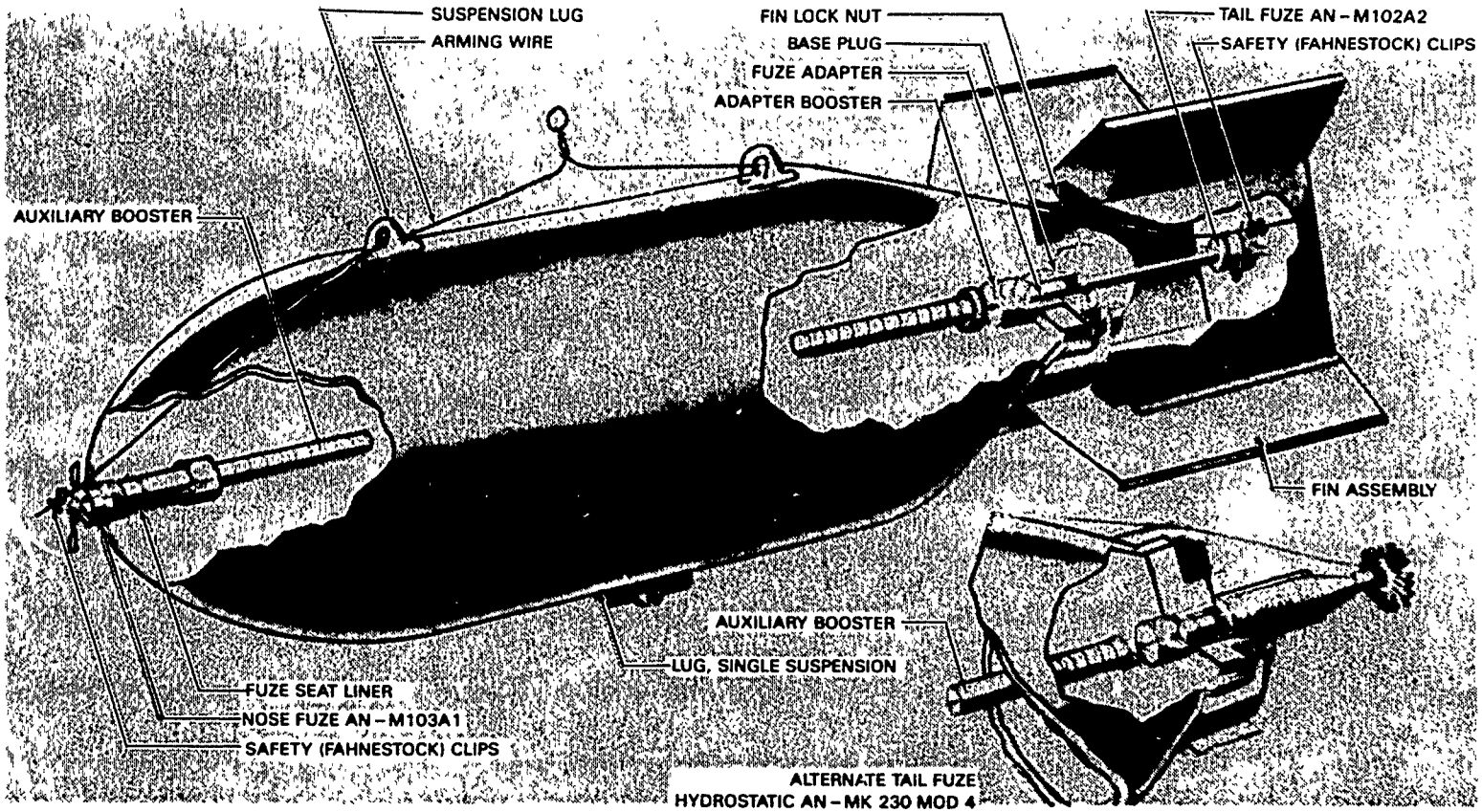


FIGURE 3-55. 2000-lb GP Bomb AN-M34 and AN-M66.

AN-GP (GENERAL-PURPOSE) SERIES BOMBS

Modifications for ASW Use

The AN series was subsequently replaced by the AN-GP series as a result of modifications. The 500-, 1000-, and 2000-lb bombs were modified to make it possible for their use in antisubmarine warfare (ASW) missions as well as for general bombardment, and redesignated as AN-M64, AN-M65, and AN-M66, respectively. The modification consisted of a change from the Adapter Booster M102 to the Adapter Booster M115, which permitted use of either standard Army tail fuzes or the Tail Hydrostatic Fuze AN-Mk 230. The standard explosive fill for these AN GP bombs was 50-50 Amatol until the supply of TNT became ample in 1943, at which time TNT became the standard fill. Following World War II, the standard explosive fill was changed to include Composition B.

AN-GP Antiwithdrawal Features

The AN-GP bomb series was modified to incorporate two steel pins in the base plate which locked the base plate to the main charge to prevent its removal once the bomb was filled with explosive material. Also, the adapter boosters were modified to include a hole through the booster and a groove in the threads of the base plate for a locking pin, shipped with all antiwithdrawal tail fuzes. Insertion of the pin, which was held in place by the fuze body, prevented withdrawal of the adapter booster. The incorporation of these modifications changed the designation of the AN-GP series to the AN-GPA1 series (Figures 3-56, 3-57, 3-58, 3-59, and 3-60). Table 3-10 delineates the succession of GP bomb designations as changes and/or new developments were sequentially incorporated into the general purpose bombs used by the Army and Navy.

TABLE 3-10. General-Purpose Bomb Designations.

Weight, lb	M series	Navy	AN series	AN GP series	AN GPA1 series
100	M30	Mk 4 Mod 4	AN-M30	AN-M30	AN-M30A1
250	M57		AN-M57	AN-M57	AN-M57A1
300	M31				
500	M43	Mk 12 Mod 2	AN-M43	AN-M64	AN-M64A1
600	M32				
1,000	M44	Mk 13 Mod 2	AN-M44	AN-M65	AN-M65A1
1,100	M33				
2,000	M34		AN-M34	AN-M66	AN-M66A1

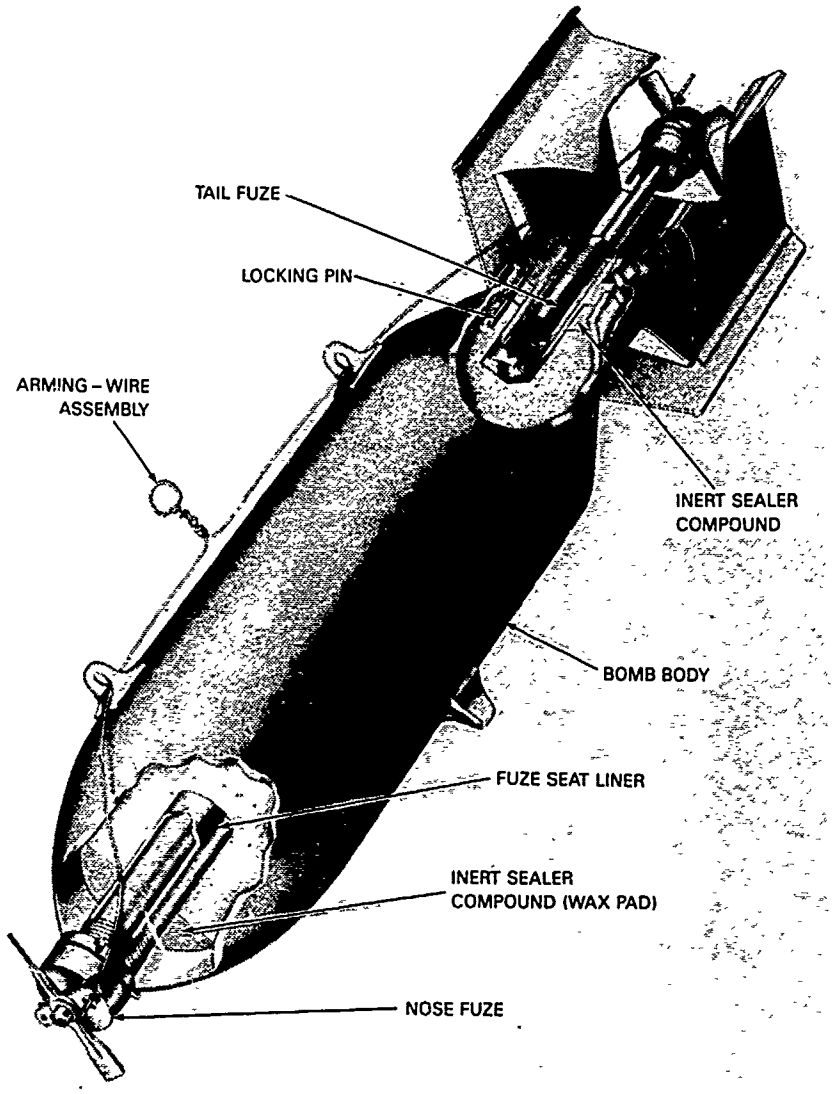


FIGURE 3-56. 100-lb GP Bomb AN-M30A1 with Fin Assembly AN-M103A1.

Bomb Body Construction

The body construction of the U.S. general-purpose (GP) bombs were either one, two, or three pieces. Methods of manufacture included (1) one-piece cast or spun, (2) two-piece cast and weldment, or (3) three-piece cast and weldment. The ogival nose shapes, tapered to join the thin parallel side walls, which terminated in a boat-tailed shape at the aft end. The nose opening was threaded for insertion and retention of a fuze liner and the base opening was threaded for a male plug that in turn housed the tail-fuze adapter booster. There were auxiliary boosters in all of the AN-GP bombs, one in the 100-lb GP class and two in all of the others, axially in line with the nose and base fuzes.

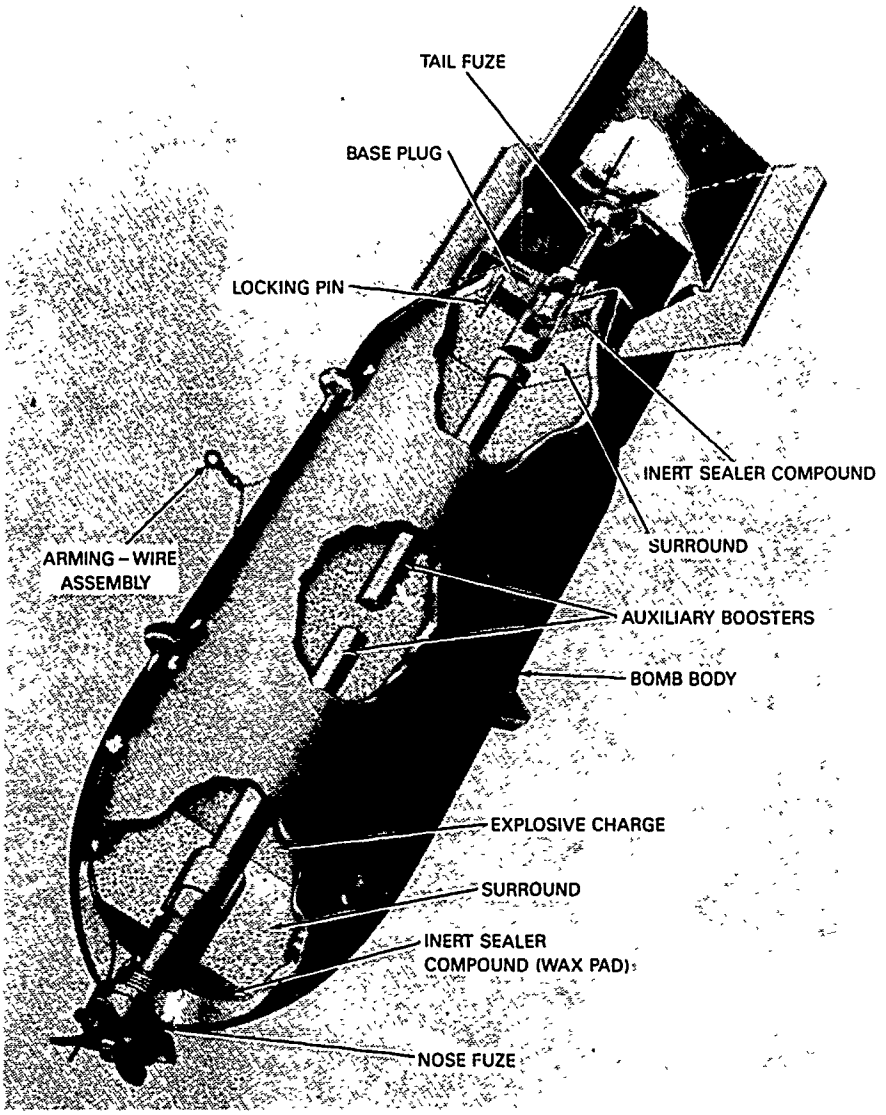


FIGURE 3-57. 250-lb GP Bomb AN-M57A1 with Fin Assembly AN-M106A1.

Bomb Suspension Systems

Dual suspension lugs, for horizontal suspension, were welded directly to the bomb case, spaced 14 inches apart on bombs up to 1000 lb and 30 inches apart on bombs 2000 lb and over. A single horizontal suspension lug was also welded to the bomb case at the center of gravity and diametrically opposite the dual lugs. The lugs were eyebolts, U-shaped from steel bars. The M series bombs could be carried on single suspension racks by using an additional single suspension lug welded on a band fitting around the

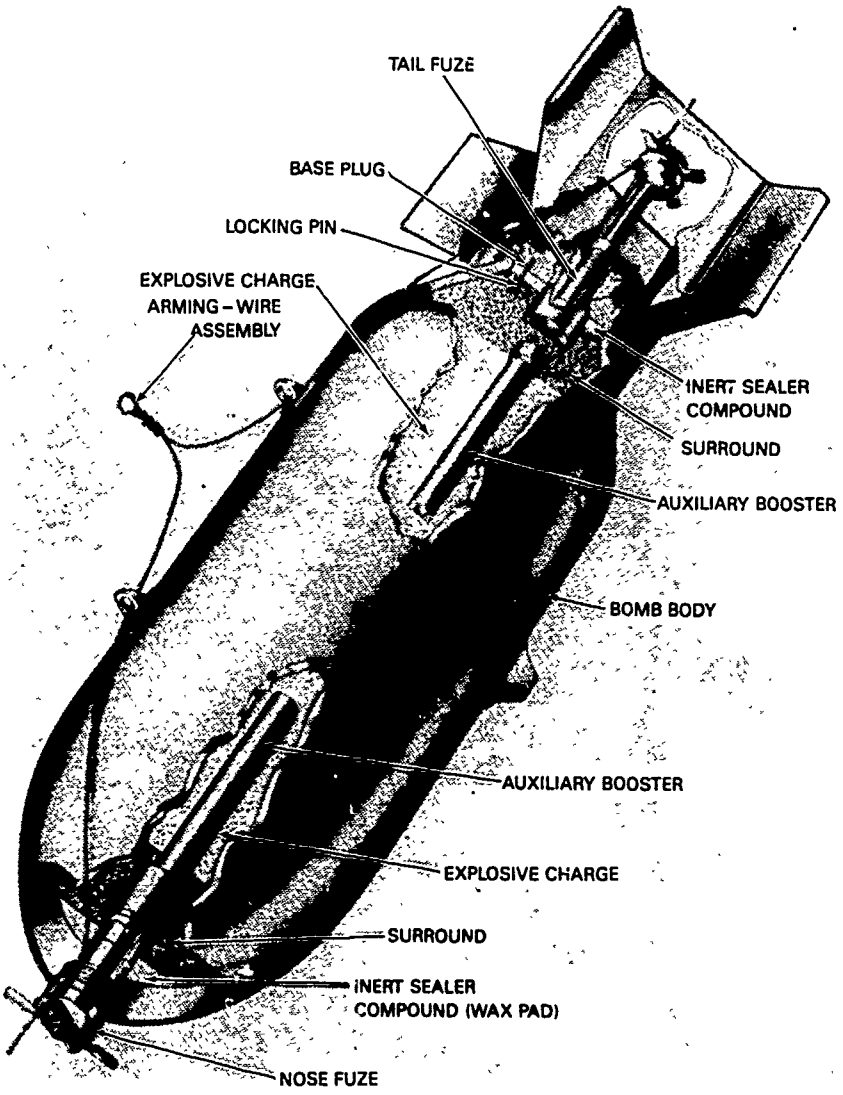


FIGURE 3-58. 500-lb GP Bomb AN-M64A1 with Fin Assembly AN-M109A1.

bomb body at the center of gravity. For dive bomb deliveries, trunnions were provided on either of two separate bands. One type provided only the trunnion; the other, more common type, provided a single hoisting lug in addition to the trunnions. In later versions of Navy-manufactured AN bombs, the suspension and hoisting fittings were not welded to the bomb case, but were attached by means of threaded bolts that fitted into holes tapped directly into the bomb case. For suspension in torpedo slings, the base of the single suspension lug had to be modified to incorporate the torpedo-sling guide key.

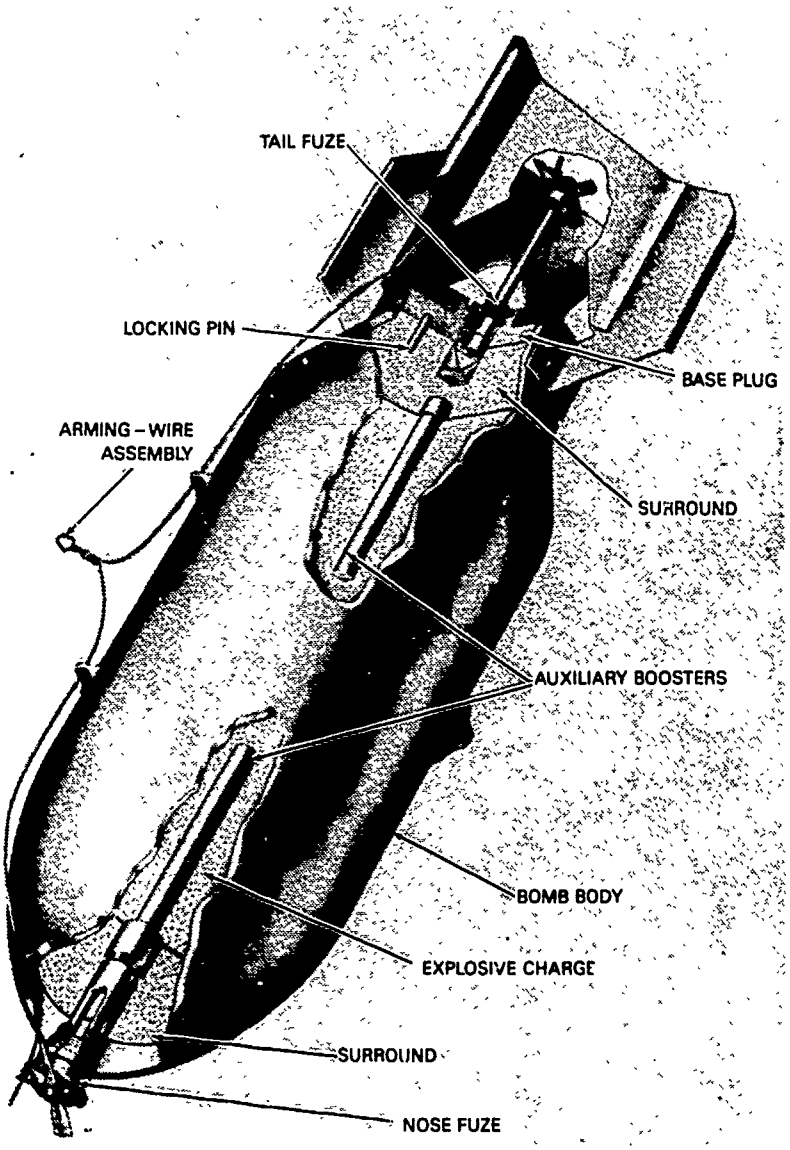


FIGURE 3-59. 1000-lb GP Bomb AN-M65A1 with Fin Assembly AN-M113A1.

To hoist bombs into Navy planes, those AN-GP bombs, which were not equipped with hoisting lugs, had to be fitted with either an expendable single or dual-lug band or by a removable band. The removable band was preferred since it did not affect the terminal velocity of the bomb. The best of those bands was the Universal Hoisting Band Mk 8. For Army aircraft, bombs were usually hoisted by canvas slings, which supposedly "did not affect air trajectory".

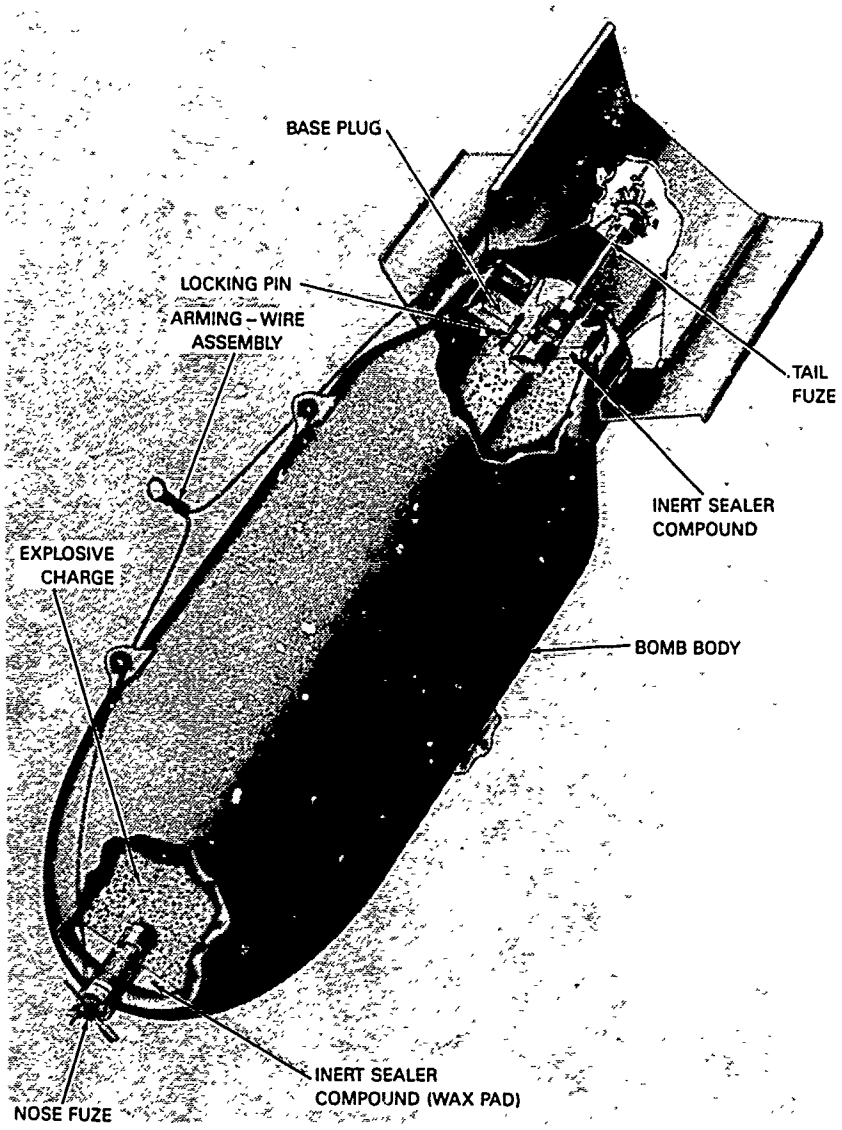


FIGURE 3-60. 2000-lb GP Bomb AN-M66A1 with Fin Assembly AN-M116A1.

Bomb Tail Construction

The tail construction of the AN-GP bombs was referred to as the box-type tail. This tail consisted of (1) a cast-steel sleeve secured to the bomb body by a fin locking nut and (2) four steel fins supported by four steel struts in the shape of a box. The fins and struts were pressed from a single piece of sheet steel and welded to the cast steel sleeve. An "A" version of these tails indicated heavier construction for high-altitude bombing.

Explosive Loading/Auxiliary and Adapter Booster

Explosive loading of the AN-GP bombs was accomplished in the following manner. With the nose fuze-seat liner in place, the bomb was vertically positioned, nose down, and an auxiliary booster M104 was placed behind the fuze liner. The M104 was a bakelite tube containing tetryl pellets. The initial pour of the explosive fill was sufficient to secure the auxiliary booster when it solidified. The remainder of the explosive fill, either Amatol 50-50, TNT, or Composition B, was added until a depth of approximately 6 inches remained to be filled. A second auxiliary booster M104 was then inserted in all bombs except the 100-lb class, and "tail-surround" or TNT-booster-surround material was added to complete the filling operation. A wooden form was inserted into the tail fuze cavity as the explosive fill was cooling. After cooling, the form was removed and an appropriate adapter booster was inserted. The adapter booster consisted of the fuze-seat liner with an additional steel cup containing a tetryl pellet. The adapter booster M102 (and M102A1) had an internal thread diameter of 1.50 inches. The adapter booster M115 had an internal thread diameter of 2.0 inches and an adapter ring for further reduction of the diameter to 1.50 inches when smaller fuzes were used.

Tests conducted by the Army demonstrated that the presence or absence of auxiliary boosters M104 did not alter the effectiveness of the detonation of these bombs. Based on the results of the tests, the Army eliminated the use of auxiliary boosters M104 from Composition-B-loaded 500-,1000-, and 2000-lb GP bombs during the latter part of 1944. Elimination of auxiliary boosters M104 from TNT- and Tritonal-loaded GP and SAP bombs was started in 1945. By 1947, all production of Composition-B-, TNT-, and Tritonal-loaded GP and SAP bombs and Composition-B-loaded fragmentation bombs excluded the auxiliary boosters M104.

Bomb Nose and Tail Surrounds

Tests conducted by the Army demonstrated that inert nose and tail surrounds improve the safety in handling of GP and SAP bombs. Based on these tests, the majority of the AN series bombs loaded with Composition B, TNT, Tritonal, and Picratol incorporated inert nose and tail surrounds. The composition of the inert surround material was 51% ester gum, 10.5% castor oil, 34.5% kaolin, and 4.0% hydrocarbon wax.

For the GP bombs, the nose surrounds were 1.25 + 0.25 inches and the tail surrounds were 0.75 + 0.25 inch. For the SAP bombs, the nose surrounds filled the nose cavity and extended no more than 0.125 inch beyond the bottom of the fuze seat liner. The tail surrounds were 0.75 + 0.25 inch. The thickness of the surrounds was such that most, if not all, of the explosive portion of the adapter boosters and the nose-fuze booster (surrounded by the fuze seat liner) extended into the main explosive fill, with the exception of the SAP nose fuze booster.

Antiricochet System

To provide a more vertical impact condition and thereby lessen the tendency of the 100-lb, 250-lb, and 500-lb GP bombs to ricochet, as well as to retard the rapid descent of these bombs when released at low altitudes, antiricochet devices M16 and M17 were developed (Figure 3-61). The antiricochet device consists of a parachute unit T3 or T4, a modified AN-M112A1 tail fuze (M151) using an anemometer-type arming vane, and a fuze adapter.

The parachute unit (T3 for the 100- and 250-lb bomb, and T4 for the 500-lb bomb) consists of a parachute and shroud lines housed in a cylindrical canister. The cover of the canister is secured by two latches diametrically opposite each other. These latches are held closed by cotter pins when issued and by arming wires when fastened to the bomb. The canisters have a threaded collar at the forward end for assembly to the adapter, which in turn is screwed to the base of the bomb body. The T3 and the T4 units are similar except for size.

The M151 (T79E1) tail fuze (modified AN-M112A1), using the M16A1 primer detonator (8- to 15-second delay), is threaded to fit in the M102 adapter booster in the 100-lb and 250-lb GP bombs and the M115 adapter booster in 500-lb GP bombs. An anemometer type vane is used to arm the fuze, the arming stem of the vane passes through the fuze transversely. The fuze body contains a plunger and cocked firing pin assembly similar to the M112 series.

Three arming wires are required when the parachute unit is attached. One of the wires passes through the adapter sleeve and the anemometer shaft. The other two wires pass through the latches on the parachute canister.

When the bomb is released, the arming wire assembly is withdrawn from the anemometer and the parachute canister latches. The anemometer vane is free to rotate and unscrews the arming stem from the fuze. The parachute canister opens as soon as the arming wires are withdrawn from the latches and the windstream acts to pull the aft cover off the assembly. The parachute opens and checks the rate of fall of the bomb, which detonates on impact.

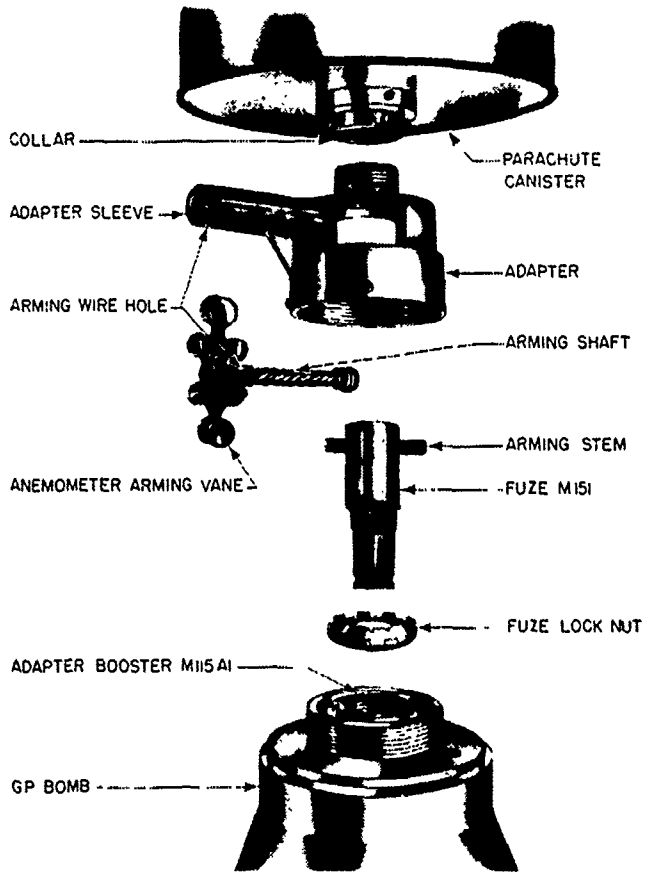


FIGURE 3-61. Antiricochet Parachute Assembly (Exploded View).

Fuze Systems

The AN series bombs utilized a large number of nose and tail fuzes for so-called regular missions, special missions (masthead (low altitude) bombing from land bases, masthead bombing from carrier or land bases, long-delay against land targets, and antiricochet), and VT or airburst missions. The 500-lb, 1000-lb, and 2000-lb bombs had antisubmarine missions that necessitated the use of hydrostatic tail fuzes AN-Mk 230 and its Mods and the Mk 231 Mod 0. The use of these larger diameter fuzes was possible by removing the screwed-in sleeve of the adapter booster M115, which was incorporated into the basic M115 design so that any of the smaller diameter Army tail fuzes could be used.

The 100-lb AN-M30A1, 250-lb AN-M57A1, 500-lb AN-M64A1, 1000-lb AN-M65A1, and 2000-lb AN-M66A1 GP Bombs all incorporated the use of antiwithdrawal devices, previously discussed on p. 115. The bombs contained antiwithdrawal pins in the base plug and a device for locking the adapter booster to the base plug. The earlier models of these bombs did not have these features that prevented the removal of the base plate and adapter booster. The sensitivity of the once-assembled-and-fuzed later versions of the "AN" series GP bombs can be better understood by the following caution note, found in most ordnance manuals, such as Reference 6, that applied to all of the later AN series bombs incorporating the antiwithdrawal devices.

> CAUTION: The AN-M30A1 (100-lb) bomb uses the AN-123A1 and the AN-M132 tail fuzes which incorporate the use of an antiwithdrawal device. Nondetonation of bombs fuzed with AN-M123A1 and AN-M132 fuzes cannot be relied upon when released SAFE because the glass solvent ampoule in the fuze may break upon impact of the bomb. Once an AN-M123A1 or AN-M132 fuze is installed, no attempt should be made to remove the fuze. Return of bombs to airfields or carriers is restricted. Bombs fuzed with AN-M123A1 or AN-M132 fuzes may return to an airfield or carrier provided that (1) bomb rack malfunction prevents release, (2) efforts to release by maneuvering of aircraft are unsuccessful, (3) bomb and fin assemblies are undamaged and fuze arming wires are in place as observed by check of aircraft before landing, and (4) fuzed bombs are immediately disposed of by authorized personnel upon landing of aircraft Do not turn an AN-M123A1 or AN-M132 fuze back and forth to engage the threads; use a screwing-in motion only. The antiwithdrawal device will cause the fuze and bomb to detonate if the fuze is rotated counterclockwise while in the adapter booster, even before the threads are engaged.

AN-M SEMIARMOR-PIERCING (SAP) BOMBS

There were two classes of semiarmor-piercing bombs produced and used by the Fleet—namely, the 500-lb AN-M58, AN-M58A1, and AN-M58A2, and the 1000-lb AN-M59 and AN-M59A1 bombs (Figures 3-62 and 3-63).

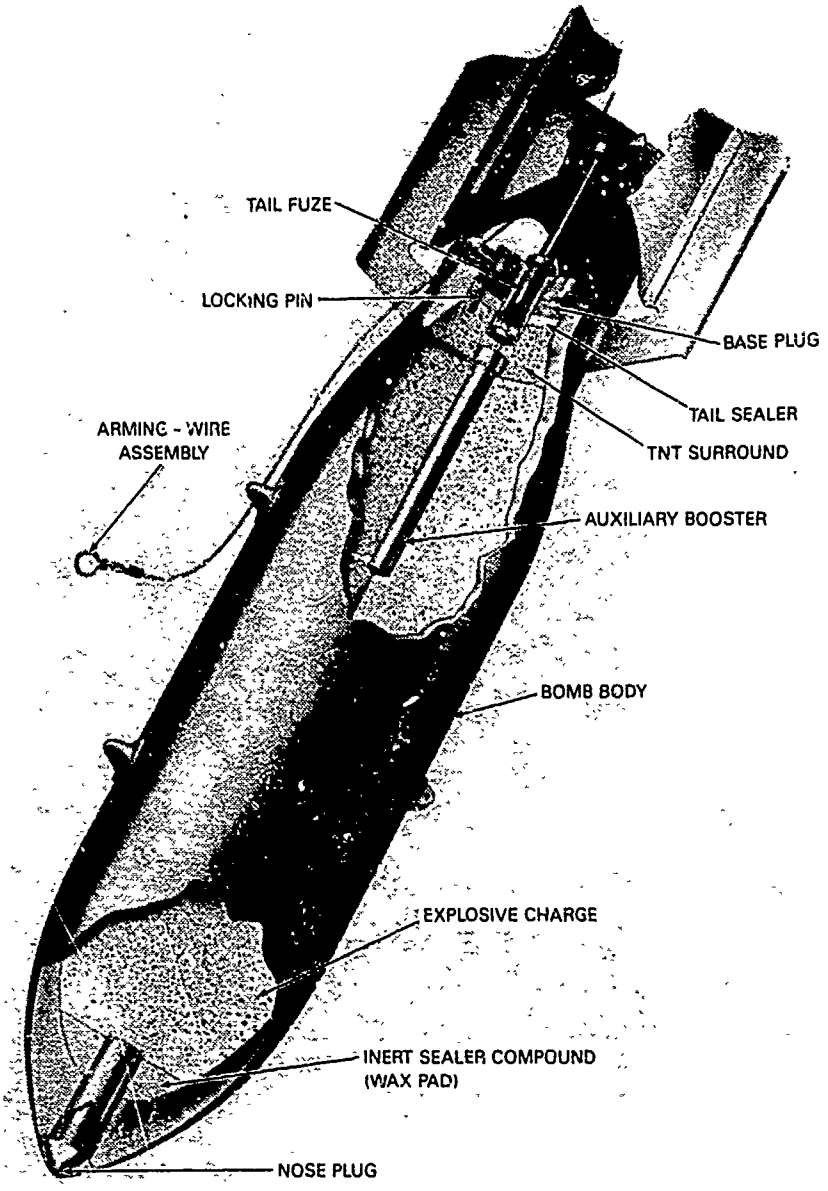


FIGURE 3-62. 500-lb SAP Bomb AN-M58A2, Cutaway View.

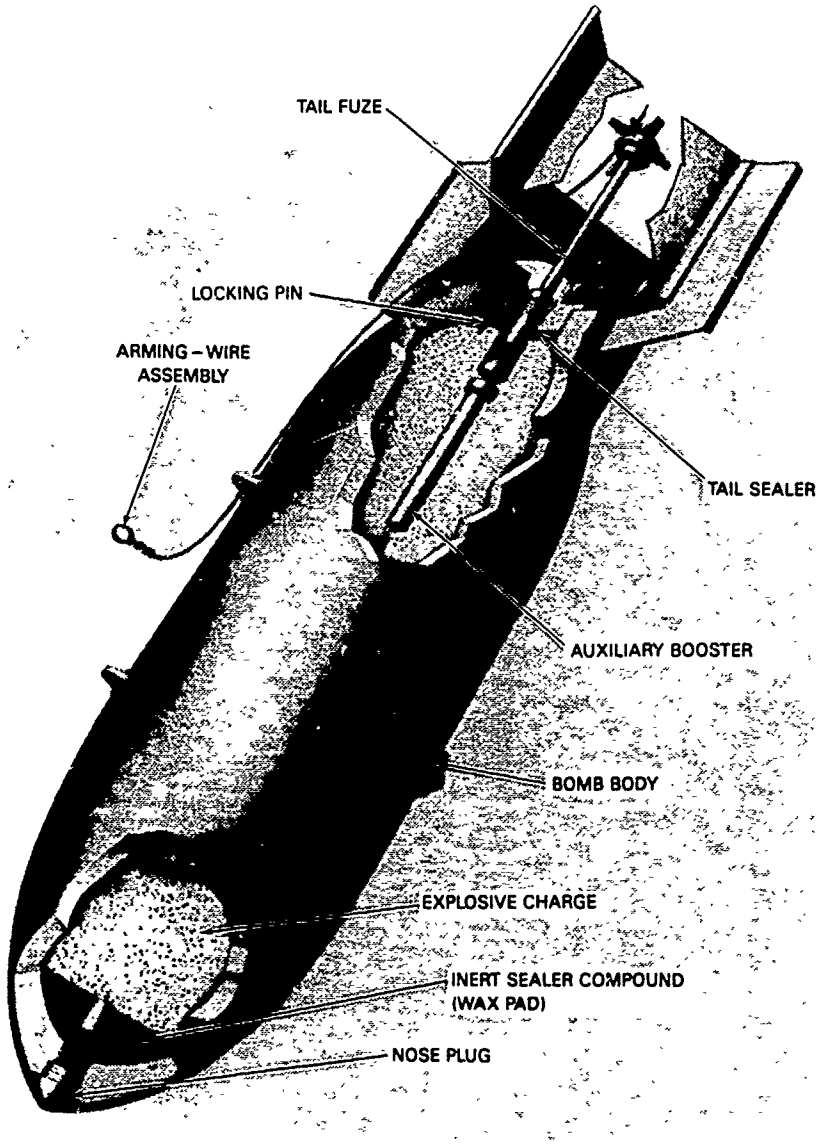


FIGURE 3-63. 1000-lb SAP Bomb AN-M59A1, Cutaway View.

Bomb Body Construction

The construction of these SAP bombs was of single-piece cast or spun steel, slightly streamlined in shape, with semipointed noses. The nose opening was threaded to receive insertion and retention of either a fuze-seat liner or a steel nose plug, both of which could be removed to permit installation of an impact sensing (instantaneous) nose fuze when a fragmentation effect was desired. The base plug locked securely in place and the adapter booster could be locked to the base plug. Both the 500-lb and 1000-lb bombs were designed to accommodate nose or tail fuzes. However, tactical requirements usually nullified the need for a nose fuze and the nose cavity was normally filled with a solid steel plug. The 500-lb and 1000-lb SAP bombs were developed to provide greater penetration capability than was afforded by a comparable weight general-purpose bomb. A box-type tail assembly was attached to the end of the bombs by a fin locknut. Suspension lugs for either single or dual suspension were welded to the case, similar to GP bombs, and a band could be installed with trunnions to meet dive-bombing requirements.

Explosive Loading

The SAP bombs were filled with either Amatol 50/50, TNT, or Picratol which accounted for the differences in released weights. Bombs filled with Amatol included a booster surround of TNT and the auxiliary booster M104, which was inserted during the filling process. Bombs filled with Picratol included an auxiliary booste . less the TNT surround. Bombs filled with TNT did not include an auxiliary booster. An inert sealing compound (wax pad) was poured into the nose section of the bomb before explosive loading to cushion the explosive against premature detonation on impact against hard targets. Bombs with wax in the nose area were identified by the marking "with pad".

As with the AN-GP bombs, when required, these SAP bombs were configured with base-plate locking pins and special adapter boosters to accommodate antiwithdrawal type fuzes such as the AN-M124A1 (500-lb class) or AN-M125A1, AN-M134 (1000-lb class) tail fuzes and to prevent removal of the base plate, fuzes, or adapter boosters. The cautions regarding fuzing and defuzing the AN-GP Bombs (p. 124) when dealing with antiwithdrawal type fuzes, applied to these SAP bombs.

ARMOR-PIERCING (AP) BOMBS

There were two classes of armor-piercing bombs, produced and used by the Fleet—namely the 1000-lb AN-Mk 33 and the 1600-lb AN-Mk 1.

Bomb Body Constuction

Both the 1000-lb and 1600-lb bomb bodies were constructed from single-piece steel forgings, machined to the desired solid, pointed nose, parallel sides, and slight boat-tail configurations. A male-type base plate was used as the aft closure to the bomb housing for the auxiliary booster and tail fuze, and mounting interface for the box-type fin assembly and fin lock nut. See Figures 3-64 and 3-65 for details.

Suspension Systems

The suspension systems for these AP bombs utilized hoisting and suspension lugs that bolted directly into holes drilled into the bomb case. The 1000-lb bomb case had two sets of four holes to permit attachment of two suspension lugs, 14 inches apart. One hoisting lug was attached between and in line with the two suspension lugs, and another single suspension lug was mounted to the underside. The 1600-lb bomb case had four sets of threaded holes in the bomb body to allow mounting of lugs for either 14 or 30-inches suspension. A single hoisting lug was attached between and in line with the two suspension lugs, while a single suspension lug was mounted to the underside (180 deg apart from the hoisting lug) by means of slotted capscrews. Both AP bombs were designed to accommodate trunnions for dive-bombing requirements. The later 1600-lb AP Mk I type bombs were grooved to position the suspension band. Older bombs had a stud which fitted into a hole in the bomb body.

Fuze Systems and Explosive Loading

The only authorized fuze for either AP bomb was the AN-Mk 228 impact-type tail fuze with an 0.08-second delay.

The explosive fill for these bombs was pressed explosive "D" or cast TNT. The tail fuze pocket required the use of the granular TNT auxiliary booster Mk 1. The charge-to-weight ratio of both bombs was approximately 13%.

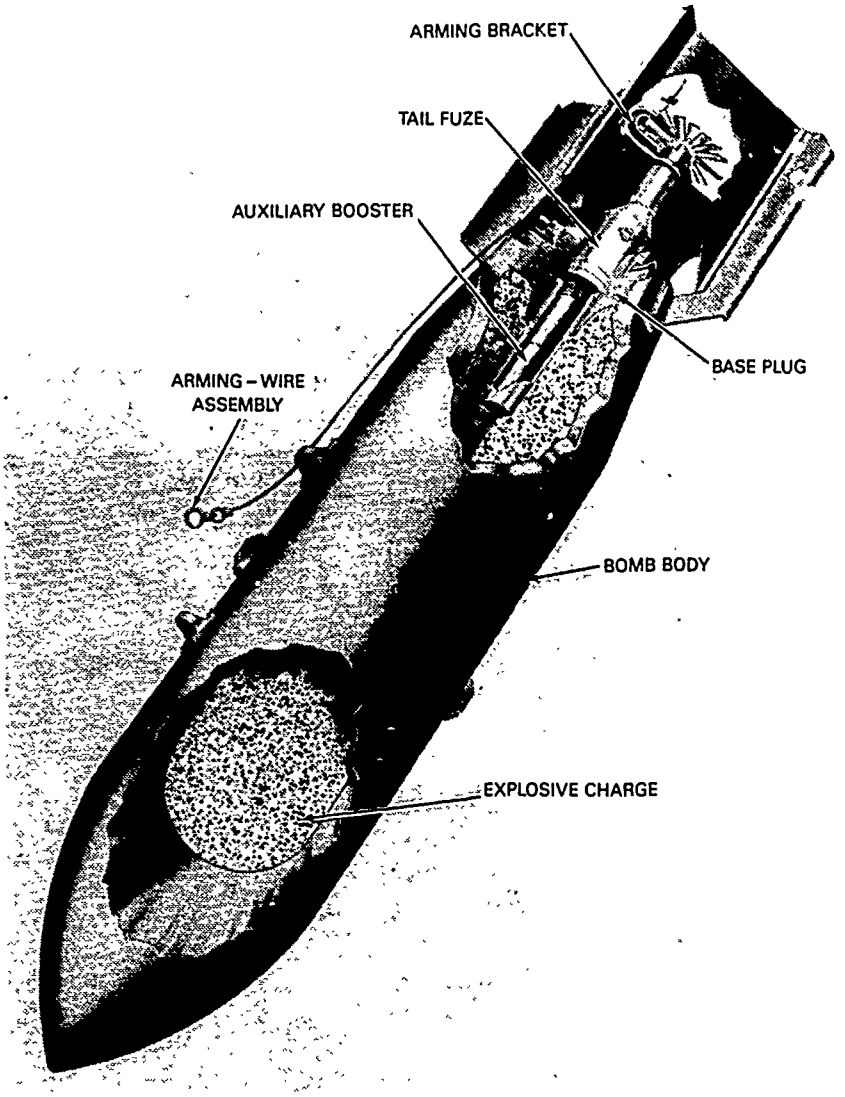


FIGURE 3-64. 1000-lb AP Bomb AN-Mk 33 Mods 1, 2, and 3, Cutaway View.

1000-LB AIRCRAFT MINE

The 1000-lb Aircraft Mine AN-Mk 26 Mod 1 consisted of three steel sections welded together—basically a hemispherical nose shape and tapered tail section welded to a cylindrical steel tube or case. The tail section was closed by a concave cover that was fastened with cap screws. A ring or shroud, for mounting a parachute assembly, was welded around the aft end of the mine case. The Tail Parachute Pack Mk 1, containing a

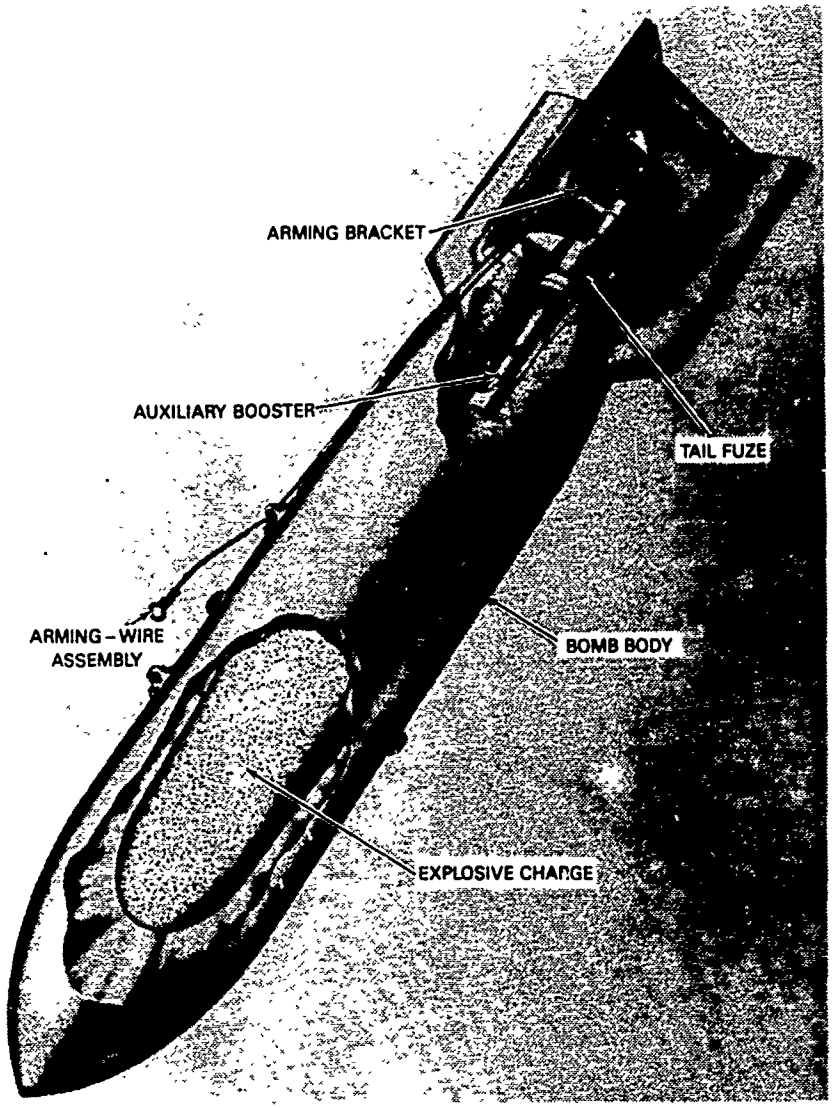


FIGURE 3-65. 1600-lb AP Bomb AN-Mk 1 Mods 1, 2, and 3, Cutaway View.

Mk 2 parachute, was fitted to the tail when the mine was installed or loaded aboard the aircraft. The parachute-type retardation device was used to reduce the shock of water impact and was released from the mine case upon water impact by a release mechanism. The suspension system consisted of two standard lugs welded onto the mine case, 14 inches apart and placed 90 deg from the clock starter/delay mechanism and extender pockets (Figure 3-66).

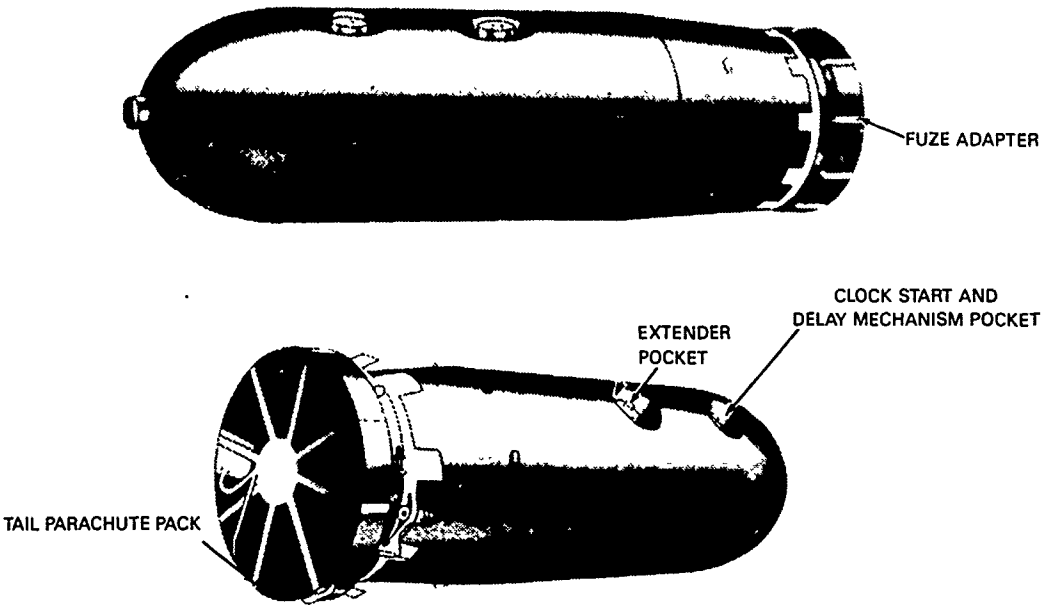


FIGURE 3-66. 1000-lb Aircraft Mine AN-Mk 26 Mod 1.

The normal use for this parachute-retarded (release altitudes of 200 feet or higher) aircraft mine was against surface ships in water depths of 16 to 120 feet and against submarines in water depths up to 500 feet. The Mk 26 Mod 1 was a magnetic induction mine with the M9-1 search coil firing mechanism. The extender and clock starter were caused to function by hydrostatic pressures at depths of 16 feet (7 psi) or greater. The clock delay ran for 170 minutes before arming the mine.

This mine was not suitable for use as a bomb since accurate releases by parachute was difficult, and if the parachute was not used or failed, the case tumbled. The fuzes would require longer air travel to arm than usual, because of the shape of the mine and the manner of fall through the air.

OTHER TYPES OF "AN" BOMBS

In addition to the bomb types previously described in this Section, there were other types of bombs such as incendiary and demolition that were subsequently standardized and given "AN" designations. However, not all of these bombs, such as the 4000-lb light-case Demolition Bomb AN-M56 and AN-M56A1, were used by the Navy.

DEMOLITION BOMBS, NEW SERIES (AIR FORCE)

GENERAL DESCRIPTION

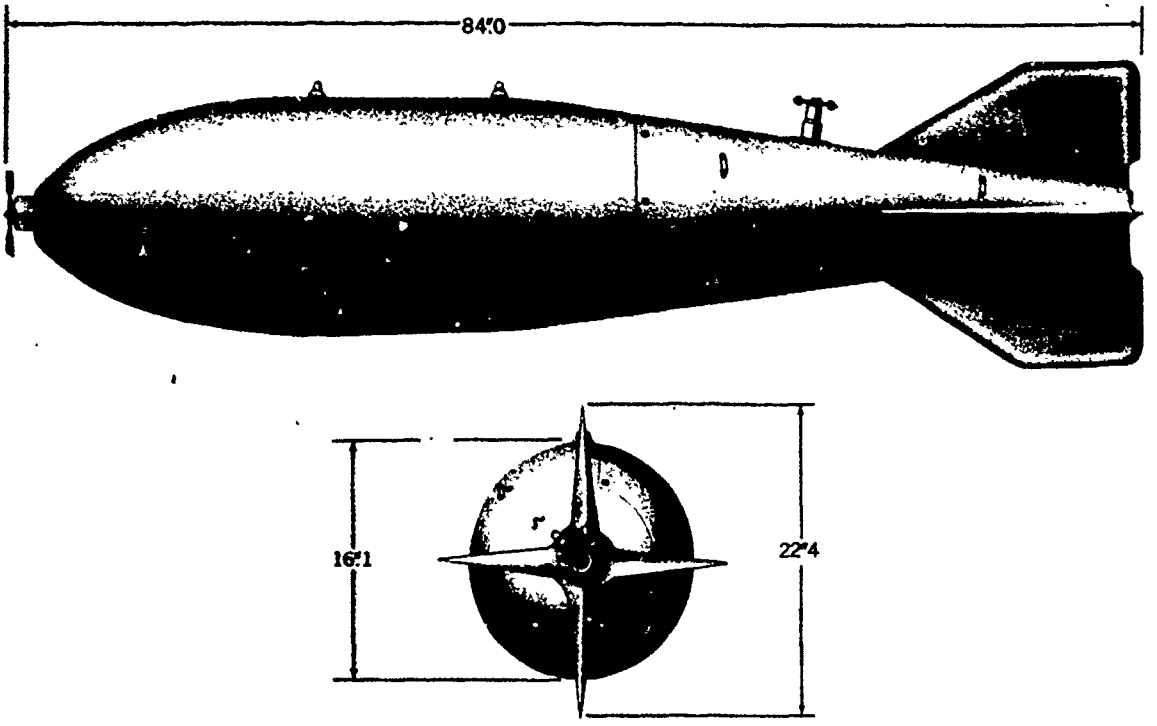
The new series demolition bombs, the 750-lb Demolition Bomb M117 and the 3000-lb Demolition Bomb M118, were designed for a higher blast effect than a general-purpose bomb of comparable weight. They were designed for improved aerodynamic performance and accuracy in flight when released from most altitudes and airspeeds.

The M117 and M118 demolition bombs were designed for either mechanical or electrical fuzing. For electric fuzing, these bombs were equipped with two conduits (plumbing) for the fuze cable harness. The conduits connected the nose and tail cavities with a charging receptacle located between the suspension lugs that are threaded into lug inserts on the bomb case. These bombs were equipped for double suspension. The M117 bomb has a 14-inch span between lugs, whereas the M118 bomb has a 30-inch span. Unlike the smaller (old series) general-purpose bombs, the new series bombs have adapter boosters capable of receiving tail fuzes with a 2-inch diameter thread instead of the 1.5-inch diameter thread. A fuze adapter is used on the inside of the adapter booster to convert the fuze seat to accommodate fuzes with the smaller 1.5-inch diameter threads. A single hoisting lug may be attached to the 3000-lb M118 bomb at the center of gravity and used for an alternate 14-inch suspension mount. All seams and crevices are sealed with an inert compound to prevent leakage.

750-LB M117 DEMOLITION BOMB

The 750-lb M117 bomb has a short ogival nose, a cylindrical body, and a tapered aft end. A short, stubby conical-type fin assembly is bolted to the rear end of the bomb to improve its aerodynamic performance (Figure 3-67). The M117 bomb was designed primarily for electric fuzing. Pending the availability of electric fuzes, mechanical fuzes are used in the nose cavity, tail cavity, or both. An adapter booster must be installed in the fuze cavities to permit use of mechanical fuzes. When mechanical fuzes are used, a plug is threaded into the charging receptacle cavity.

When a mechanical tail fuze is used, it projects into the airstream on the side of the bomb's conical fin, rather than straight out the aft end. To accomplish this, the fuze has a flexible arming stem. To install the fuze, an access cover is removed from the side of the fin cone and the fuze body is inserted through the opening and threaded into the fuze cavity. The arming head is secured to the side of the fin cone and the arming stem is then joined to the fuze body (see Figure 3-68 and 3-69). Approximately 50% of the total bomb weight is the explosive charge tritonal. More details of the physical characteristics of the M117 bomb are given in Figure 3-67.



Model	M117
Length of assembled bomb, in.	84.0
Body diameter, in.	16.1
Fin span, in.	22.4
Weight of filler, lb	
Tritonal	386
Weight of fin assembly M131, lb	44
Weight of assembled bomb, lb	
Loaded with Tritonal	799
Nose fuze	M904E1, M904E2, AN-M103A1, AN-M139A1, AN-M140A1, VT fuze AN-166, AN-166E1, M188, T750, M990 (T905) (electric)
Tail fuze	M190 (T759), M990 (T905) (electric)
Adapter-boosters (for mechanical fuzing	M126A1 (T45E1) (nose), T46E4 (tail)
Arming wire assembly	M52 (or from bulk stock)

FIGURE 3-67. 750-lb Demolition Bomb M117 (Mechanically Fuzed), Exterior View.

Retarder-Type MAU-91 Fin Assembly

The need to slow the descent rate of the standard M117 bomb to permit low-altitude bombing was met by the development of the MAU-91/B and MAU-91A/B retarder-type fin assembly. This fin presents a low-drag configuration when closed, or it can be activated at the pilot's discretion to present a high-drag configuration. The fin assembly,

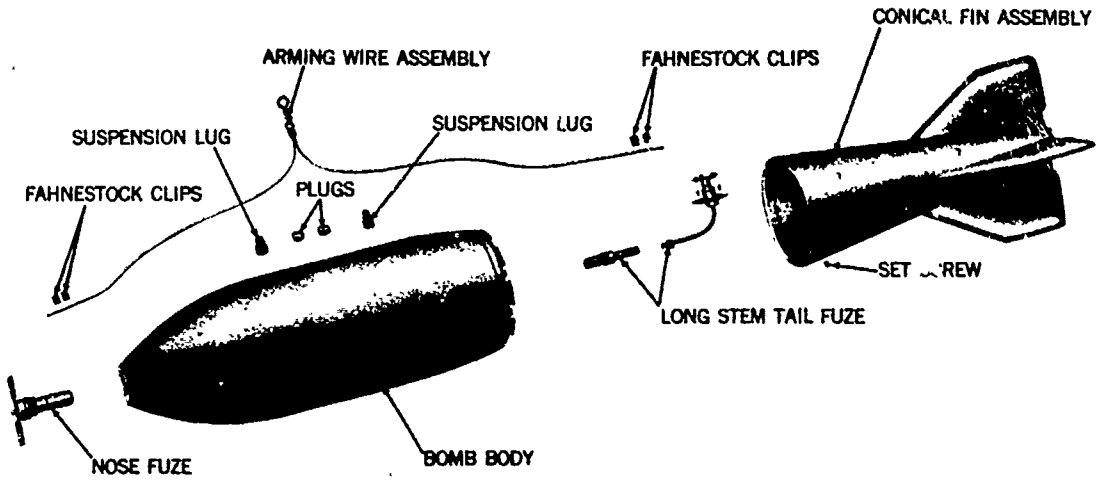
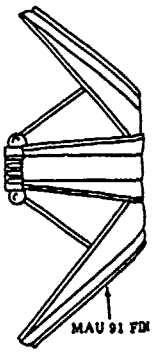


FIGURE 3-68. 750-lb Demolition Bomb M117 (Mechanically Fuzed), Exploded View.

wnich fastens to the rear of the bomb, consists of four extendable fin-drag plates attached to the bomb body by means of a support member comprised of a support flange and tube. The basic design is similar to the Mk 14 and Mk 15 "Snakeye Fins," developed for the 250-lb Mk 81 and 500-lb Mk 82 LDGP bombs. The drag plates are held in the closed position by a release band retained by an arming wire. When the arming wire is withdrawn, the drag plates snap open like an umbrella due to a force induced by a leaf spring under each fin-drag plate and the impinging air loads. The drag plates are stopped approximately perpendicular to the air stream, affording maximum stability and drag area (shown to the right). The Mk 344 Mod 0 and Mk 376 Mod 0 retardation sensing fuzes were used initially for high-drag deliveries. Later the FMU-54/B, FMU-54A/B, FMU-112/B, FMU-117/B, and FMU-139A/B were used as they became operationally available, each basically replacing the previous retardation sensing fuzes.



M117 Destructor Mine

The 750-lb M117 GP bomb warhead was used in the M117 Destructor Mine along with the Destructor Modification Kit Mk 75, which included the Mk 30 arming device, Mk 59 booster, Mk 72 cable, and Mk 42 firing device. The MAU-91/B retarder type fin assembly was used to decelerate the mine and reduce its impact velocity (Figure 3-70).

3000-LB M118 DEMOLITION BOMB

The 3000-lb M118 bomb also has a short ogival nose, a cylindrical body, and a tapered aft end. A long, conical-type fin assembly, approximately half of the total length of

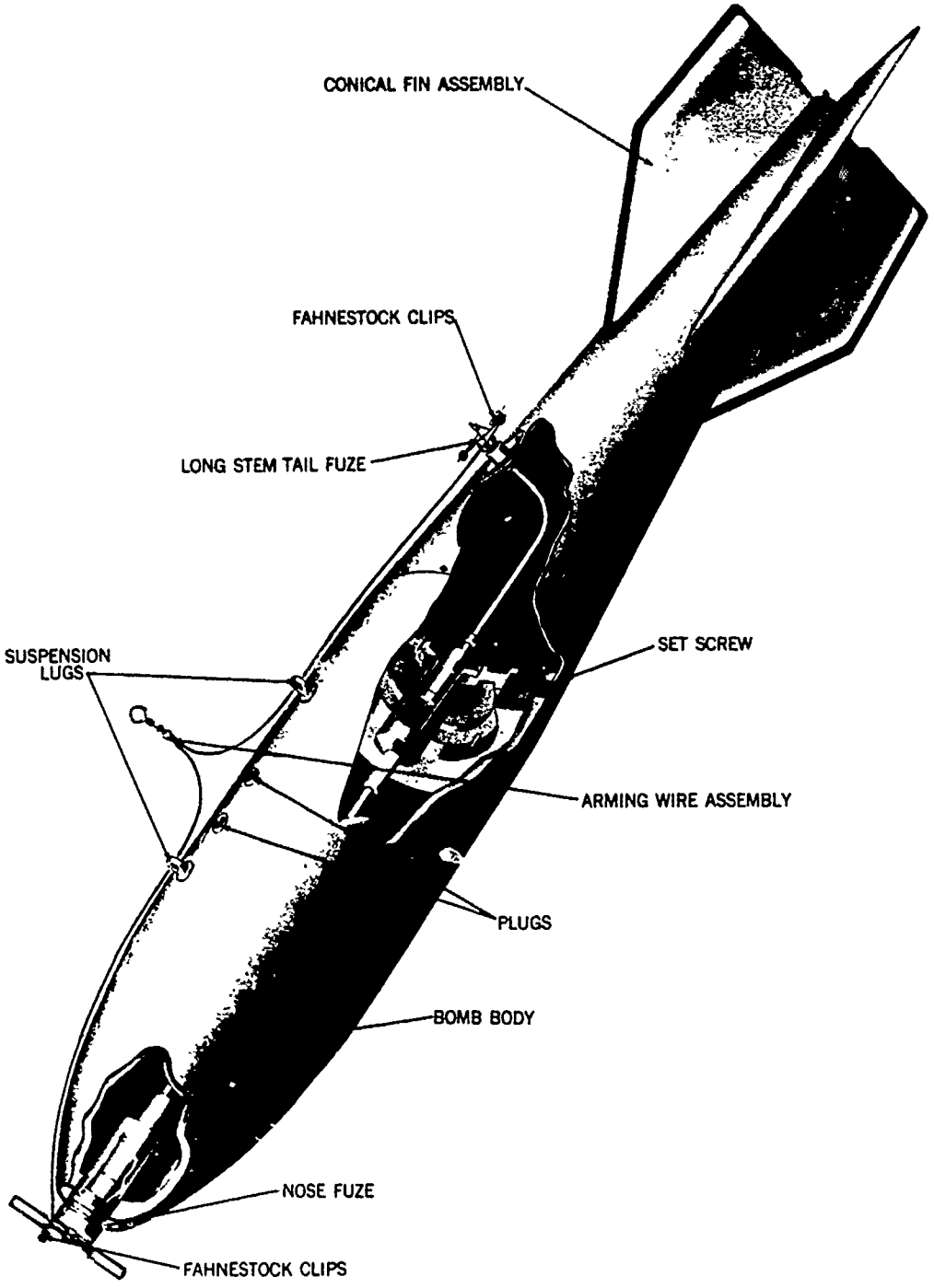


FIGURE 3-69. 750-lb Demolition Bomb M117 (Mechanically Fuzed), Cutaway View.

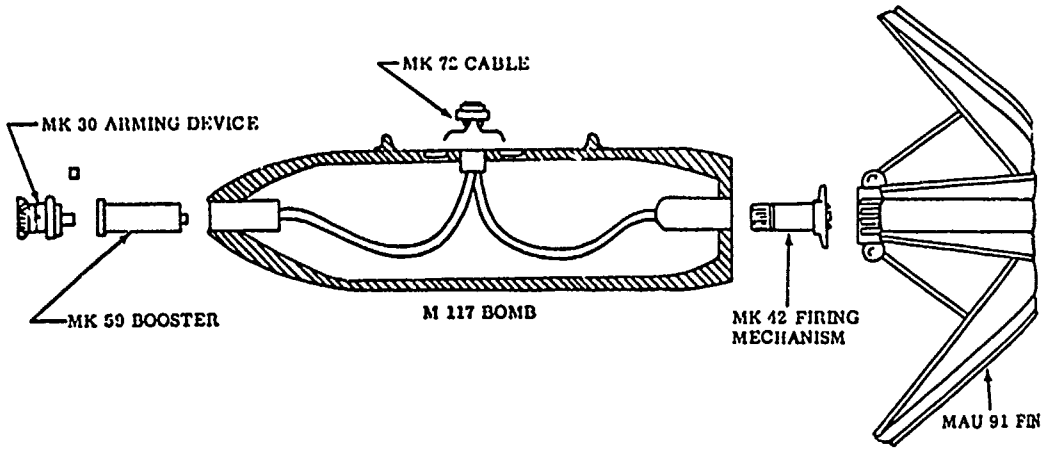


FIGURE 3-70. M117 Destructor Mine.

the assembled bomb, was contoured to augment the aerodynamic shape of the bomb body (Figure 3-71). The M118 bomb was designed primarily to use mechanical fuzes in the nose or tail cavity or both. As with the M117 bomb, when mechanical fuzes were used, a plug was threaded into the charging receptacle cavity, and adapter boosters were installed in the fuze cavities.

When the M192 mechanical tail fuze was used, the fuze had to be mounted and secured similar to that previously described for the M117 bomb (Figures 3-72 and 3-73). Approximately 65% of the total weight of the bomb is the explosive charge, tritonal. More details of the physical characteristics of the M118 bomb are given in Figure 3-71.

ASSEMBLY PROCEDURES

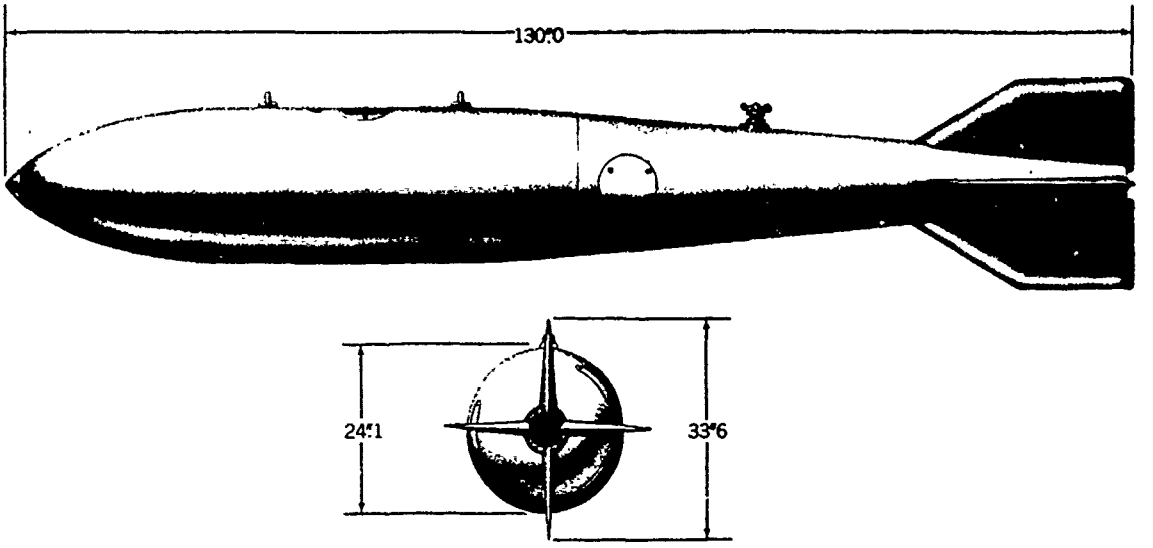
The same assembly procedures and cautions apply to both the 750-lb M117 and 3000-lb M118 bombs.

In the assembly of the M117 and M118 bombs, the following step-by-step procedures and cautions were to be observed and carried out.

CAUTION: Fuzes and bombs are not to be unpacked in advance of requirements. Return them to their original packing if not used.

1. Remove the bomb body and components from their packing cases. Remove the shipping ring from the rear of the bomb body by unscrewing the studs.

CAUTION: Inspect for damage (cracks, broken weldments, etc.) which might cause leaks in the bomb body or weaken lugs or their attachment the bomb body.



Model	M118
Length of assembled bomb, in.	130.0
Body diameter, in.	24.13
Fin span, in.	33.6
Weight of explosive charge, lb	
Tritonal	1975
Weight of assembled bomb, lb	
Loaded with Tritonal	3049
Nose fuze	M904E1, M904E2, M130A1, M139A1, M140A1, M166E1, M166, M168, M914, M188, M163, M164, M165, FMU-26/B, FMU-72/B
Tail fuze	M905, M906
Adapter-boosters (for mechanical fuzing)	T45E1, T46E4, T45E2, M115A1
Arming wire assembly	T12 (or from bulk stock)

FIGURE 3-71. 3000-lb Demolition Bomb M118 (Mechanically Fuzed), Exterior View.

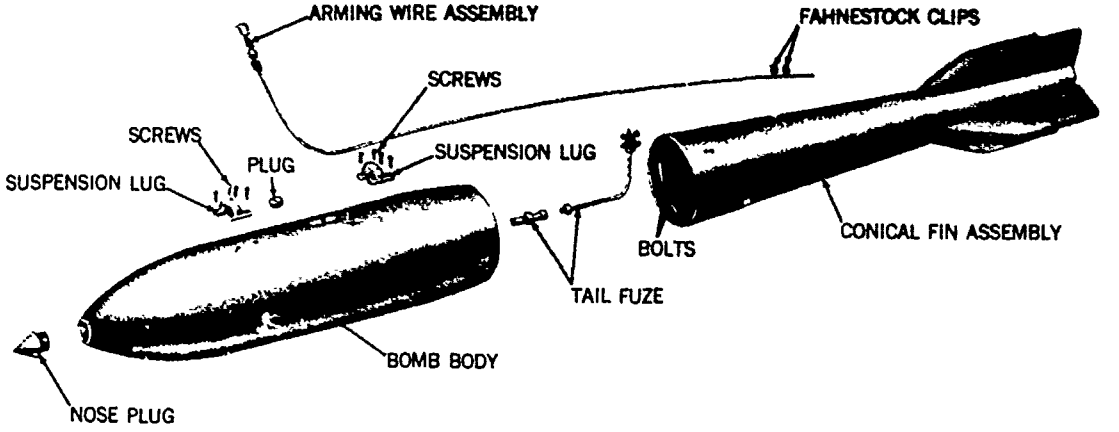


FIGURE 3-72. 3000-lb Demolition Bomb M118 (Mechanically Fuzed), Exploded View.

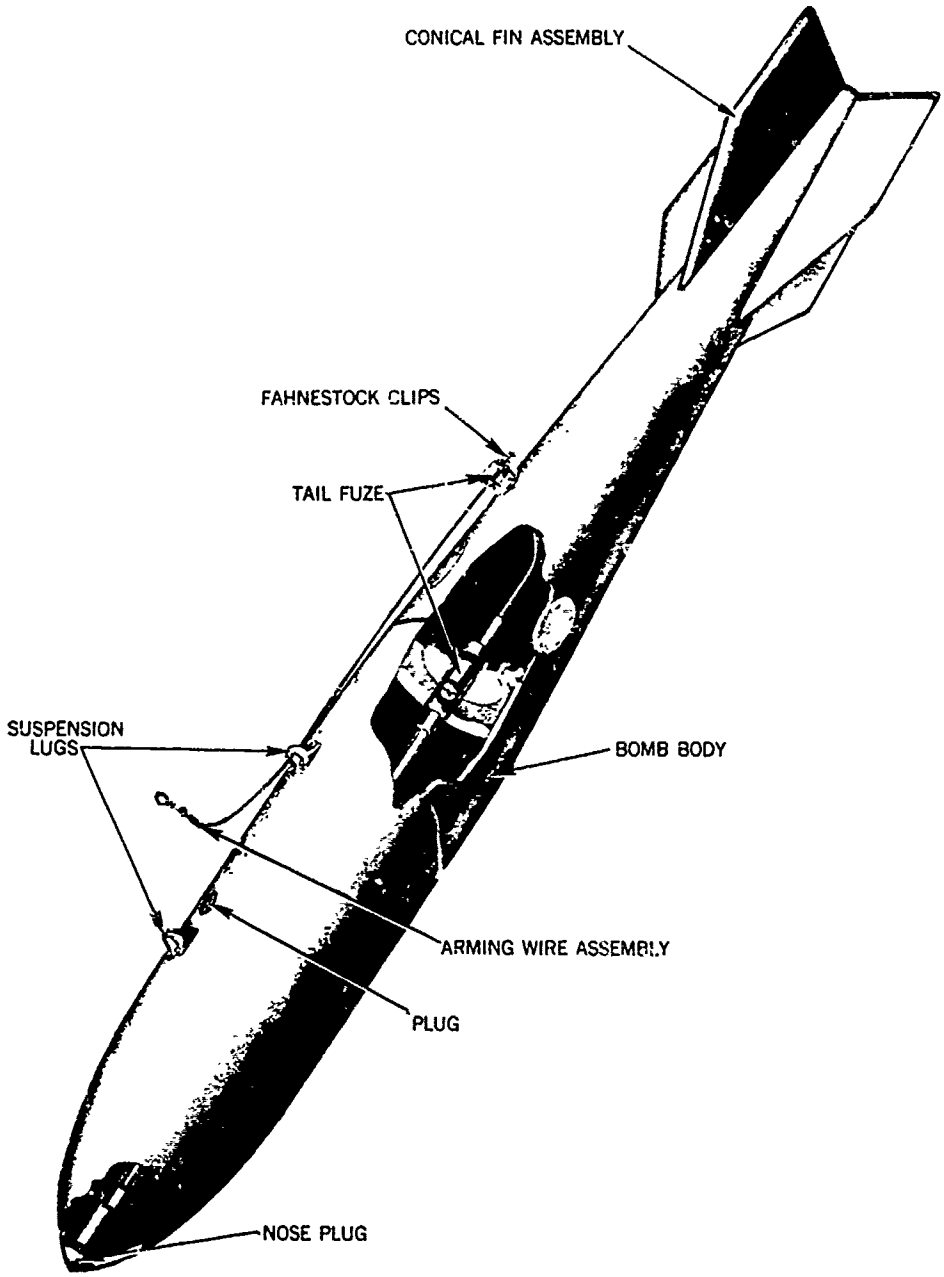


FIGURE 3-73. 3000-lb Demolition Bomb M118 (Mechanically Fuzed), Cutaway View.

2. Place the conical fin assembly over the end of the bomb with one of the fins in line with the suspension lugs. If suspended in external racks, turn the fin and locate it to clear the aircraft structure and the ground when installed. Secure the fin to the aft end of the bomb with setscrews located on the edge of the cone. Assemble the two suspension lugs in their respective threaded holes.

3. Remove the hand-hole cover on the fin cone by taking out the securing screws.

4. Remove the base fuze-hole plug threaded into the rear fuze cavity.

5. If a nose fuze is required, remove the nose fuze-hole plug.

6. Install the adapter-boosters in the nose and tail fuze cavities as required for mec' .nical fuzing.

7. Install the bomb on the aircraft and securely lock the bomb in place. If the bomb bay does not provide enough space for fuzing, fuzing shall be done prior to hoisting the bomb into place on the rack.

8. Remove the required number of fuzes and arming wire assemblies from their containers.

CAUTION: If containers are punctured, split, or if the seal is broken in any way, the fuzes contained therein shall be considered unserviceable. This does not apply to fuzes repacked in the field and resealed with adhesive tape for temporary protection. These fuzes should be examined carefully for serviceability.

9. Thread the tail fuze body into the tail fuze cavity handtight.

10. Insert the flexible arming stem with fuze head through the fuze opening in the fin cone skin. Thread the retaining collar on the flexible arming stem over the fuze neck of the fuze body, and tighten the collar by hand. Secure the fuze head to the fin cone skin with the studs supplied with the fuze.

11. Install the nose fuze into the nose fuze cavity handtight.

12. Insert the arming wires 'rough the suspension lugs to each fuze. The arming wires should protrude 2 inches beyond the fuze vanes. Cut off the excess wire. If the bomb is tail-fuzed only, cut off one branch of the arming wire assembly. The arming wire should be free from kinks, twists, and burrs.

Electric Fuzing

1. Install the electric fuzes in the nose and tail fuze cavities.

2. Replace the nose fuze-hole plug, base fuze-hole plug, and fin access hand-hole cover.

3. Remove the charging receptacle plug from the bomb body.

4. Install the bomb on the aircraft and lock the bomb securely in place. If the bomb bay does not provide enough space for fuzing, fuzing shall be done prior to hoisting the bomb into place on the rack.

750-LB BLU-31/B BOMB

The 750-lb BLU-31/B bomb, shown in Figure 3-74, was a modification of the MLU-10/B land mine, to inhance its performance against hard targets. The BLU-31/B had a thickened heavy-walled blunt nose and a cylindrical one-piece forged steel case that was tapered slightly at the rear to interface with the tail section. It was fin-stabilized using the 500-lb Mk 82 low-drag conical fin MAU-93/B, modified to accept the ATU-35/B side drive assembly. The BLU-31/B bomb used both the M905 and M906 mechanical fuzes as well as the FMU-26/B, FMU-26A/B, FMU-26B/B, FMU-63/B, FMU-72/B, and FMU-81/B electric fuzes in the nose fuze cavity. It was equipped with two conduits for fuze cable lanyards for the FMU-type electric fuzes. The conduits connected the nose and tail fuze cavities with a charging well that was located between the suspension lugs. The BLU-31/B bomb used the M147 tail adapter booster which was only capable of receiving tail fuzes with 2-inch threads. Approximately 40% of the total weight of the BLU-31/B bomb is explosive filler (Tritonal).

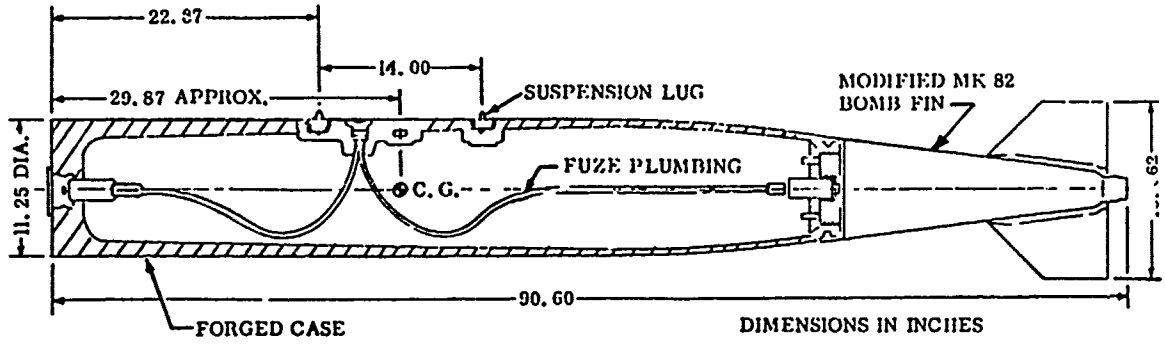


FIGURE 3-74. 750-lb BLU-31/B Bomb (Modified Land Mine).

The BLU-31/B replaced the air emplaced, delay-fuzed land mine MLU-10/B and the skip bomb BLU-14/B. Its delivery mode was either as a skip bomb or as a land mine depending upon fuzing. The blunt nose configuration allowed the bomb to be delivered at low altitudes with resultant low angles of impact due to its reduced ricochet characteristics.

15,200-LB BLU-82/B BLAST BOMB

The 15,200-lb BLU-82/B Blast Bomb was a steel weldment consisting of a cylinder 4.5 feet in diameter, 7 feet long, and 0.25 inch thick, welded to a nose cone 3.5 feet long and 0.5 inch thick. The BLU-82/B bomb used a parachute for ballistic stabilization, standard M904E series mechanical nose fuzes, along with the M1A1 fuze extender, and an M905 mechanical tail fuze that was used in conjunction with a battery-powered electric-drive motor for arming (Figure 3-75).

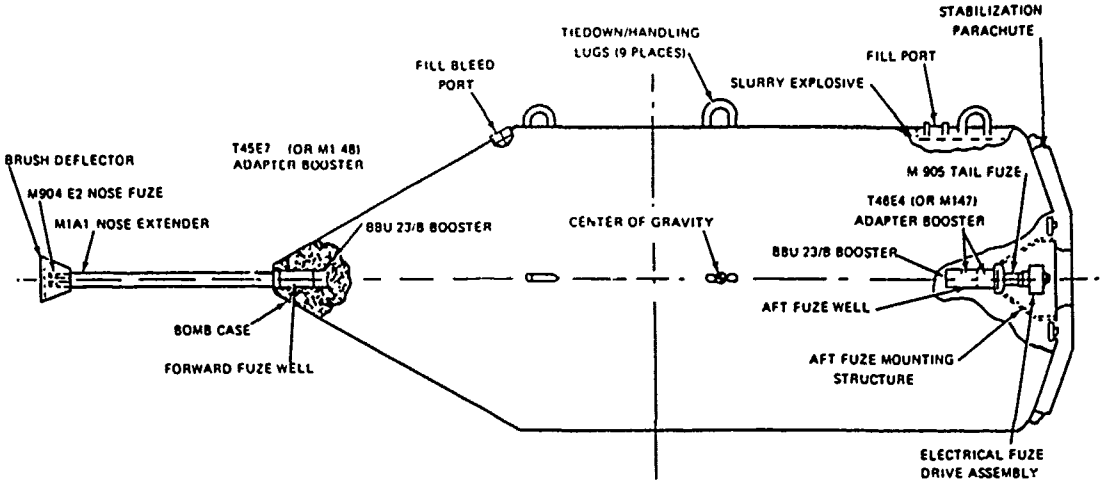


FIGURE 3-75. 15,200-lb BLU-82/B Blast Bomb.

The BLU-82/B bomb was dropped from a C-130 aircraft. The bomb was mounted on a wooden cradle which was attached to an aerial delivery platform. The bomb was released by shoving the platform out of the rear of the aircraft at the desired time. The bomb contained 12,600 lbs of DBA-22M explosive—a jelled slurry explosive containing ammonium nitrate, aluminum, and stabilizers. The inside of the bomb was coated with a special epoxy finish to protect it from the ammonium nitrate. The primary purpose of the BLU-82/B blast bomb was to create helicopter landing zones in jungle terrain.

LOW-DRAG GP MK 80 SERIES BOMBS

Following World War II, the development and introduction of high-speed aircraft into the U.S. Fleet, coupled with the experiences gained during the war relative to the massive destructive force of aircraft bombs which accounted for more casualties and material damage than any other weapon used, motivated the U.S. Navy to initiate a new Aircraft Bomb Development Program.

NEW LOW-DRAG GP BOMB DEVELOPMENT

Early in 1950, the new Low-Drag GP Bomb Development Program was formally presented (Reference 8). The Navy stated that its Bureau of Ordnance had been tasked to optimize the design of GP bombs for external aircraft carriage. It was known at this time that the Air Force, through the agency of the Army Ordnance Department, was concentrating on the design of GP bombs for internal aircraft carriage. The Navy's position was as follows:

> "In the design of the Navy's new bombs, we selected one primary design criterion to hold fast to, and compromised on the others as need be. We held that the fundamental requirement of the new bombs was their suitability for external carriage on high-speed airplanes, and that such other desirable characteristics of the bombs as might be obtained, we would obtain; and those characteristics other than suitability for external carriage which we had to sacrifice, we would sacrifice; but at all events we would do everything to make the bomb suitable for external carrying on high-speed planes."

The new Low-Drag GP Bombs were designed for mechanical, electrical, proximity, or variable-time (VT) fuzing. Conduits or charging tubes connect the nose and tail fuze cavities with the charging receptacle. An arming and safety switch (Mk 122 Mod 0) was designed to be installed in the bomb charging well between the lugs on the outer surface of the bomb case. This arming and safety switch electrically connects the bomb fuze control circuits in the aircraft to the electric fuze circuits in the bomb. The switch serves the function of providing selective aircraft power to the fuze. It is electrically connected to the fuze in the bomb tail fuze cavity with the bomb internal fuze cable harness installed in the bomb plumbing. A short lanyard and a length of shielded coaxial cable extend from the switching unit and are attached to the aircraft when the bomb is loaded. The switch is secured in the charging well by a retaining nut which engages the threads in the charging well.

New Fuzes (Mechanical and Electrical)

The mechanical and VT fuzes required the installation of new adapter-boosters to provide fuze seats of smaller diameter (see Section 2). When mechanical fuzes are used, a plug is threaded into the charging receptacle cavity. A removable cover in the side of the low-drag conical fin allows access to the aft fuze after the tail fin has been assembled to the bomb. There are nose and base plugs and a support cup for the nose fuze cavity for all the new low-drag GP bomb bodies (warheads) when fuzes are not installed (shipping and storage configurations).

If only tail fuzes are installed, the support cup is reinserted into the nose cavity to prevent collapse of the fuze well on impact with hard targets. A sectional and exploded view of a typical new low-drag GP bomb is shown in Figure 3-76.

Bomb Body

The material used to form the bomb body or case is annealed low carbon (AISI 1018 to 1026) steel tubing (welded or seamless) that undergoes a hot pressing or swaging process to attain the basic streamlined configuration.

The minimum physical properties after heat treatment—initially 40,000 psi yield strength, 70,000 psi tensile strength, and 16% elongation in 2 inches—were later changed to 70,000 psi yield strength and 105,000 psi tensile strength. The elongation specification was not changed. Cutouts are made in the formed tube for insertion and weldment of a forward lug and charging well insert, and an aft suspension lug insert. A ring adapter is also welded to the base of the bomb body to complete the forming and welding operations. Finally, forward and aft fuze liner assemblies and retainers, charging tubes and fittings, a base plug, shipping plugs and caps are attached to the bomb body to complete the bomb body assembly (see Figure 3-76). Figure 3-77 is a typical illustration of a Mk 80 series GP bomb body. The bomb bodies initially had base plugs containing locking pins which were embedded in the solidified explosive filler. The locking pins were eliminated during the 1960s in favor of using a sealing and locking compound (loctite) on the threads of the ring adapter and base plug. Two suspension lugs spaced 14 inches apart for the 250-lb, 500-lb, and 1000-lb bombs and 30 inches apart for the 2000-lb bombs and a hoisting lug, at the center of gravity, are threaded into the lug inserts on the bomb bodies when the bombs are being readied for use. Later, the hoisting lug inserts were removed from the 250-lb, 500-lb, and 1000-lb bomb bodies, and were retained only on the 2000-lb bomb.

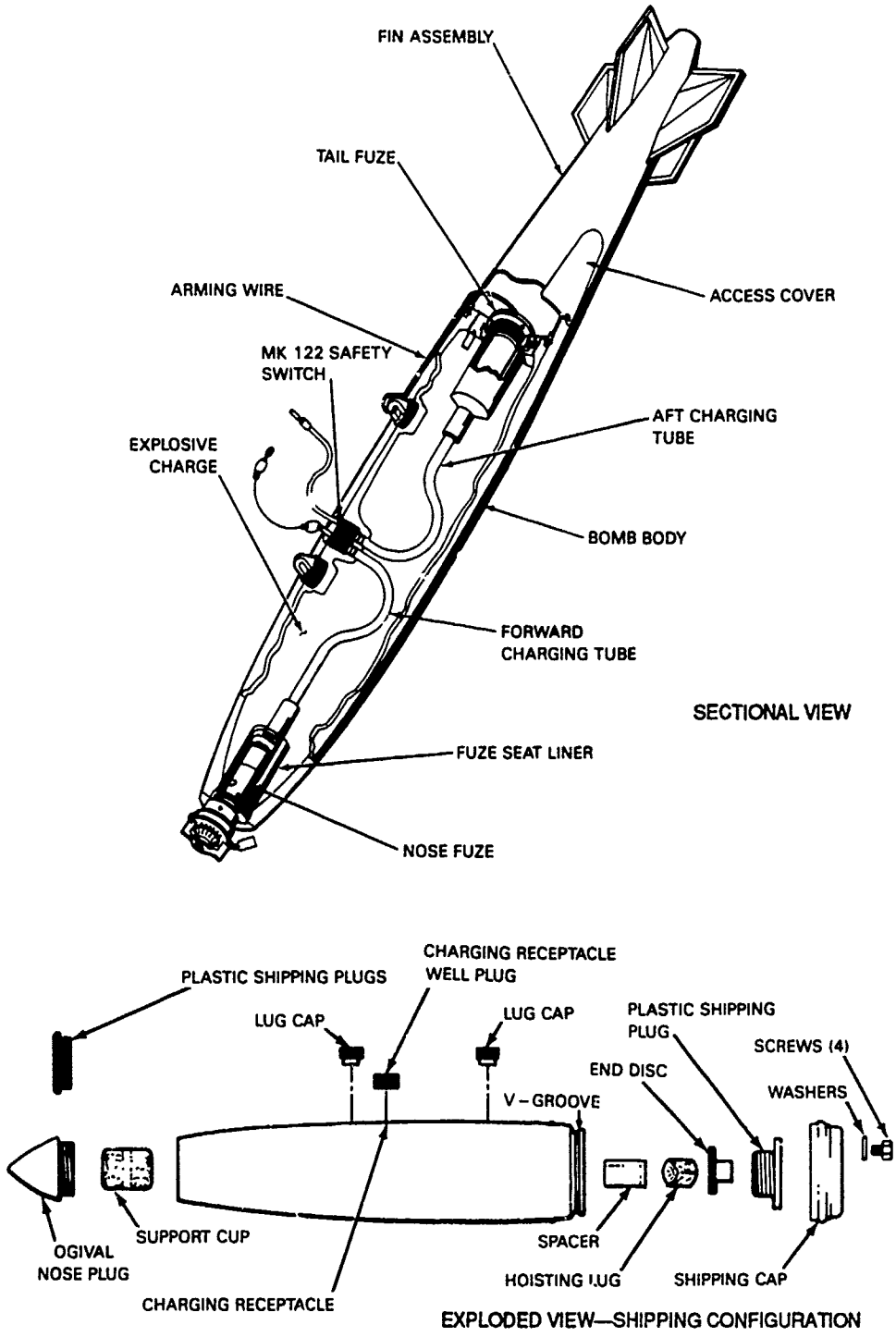


FIGURE 3-76. Typical Low-Drag GP Mk 80 Series Bomb.

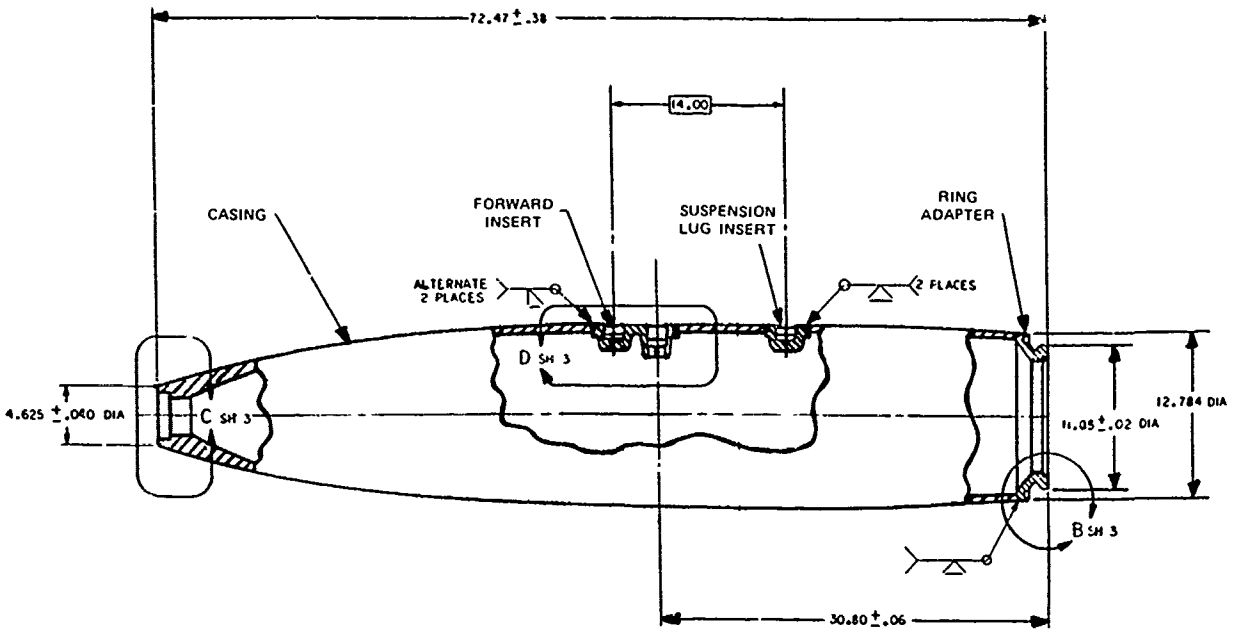


FIGURE 3-77. Typical Mk 80 Series GP Bomb Body.

Explosive Filler

When the low-drag bomb program was begun, no explosive filler had yet been selected. The explosives being considered were Tritonal and an HBX-type explosive. According to Reference 9, BUORD's position in 1950 was as follows:

> There was not enough information at its disposal to recommend a filler for these bombs. The most powerful explosive in service use at that time was HBX. The GP bombs had never been loaded with HBX, since all loadings had been made by the Army, and the Army had never standardized HBX as a filler. The best bomb filler used by the Army was Tritonal. . . . If the new bombs were to be loaded by the Army, they would use Tritonal as filler. However, if the Navy loaded the bombs, the filler would probably be HBX.

HBX-type explosives were developed in the latter part of World War II as replacements for Torpex. Torpex, an explosive consisting of RDX, TNT, and aluminum, was the most powerful explosive used by any nation during World War II. It was developed in England, where its use as an explosive filler in warheads and

depth bombs began late in 1941. By late 1942, Torpex II (a 42/40/18 mixture of RDX/TNT/aluminum) was being loaded into warheads, mines, and depth bombs for the U.S. Navy. Between June 1943 and September 1944, there were nine major accidents involving Torpex II. Three explosions occurred at loading facilities and at least one explosion occurred aboard an ammunition ship of which the writer has personal knowledge. Investigation indicated that all of these accidents were directly related to the sensitivity of Torpex II. As a result of these sensitivity problems, various forms of "desensitized Torpex" were sought. The first of these was called HBX (high blast explosive). HBX was formed by adding 5% of D-2 wax to Torpex II, resulting in a composition of 40% RDX, 38% TNT, 17% aluminum, and 5% D-2 wax desensitizer. When 5% (by weight) of calcium chloride was added to this formulation, it was called HBX-1.

In 1949, the Bureau of Ordnance tasked the Naval Ordnance Laboratory (NOL) to find an HBX formulation, optimized for air blast. The optimum composition (Reference 10) was 45% RDX, 29% TNT, 21% aluminum, and 5% D-2 wax. This mixture was designated initially by BUORD as HBX-6.

"The H-6 designation was assigned to this composition at NOL during the first castability tests and was carried along through the air blast tests and many other field tests. According to practice, its name would have been HBX-6, the next main charge explosive to be adopted by the Navy. However, when the time came for recommendation for use, H-6 was so well-fixed in the reports and vocabulary of the people that it seemed impossible to change, or at least it would have caused useless confusion to change, so the laboratory designation became the official name" (Reference 11).

Loading and Testing

Loading and testing of H-6 in the Mk 80 series low-drag GP bombs began as early as May 1955, when 250-lb Mk 81 bombs and 500-lb Mk 82 bombs were loaded for a series of safety and performance tests (40-ft drop, dent, armor-plate penetration, and aircraft drops). Loading was to have been completed in September 1955. Based upon satisfactory results of all the safety and performance tests, an official recommendation by the Research Division of the Bureau of Ordnance was made on 11 May 1956 to load H-6 into the Mk 80 series bombs. The test data and other supportive information for the recommendation is contained in Appendix B of Reference 11. According to the procedure outlined in Appendix B, Composition B was to be used as the source of both RDX and TNT. Within the tolerance of the specification, the TNT concentration could vary by ± 3% from the original 29.0%.

NEW LOW-DRAG GP BOMBS MK 81, 82, 83, 84

The new low-drag GP bombs, as they were initially designed, tested, and evaluated during the early 1950s, consisted of the 250-lb EX 2, 500-lb EX 12, 1000-lb EX 10, and 2000-lb EX 11. After completion of the operational evaluation phases, approximately during the 1954 through 1955 time frame, the experimental designators "EX" were changed to the Mk 80 series. Specifically, the bombs were changed to: 250-lb Mk 81, 500-lb Mk 82, 1000-lb Mk 83, and 2000-lb Mk 84.

As of July 1956, H-6 was designated as the high explosive filler for the Navy's Mk 80 series Mk 81, Mk 82, Mk 83, and Mk 84 GP bombs. The Air Force high explosive fill for the Mk 82, Mk 84, and Mk 117 bombs is tritonal. The specific fills are identified by yellow stenciled nomenclature on the bomb body and a yellow band around the body identifies the explosive nature of the bomb body. The base color of the bombs is olive drab.

All of the Mk 80 Series GP Bombs are available in both slick (standard-Air Force) and fire-retardant, thermally coated/protected versions (standard-Navy).

Mk 81 GP Bomb (250-lb)

The 250-lb Low-Drag General-Purpose Bomb Mk 81 Mod 1 has a slender body with a pointed nose (see Figures 3-78, 3-79, and 3-80). A conical fin MAU-94/B is attached to the aft end of the body by eight setscrews. The Mk 81 bomb can be assembled with the Mk 14 Mods 0, 1, and 2 retarder-type fin assembly instead of the conical tail assembly (discussed later in this section). Physical characteristics of the Mk 81 low-drag GP bomb are given in Table 3-11.

Mk 82 GP Bomb (500-lb)

The 500-lb Low-Drag General Purpose Bomb Mk 82 Mod 1 is identical in shape to the Mk 81. This bomb also has a low-drag conical fin attached to the end of the body by six setscrews. Initially the MAU-93/B conical fin was used, but was later replaced by the BSU-33A/B conical fin. The BSU-33A/B fin incorporates spin tabs and a fin cant to induce bomb spin to reduce ballistic instability (Figures 3-81, 3-82, and 3-83). The Mk 82 bomb can be assembled with the Mk 15 (Mods 1 through 6), BSU-49/B, or BSU-86/B retarder-type fin assemblies instead of the conical tail assembly (discussed later, p. 159). Physical characteristics of the Mk 82 low-drag GP bomb are given in Table 3-12.

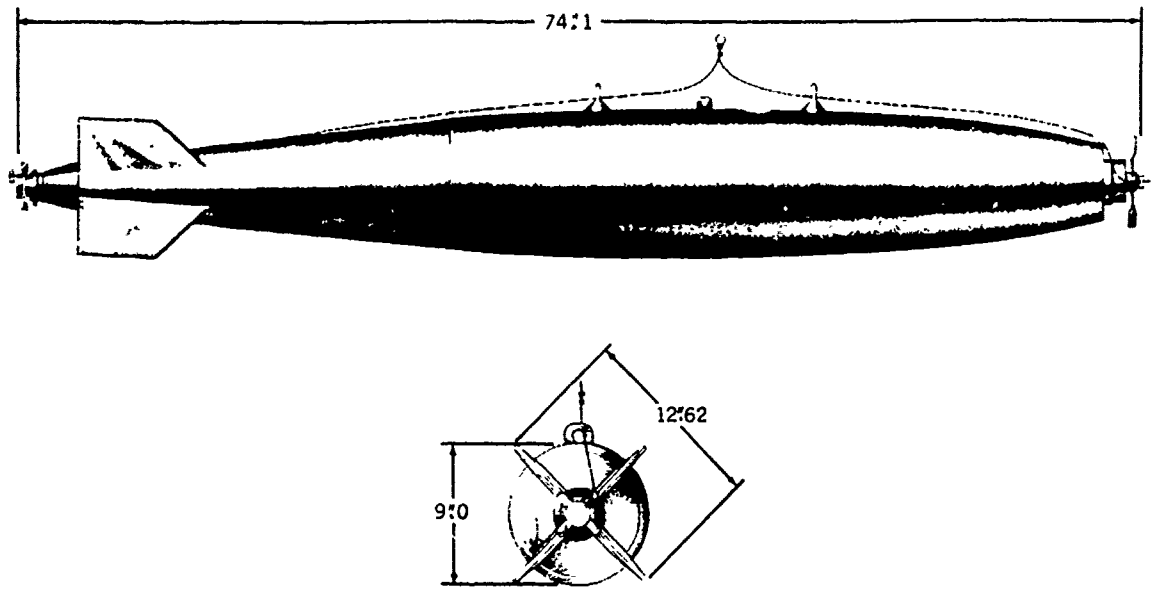


FIGURE 3-78. 250-lb Low-Drag GP Bomb Mk 81 Mod 1 (Mechanically Fuzed), Exterior View.

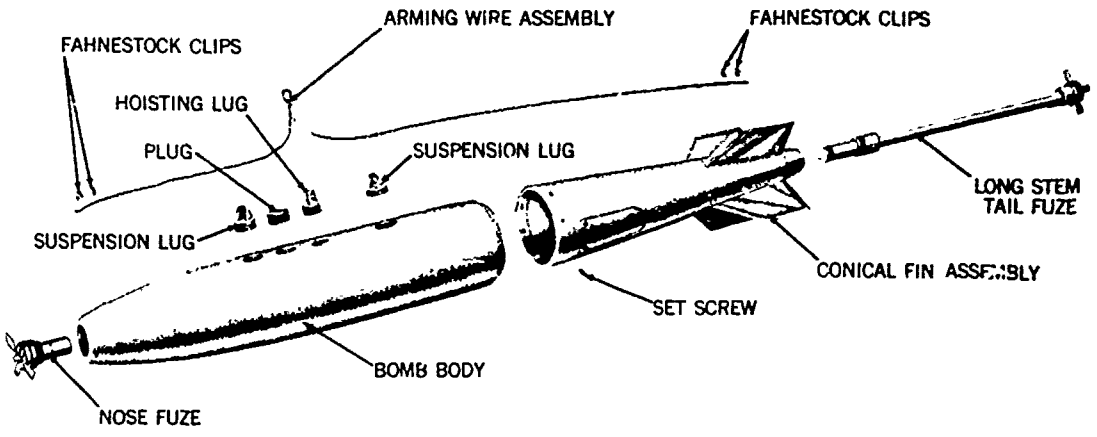


FIGURE 3-79. 250-lb Low-Drag GP Bomb Mk 81 Mod 1 (Mechanically Fuzed), Exploded View.

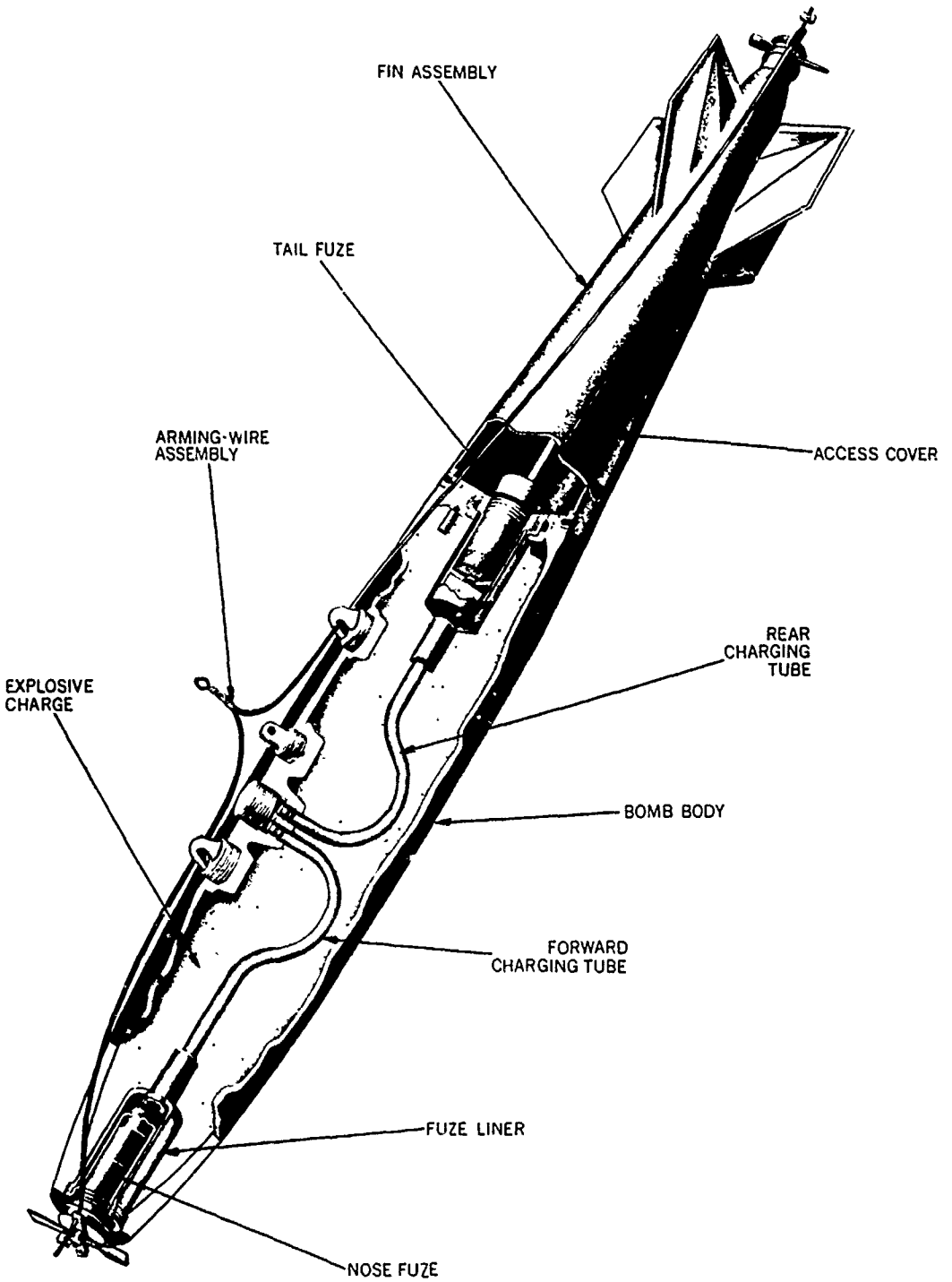


FIGURE 3-80. 250-lb Low-Drag GP Bomb Mk 81 Mod 1 (Mechanically Fuzed), Cutaway View.

TABLE 3-11. Physical Characteristics of 250-lb Mk 81 Mod 1 GP Bomb.

Mark	81
Mod	1
Length of assembled bomb, in.	74 1
Body diameter, in.	9.0
Fin span, in.	12.62
Weight, explosive charge, lb	100.0
Weight, assembled bomb, lb	260.0
Arming-wire assembly	
For nose fuze	Mk i or AN-M6A2
For tail fuze	M13
Cable assembly (for electric fuzing)	M71 (T26)
Adapter-booster	
Nose	T45E1
Tail	T46E4
Nose fuzes:	AN-M103A1, AN-M139A1, AN-M140A1, Mk 243 Mod 0, Mk 244 Mod 1, AN-M168 (VT), AN-M166 (VT), M193 (VT-T768 electric), M910 (VT-T750 with T49 drive, M990 (T905) (electric), M904 (T709)
Tail fuzes:	T750 (VT) with T49 drive, M913 (VT) (T768 electric), XB-113 (electric), M905 (T771 with T49 drive), M906 (T778 with T49 drive), M990 (T905 electric), M194 (T791)

TABLE 3-12. Physical Characteristics of 500-lb Mk 82 Mod 1 GP Bomb.

Mark	82
Mod	1
General arrangement	1380543
List of drawings	165796
Fin assembly drawing No.	1380512
Length of assembled bomb, in.	86.90
Body diameter, in.	10.75
Fin span, in.	15.1
Weight of explosive charge, lb	192.0
Weight of assembled bomb, lb	531.0
Arming-wire assembly	Mk 1 or AN-M6A2 (for nose fuze), M13 (for tail fuze)
Cable assembly (for electric fuzing)	M72 (T32)
Adapter-booster	
Nose	T45E1
Tail	T46E4
Nose fuzes:	AN-M103A1, AN-M139A1, AN-M140A1, Mk 243 Mod 0, Mk 244, AN-M166 (VT), AN-M168 (VT), M913 (VT) (T768) (electric), M990 (T905) (electric), M904 (T709), M910 (VT) (T750 (with T49 drive)
Tail fuzes:	M195 (T792), M990 (T905) (electric), M910 (VT) (T750) (with T49 drive), M913 (VT) (T768) (electric), XB-113 (electric), M905 (T771) (with T49 drive), M906 (T788) (with T49 drive)

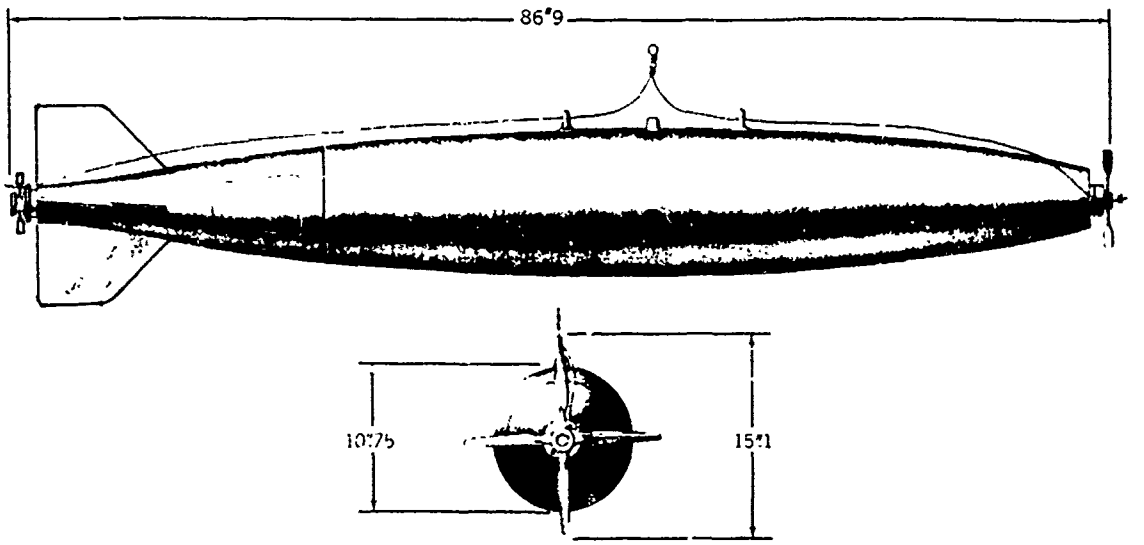


FIGURE 3-81. 500-lb Low-Drag GP Bomb Mk 82 Mod 1 (Mechanically Fuzed), Exterior View.

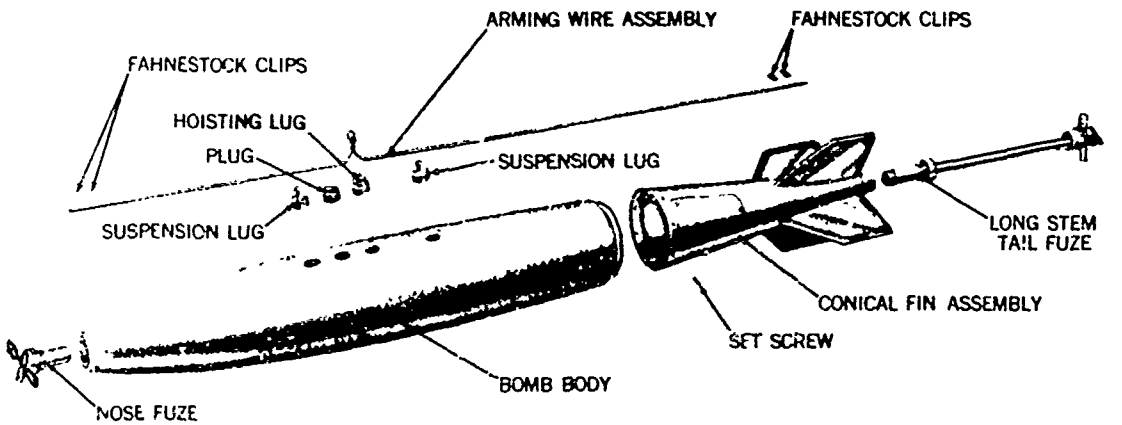


FIGURE 3-82. 500-lb Low-Drag GP Bomb Mk 82 Mod 1 (Mechanically Fuzed), Exploded View.

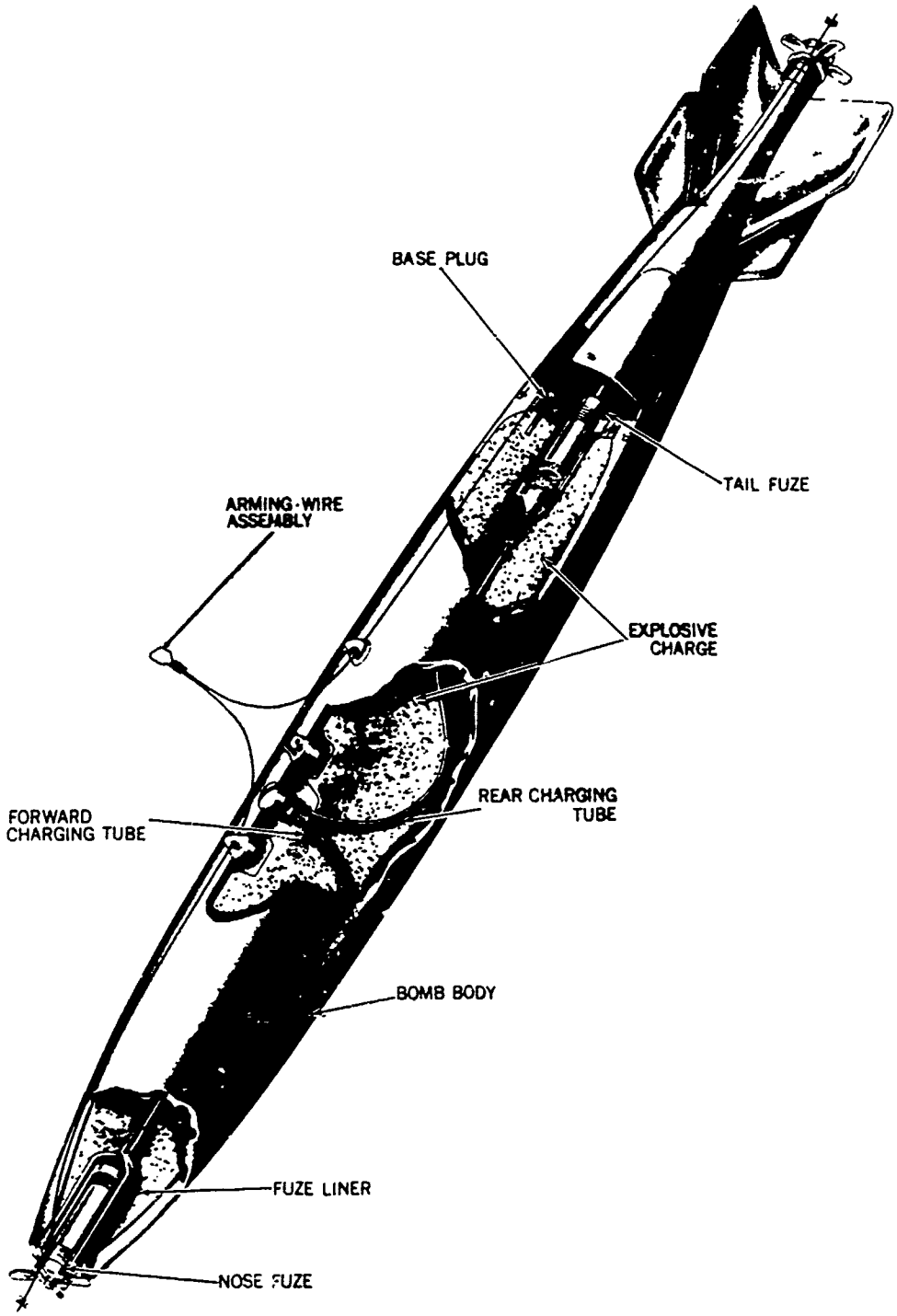


FIGURE 3-83. 500-lb Low-Drag GP Bomb Mk 82 Mod 1 (Mechanically Fuzed), Cutaway View.

Mk 83 GP Bomb (1000-lb)

The 1000-lb Low-Drag General Purpose Bomb Mk 83 Mod 4 is identical in shape to the Mk 81 and Mk 82 low-drag GP bombs, and normally has a low-drag conical fin attached to the aft end by six setscrews (Figures 3-84, 3-85, and 3-86). The Mk 83 bomb can be assembled to the MAU-91/B (with the use of adapter ADU-320/B) or BSU-85/B retarder-type fin assemblies instead of the conical fin assembly (discussed later, p. 159). Table 3-13 gives characteristics on the Mk 83 low-drag GP bomb.

Mk 84 GP Bomb (2000-lb)

The 2000-lb Low-Drag General Purpose Bomb Mk 84 Mod 1 is identical in shape to the Mk 81, Mk 82, and Mk 83 low-drag GP bombs, and normally has a low-drag conical fin attached to the aft end of the bomb body by eight setscrews (Figures 3-87, 3-88, and 3-89). The Mk 84 bomb can be assembled with the BSU-50/B retarder-type fin assembly instead of the conical tail assembly. Physical characteristics of the Mk 84 low-drag GP bomb are given in Table 3-14. The retarder-type fin assemblies for the Mk 80 Series low-drag GP bombs are discussed in more detail later in this section.

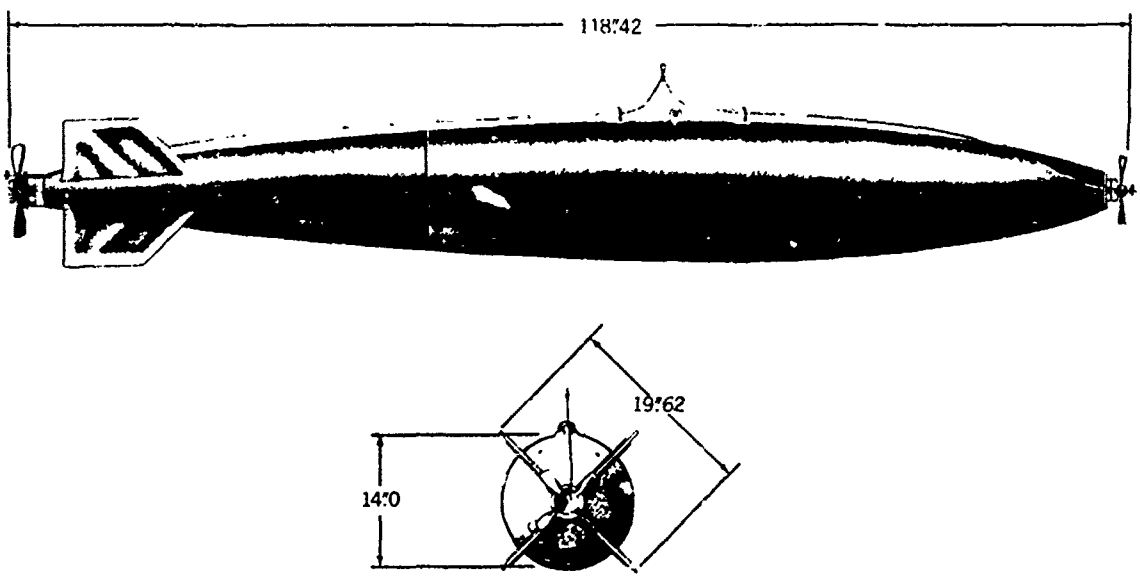


FIGURE 3-84. 1000-lb Low-Drag GP Bomb Mk 83 Mod 3 (Mechanically Fuzed), Exterior View.

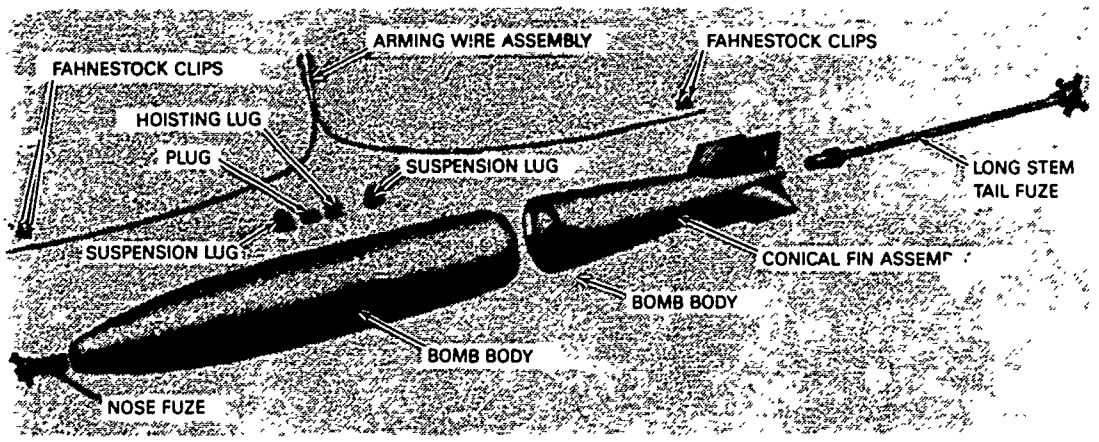


FIGURE 3-85. 1000-lb Low-Drag GP Bomb Mk 83 Mod 3 (Mechanically Fuzed), Exploded View.

TABLE 3-13. Physical Characteristics of 1000-lb Mk 83 Mod 3 GP Bomb.

Mark	83
Mod	3
General arrangement	1380261
List of drawings	165791
Fin assembly drawing No.	1380505
Length of assembled bomb, in.	118.42
Body diameter, in.	14.0
Fin span, in.	19.62
Weight of explosive charge, lb	445.0
Weight of assembled bomb, lb	985 0
Arming-wire assembly	Mk 1 or AN-M6A2 (for nose fuze), M16 (for tail fuze)
Cable assembly (for electric fuzing)	M73 (T27)
Adapter-booster	
Nose	T45E1
Tail	T46E4
Nose fuzes:	AN-M103A1, AN-M139A1, AN-M140A1, Mk 243 Mod 0, Mk 244 Mod 1, AN-M166 (VT), AN-M168 (VT), M910 (VT) (T750) (with T49 drive), M913 (VT) (T768) (electric), M990 (T905) (electric)
Tail fuzes:	M913 (VT) (T768) (electric), M905 (T771) (with T49 drive), M906 (T788) (with T49 drive), M177 (T745), M183 (T783), M185 (T740), M990 (T905) (electric), XB-113 (electric)

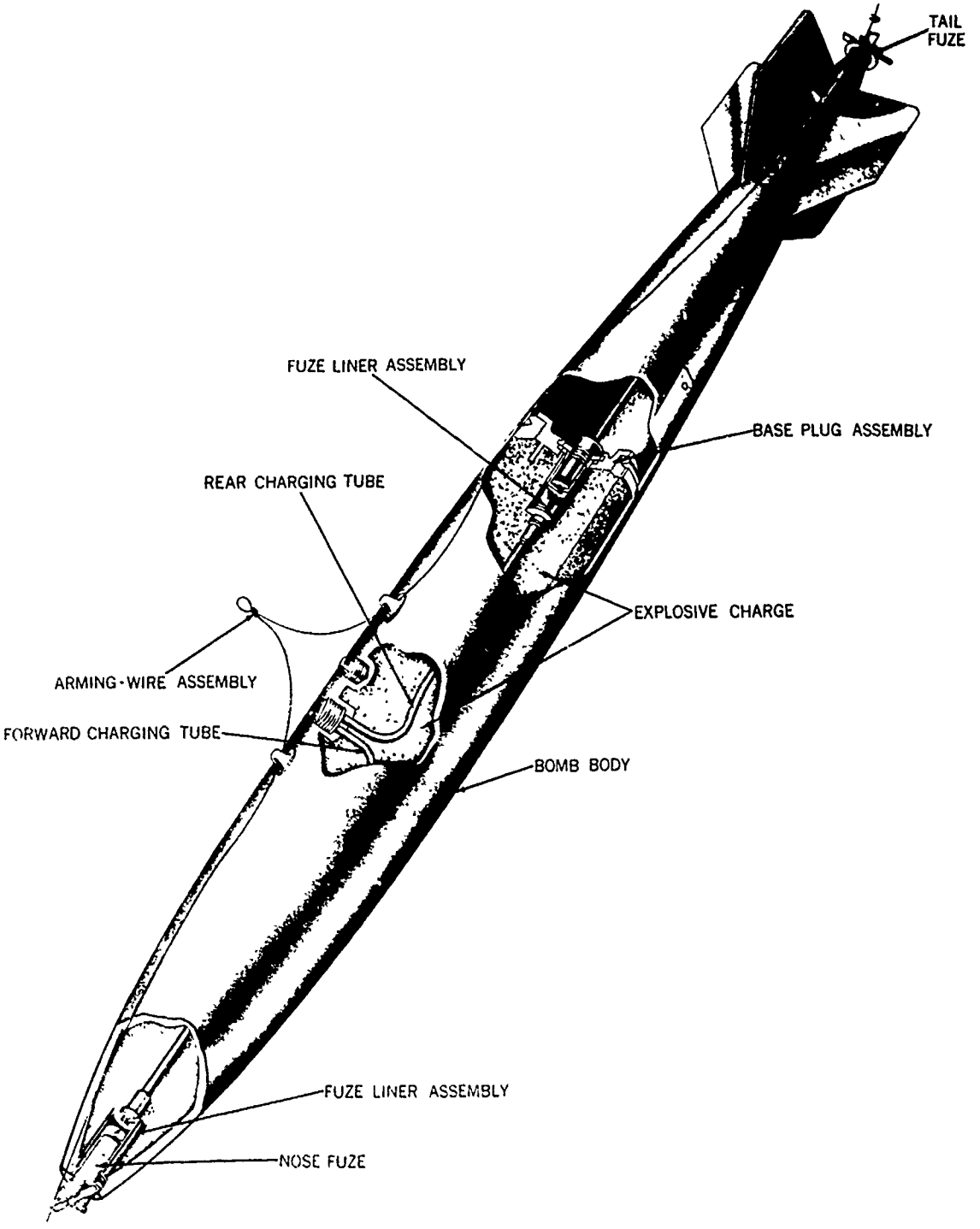


FIGURE 3-86. 1000-lb Low-Drag GP Bomb Mk 83 Mod 3 (Mechanically Fuzed), Cutaway View.

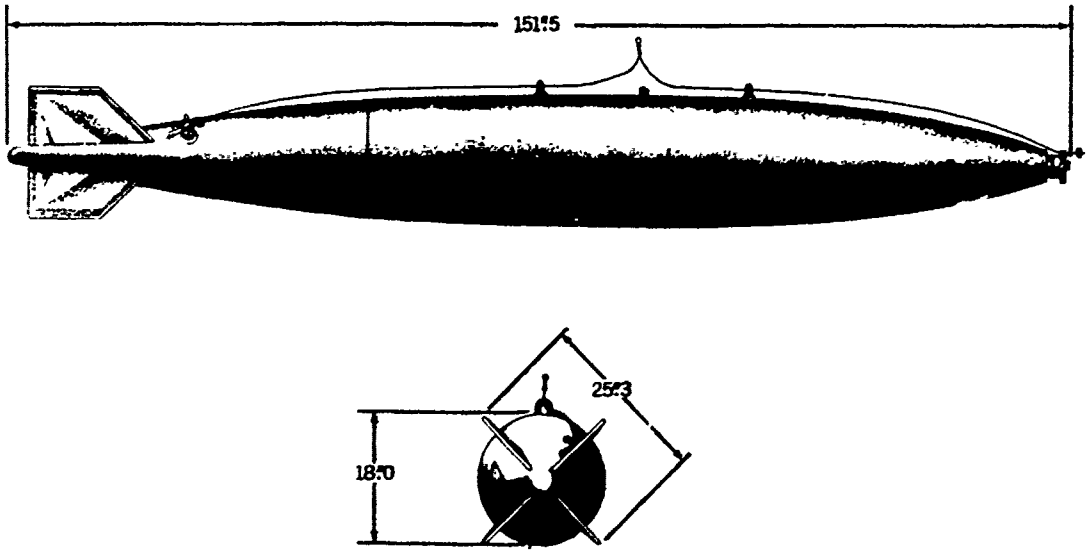


FIGURE 3-87. 2000-lb Low-Drag GP Bomb Mk 84 Mod 1 (Mechanically Fuzed), Exterior View.

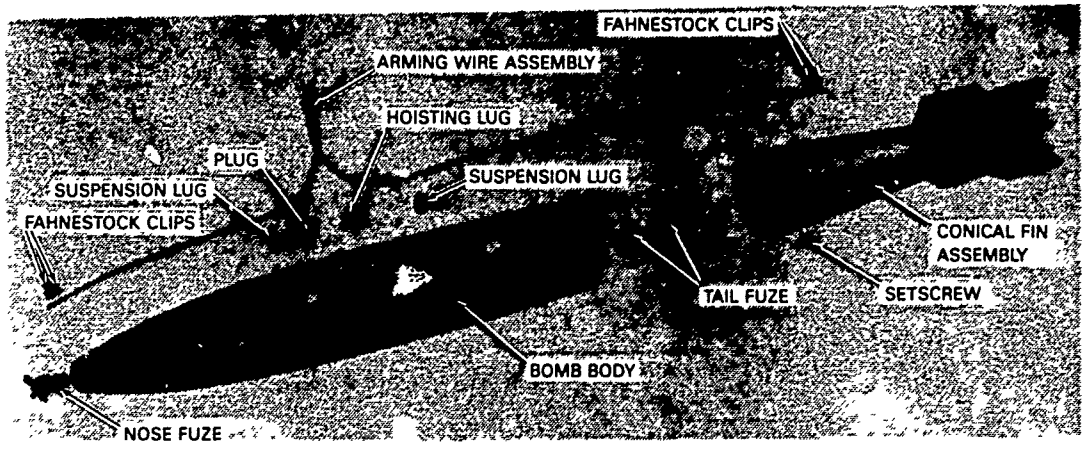


FIGURE 3-88. 2000-lb Low-Drag GP Bomb Mk 84 Mod 1 (Mechanically Fuzed), Exploded View.

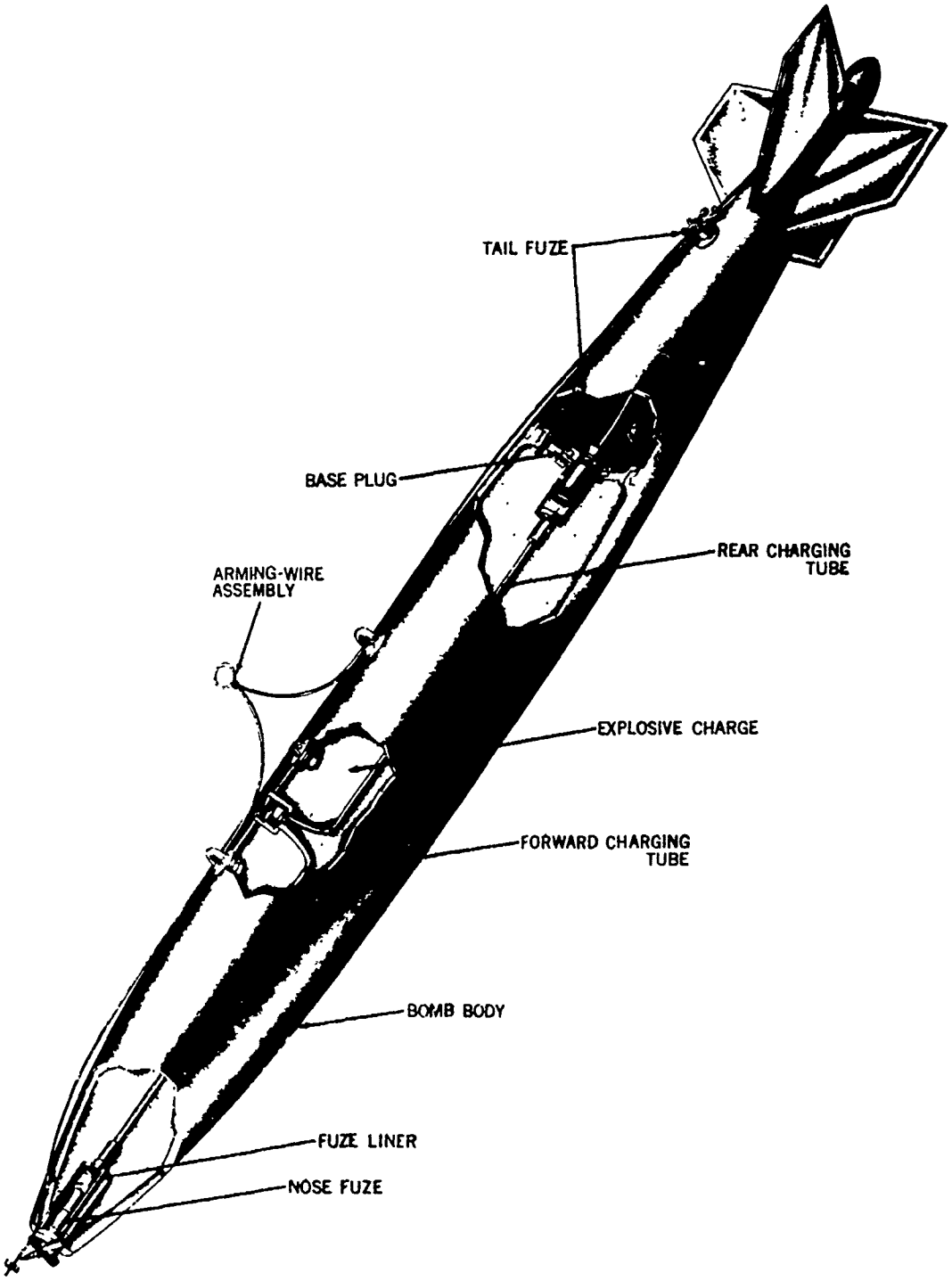


FIGURE 3-89. 2000-lb Low-Drag GP Bomb Mk 84 Mod 1 (Mechanically Fuzed), Cutaway View.

TABLE 3-14. Physical Characteristics of 2000-lb Mk 84 Mod 1 GP Bomb.

Mark	84
Mod	1
General arrangement	1380522
List of drawings	165795
Fin assembly drawing No.	1380529
Length of assembled bomb, in.	151.50
Body diameter, in.	18.0
Fin span, in.	25.31
Weight of explosive charge, lb	945.0
Weight of assembled bomb, lb	1970.0
Arming-wire assembly	Mk 1 or AN-M6A2 (for nose or tail fuze)
Cable assembly (for electric fuzing)	M74 (T28)
Adapter-booster	
Nose	T45E1
Tail	T46E4
Nose fuzes:	AN-M103A1, AN-M139A1, AN-M140A1, AN-M166 (VT), AN-M168 (VT), T750 (VT), M904 (T709), M913 (VT) (T768) (electric), M990 (T905) (electric)
Tail fuzes:	M913 (VT) (T768) (electric), M190 (T759), M990 (T905) (electric), XB-113 (electric)

DEVELOPMENT OF METAL/PARACHUTE RETARDATION DEVICES

To meet the fundamental requirement stated in Reference 8, suitability for external carriage on high-speed aircraft, the basic aerodynamic shape of the new low-drag GP bomb bodies and fin assemblies were streamlined to reduce air resistance and enhance ballistic accuracy when released from most altitudes and at most airspeeds principally in the transonic and supersonic ranges.

The Navy had established requirements for both high-altitude bombing missions and low-altitude high-speed (up to 600 knots indicated air speed (IAS)), air-strike missions. The air-strike mission required the development of advanced retardation-type fin assemblies to provide safe escape to the pilot and aircraft from the inherent hazards from bomb fragments, ricochet, or blast. The use of an improved or advance type decelerator or retardation device, would also reduce the circular error probability (CEP) and enhance target identification by allowing the pilot to retain the bombs longer and approach the targets more closely before release.

Previously, parachutes were the primary retardation systems used on bombs. These were specifically designed, sized, and packaged into tail assemblies to provide retardation when required to free-fall bombs. For the higher transonic-speed requirements, as well as ballistic accuracy enhancement, a new type of retarder for GP bombs was required.

Retarder Fin Assembly

In 1960, the Bureau of Naval Weapons (BUWEPS) tasked the then-Naval Ordnance Test Station (NOTS), China Lake, to develop a retardation-type fin for the 250-lb Mk 81 GP bomb. NOTS worked with Douglas Aircraft Co. under a BUWEPS contract, in the design, testing, and evaluation of a high-drag-only fin. After the initial effort in which prototypes were built and tested, BUWEPS redirected the effort to a dual-mode low-drag (unretarded) and high-drag (retarded) fin assembly. This assembly was designated as the Mk 14 Mod 1, Snakeye I.

In August 1963, BUWEPS further tasked NOTS, under WEPTASK No. RM3773-009/216-1/F008-99-07, to design, develop, fabricate, test, and evaluate a retarding device for the 500-lb Mk 82 Low-Drag General-Purpose Bomb. The Mk 81 and Mk 82 bombs with the retarder-type fin assembly and appropriate fuzing formed the Snakeye I weapon systems. This latter WEPTASK was a continuation of earlier efforts devoted to weapon feasibility studies and fabrication of experimental models. The pertinent requirements of the WEPTASK were:

1. Provide for the design, development, prototype manufacture, test, evaluation, and documentation of a simple retarding device for use with the 500-lb Mk 82 Low-Drag Bomb body, to be delivered by all modern, high-performance aircraft using single- or multiple-carriage bomb racks. The retarding device will permit low-level delivery of the Mk 82 Low-Drag Bomb with minimum hazard to pilot and aircraft from blast, fragmentation, or ricochet of the bomb. The design should provide for the capability of releasing the bomb, at pilot option, in the alternate low-drag configuration, and should also incorporate a quick-attach feature to reduce weapon assembly time in the fleet.

2. The weapons must have adequate dynamic stability under all tactical release conditions. The ballistic dispersion for the low-drag configuration shall not exceed 10 mils (defined as the radius of the circle, on the surface, centered at the theoretical impact point, containing 99% of the impacts). A mil is defined as the ratio of a unit distance in the horizontal plane to a thousand units of trajectory arc length. The dispersion limit for the retarded configuration will be established at a later date depending on development experience and delivery accuracy requirements.

3. The weapon must possess safe separation characteristics when released at tactical speeds of up to 600 knots IAS.

4. The weapon should be designed for maximum simplicity and mass producibility. It should be completely compatible with ship and shore handling and storage capabilities, and require a minimum of revisions to current manning levels, existing ratings and skills.

5. The weapon design shall conform to Military Specification MIL-A-8591C, General Design Criteria for Airborne Stores and Associated Suspension Equipment.

6. The weapon must be immune to electromagnetic radiation. All electro-explosive devices developed under this Problem Assignment shall meet the requirements of BUWEPS Instruction 5101.2, Hazards of Electromagnetic Radiation to Ordnance (HERO).

7. Obtain and provide aerodynamic and ballistic data as required by the Naval Weapons Laboratory (NWL), Dahlgren for ballistic analysis and preparation of appropriate ballistic tables.

The design of the Mk 15 retarder fin for the Mk 82 low-drag GP bomb was basically a scaled-up version of the Mk 14 Mod 1 Snakeye I, metal fin. Douglas Aircraft Co., under contract to BUWEPS, again worked with NOTS in this later effort. The Mk 81 and Mk 82 retarder-fin assemblies, consisted of four streamlined, metal folded blades or paddles, that could be opened after release into an umbrella-like configuration to impart high drag to the bombs up to release speeds of 550 knots (less than stated 600-knot requirement) (Figures 3-90, 3-91, and 3-92). Physical characteristics are given in Table 3-15. A larger version of the Mk 14/Mk 15 type retarders was developed by the Air Force for their 750-lb Demolition Bomb M117A1, which was designated as the MAU-91 A/B fin assembly. This was also used on the 1000-lb Mk 83 bomb with an adapter ADU-320/B (Figure 3-93).

Destructor (DST) Conversion

The Vietnam conflict in Southeast Asia saw the introduction of a different kind of land or sea mine, designated as destructors (DST). These mines or destructors utilized three of the low-drag GP Mk 80 Series bombs—the 500-lb Mk [illegible] the 1000-lb Mk 83, and the 2000-lb Mk 84, designated as DST-36, DST-40, and [illegible]41 respectively (Figure 3-94). The low-drag GP bombs were converted to destructors with the installation of a kit of modular components. The Mk 75 modification kit consisted of a Mk 42 firing mechanism, Mk 32 arming device, Mk 95 battery, and a MK 59 booster. The 500-lb DST-36 utilized the Mk 15 bomb fin assembly. The 1000-lb DST-40 utilized, by means of the ADU-320/B adapter, the MAU-91A/B retarder-fin assembly. A dedicated low-drag/high-drag paracnute-type fin assembly, the Mk 11 Mod 0 Paratail, was developed by the Naval Sea Systems Command for the 2000-lb DST-41. Figure 3-95 typifies the assembly of various components of the Mk 75 modification kit, as well as retardation-type tails, into the Mk 82, Mk 83, or Mk 84 low-drag GP bombs to convert them into destructors.

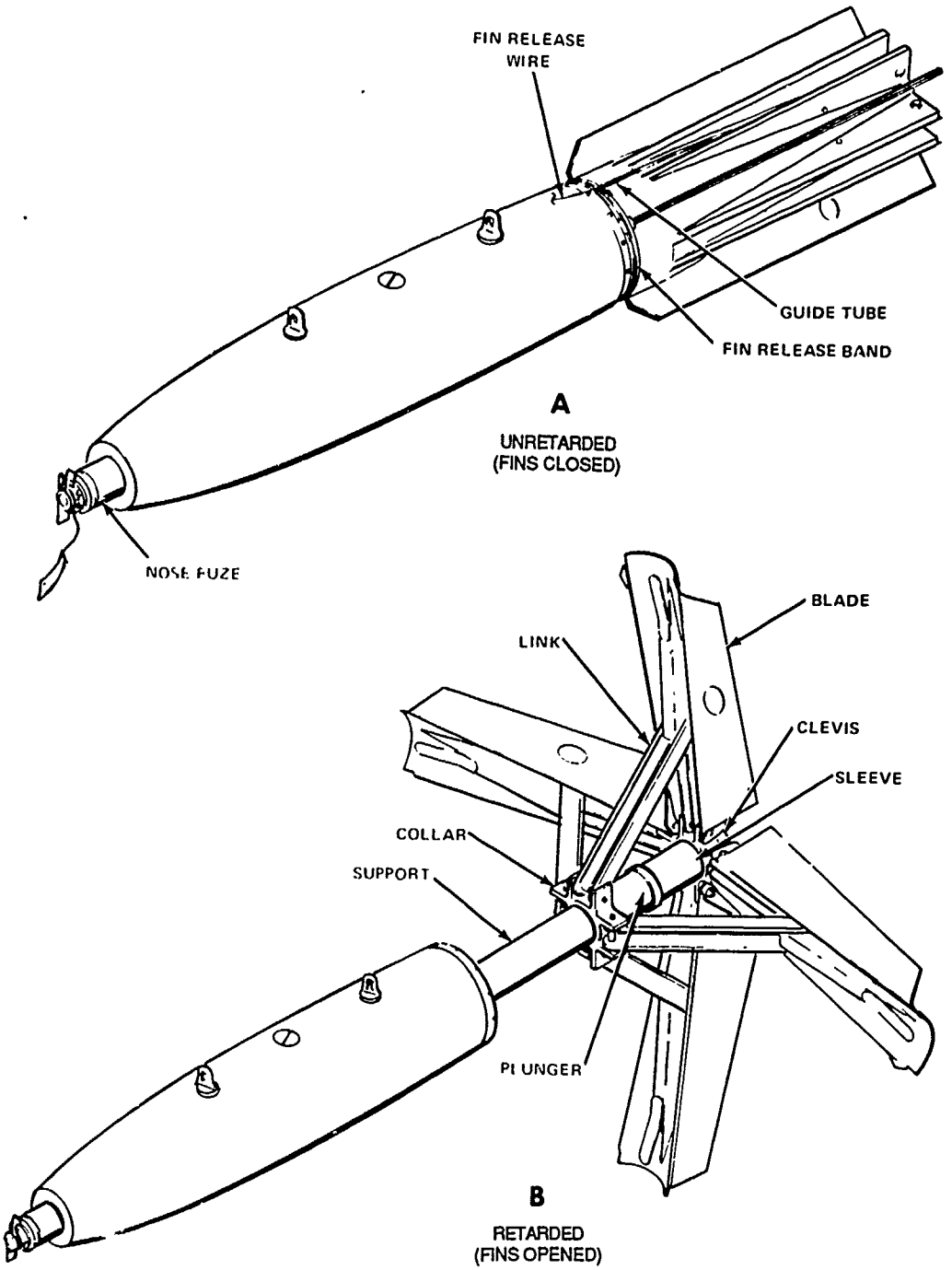


FIGURE 3-90. Mk 14 Fin with Mk 81 Bomb Body.

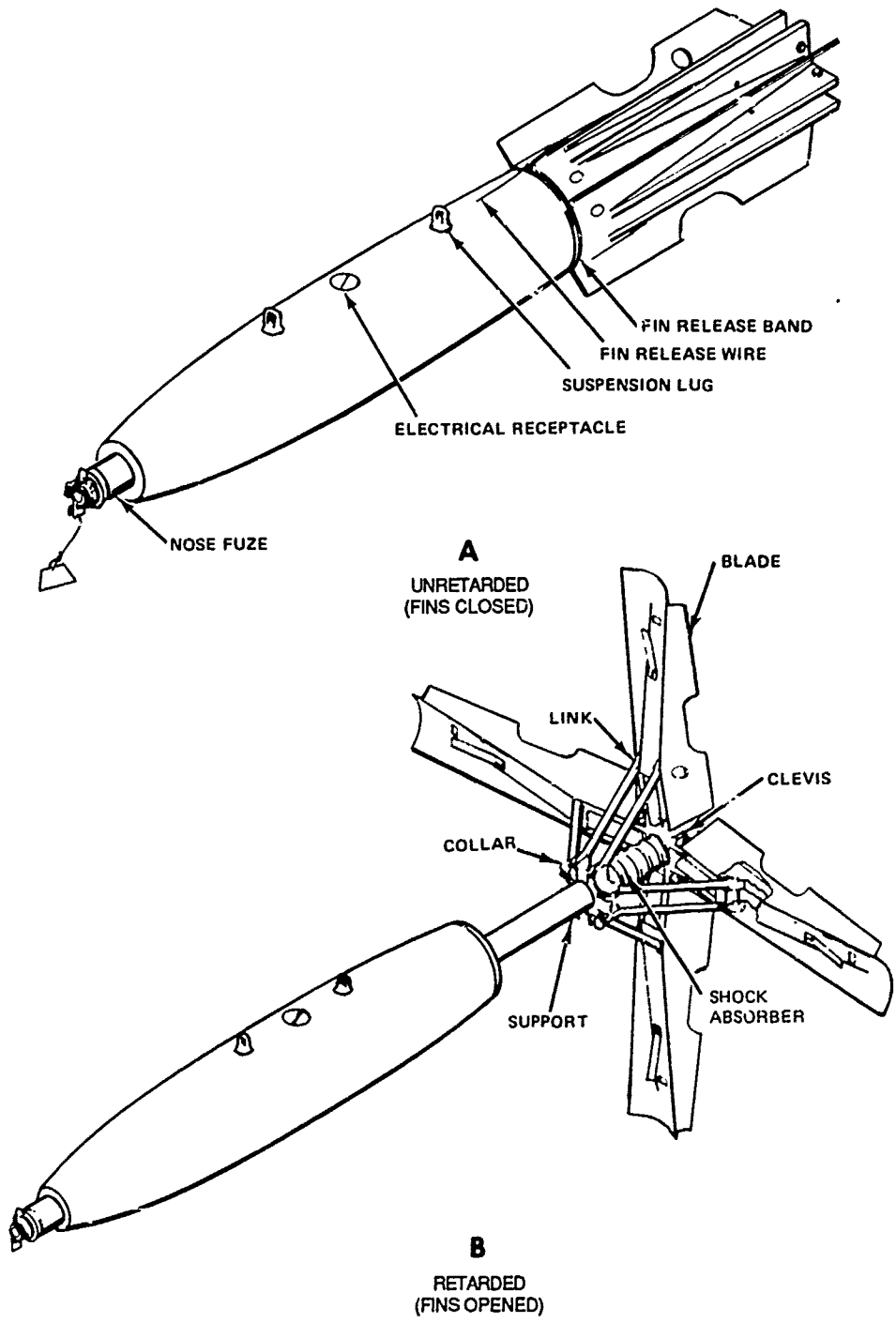


FIGURE 3-91. Mk 15 Fin with Mk 82 Bomb Body.

TABLE 3-15. Physical Characteristics of Mk 81 and Mk 82 Snakeye I.

	250-lb bomb	500-lb bomb
Model	Mk 81 Mod 1 Snakeye I	Mk 82 Mod 1 Snakeye I
Length of assembled bomb, in.	75.0	89.5
Body diameter, in.	9.0	10.8
Fin assembly	Mk 14 Mod 1	Mk 15 Mod 1
Fin span, closed, in.	12.8	15.1
open, in.	54.25	65.3
Weight of filler, lb	100.0	192.0
Weight assembled bomb, lb	300.0	560.0
Arming wire assembly - for tail release	Mk 1 Mod 0	Mk 1 Mod 0
Cable assembly - for electric fuzing	M171	M172
Adapter-booster (nose)	M126A1 (T45E1)	M126A1 (T45E1)
Nose fuze:		
Unretarded	AN-M103A1, AN-M139A1, M163, M164, M165, M904E1, M904E2	
Retarded	AN-103A1, AN-M139A1, AN-M140-A1, M163, M164, M165, M904E2	
Tail fuze:		
Unretarded	M990D, M990D1, Mk 255 Mod 0, M990D2, M990E1, M990E2	
Retarded	M990D, M990D1, Mk 255 Mod 0, M990E2	
Nose-tail fuze system	Unretarded—M913 (VT)	

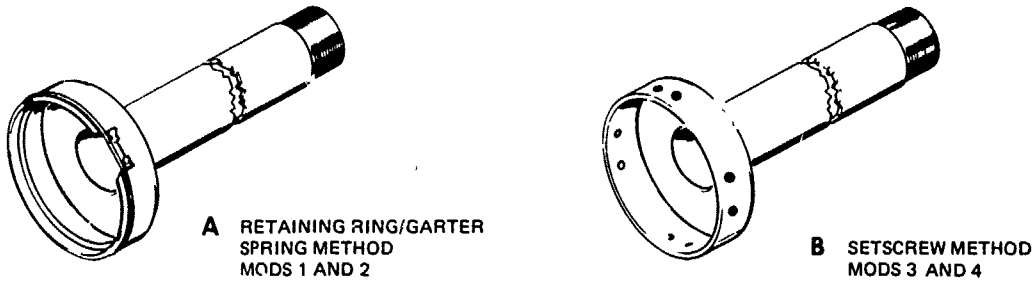


FIGURE 3-92. Methods Used to Attach Retarding Bomb Fins Mk 15 to Bombs.

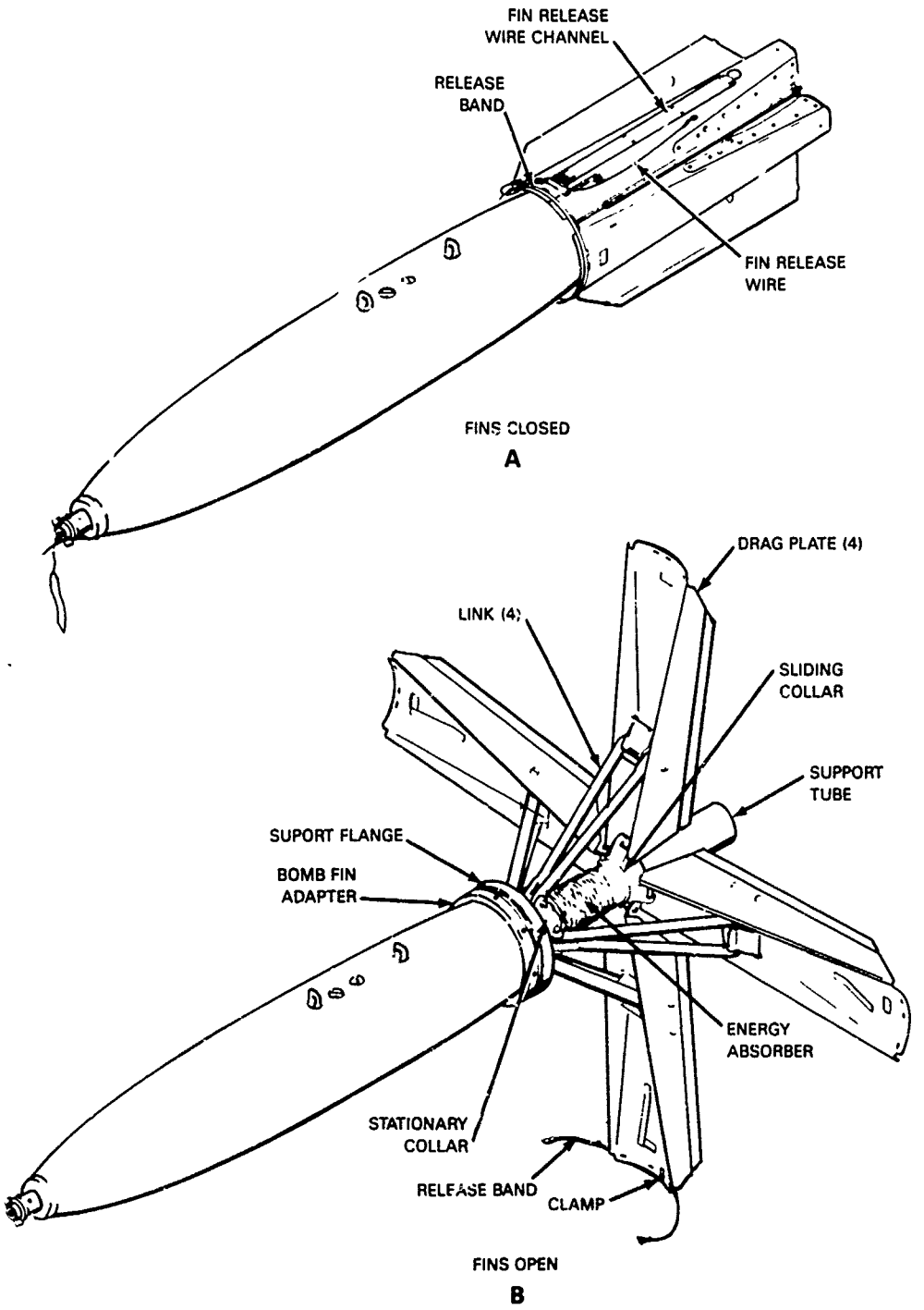


FIGURE 3-93. MAU-91 Fin with Adapter ADU-320/B Mk 83 Bomb Body.

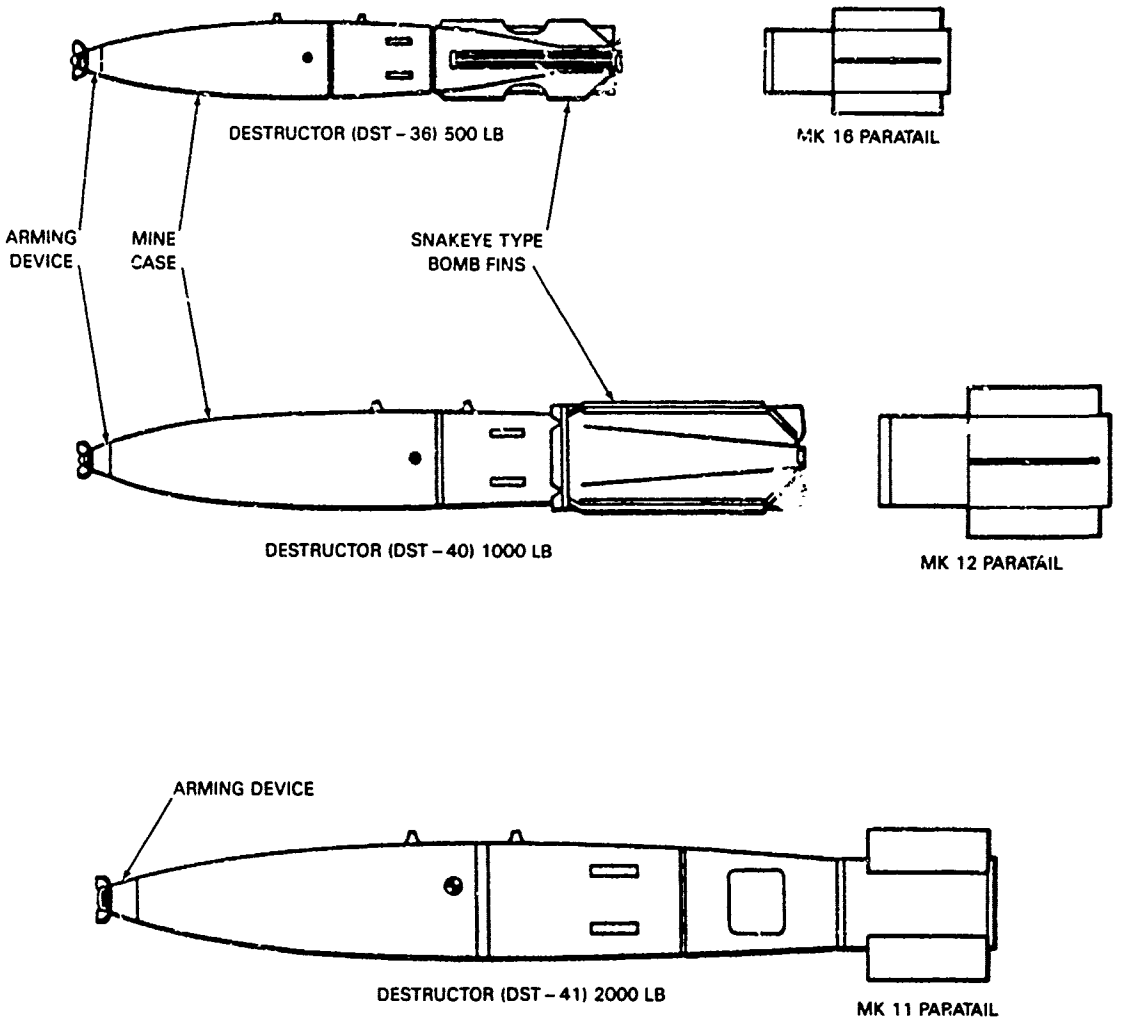


FIGURE 3-94. Typical Destructors.

Improved Bomb Stabilization/Retardation Devices

With later advancements in U.S. Air Force and Navy aircraft design and engines and vastly improved antiaircraft weapon systems, it became evident that for pilot and aircraft survivability, bomb systems had to be compatible with supersonic release conditions, i.e., not impose constraints on the operational, as well as survival capability of the attacking aircraft. As stated in various 1969 through 1973 Tactical Requirement documents of the Air Force and in the 5 April 1974 Joint Service

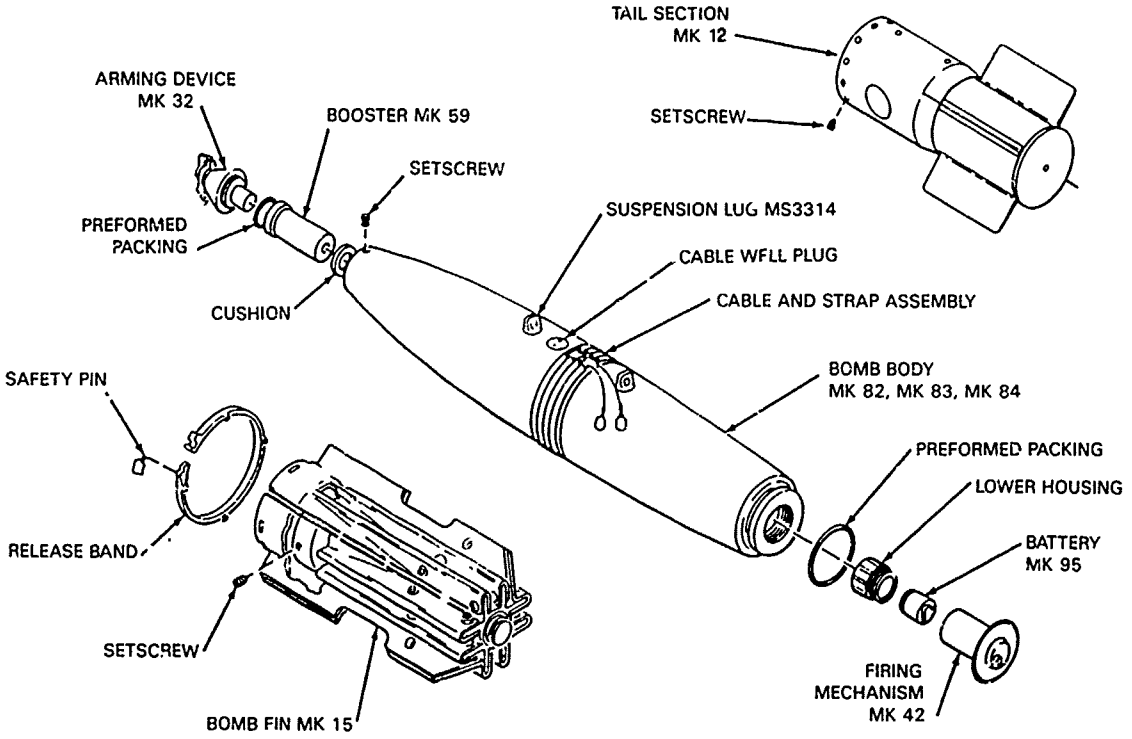


FIGURE 3-95. Typical Destructor Conversion of Mk 80 Series Bombs with Mk 75 Modification Kit Components.

Operational Requirement (JSOR) for Improved Bomb Stabilization/Retardation Devices (Reference 12), "there is a valid operational need to provide the tactical attack and strategic forces with a reliable and safe method of delivering retarded general purpose bombs. Weather conditions, antiaircraft defenses, and accuracy requirements often dictate bomb delivery from very low altitudes. Free-fall delivery parameters may not allow safe separation of the delivery aircraft. A reliable aerodynamic drag device is required to provide safe separation of bombs from aircraft and prevent fragmentation or blast damage to the attacking aircraft.

Previous efforts to provide the required capability resulted in the development and procurement of the Mk 14, Mk 15, and MAU-91 high-drag fins. These devices imposed serious operational restrictions on the delivery aircraft and greatly reduced tactical flexibility. The Mk 15 demonstrated numerous instances of structural failure when employed above 500 knots. The quantity deployment of infantry-launched SAM missiles increase the importance of high-delivery speeds. Current drag devices have unacceptable functional reliabilities and impose safety hazards to aircraft and crew. The MAU-91

required a lengthy build-up time and unconventional lanyard routing to preclude structural damage to the aircraft at weapon release. Numerous modifications to the fins did little to improve the operational acceptability. Because of these serious deficiencies, a new method of affording high/low-drag pilot-option delivery of general purpose bombs was urgently required. Later efforts by both the Air Force and the Navy to develop a satisfactory system were directed toward a ram air inflatable retardation (AIR) device. Feasibility of this concept had been demonstrated and it appeared that this approach offered the greatest potential for development and subsequent production at reasonable cost."

RAM AIR INFLATABLE RETARDATION DEVICE (FABRIC)

The general performance requirements for the ram air inflatable retardation (AIR) system were defined in the following documents:

1. Improved General Purpose Bombs, TAC ROC 49-68, April 1969 (document confidential)
2. Improved General Purpose Bombs, AMEND No. 1 to TAC ROC 49-68, November 1971 (document confidential)
3. Supersonic Delivery Capability, PMD R-P-2121(2)64602F/5613, July 1973 (document confidential)
4. Improved Bomb Stabilization/Retardation Devices, JSOR, February 1974 (document unclassified)

The requirements were as follows:

1. Allow supersonic carriage and release (Mach 1.25 at sea level).
2. Allow pilot option of high/low-drag delivery.
3. Allow for parent pylon, MER, TER carriage on those aircraft for which the weapons are to be certified.
4. Exhibit predictable and repeatable ballistics in both delivery modes.
5. Possess low-drag stability greater than that of present weapon tail fins.
6. Possess rapid and repeatable inflation characteristics when released in the retarded mode.
7. Not exceed overall length and diameter of current systems.
8. Allow safe weapon separation from the aircraft, high or low drag.
9. Induce sufficient deceleration forces to arm "G" sensing fuzes.

10. Require minimum maintenance and require no unique tools/auxiliary ground equipment (AGE).
11. Be compatible with standard munitions handling and loading equipment.
12. Have a minimum shelf life of 10 years; 20 years desired.
13. Have a functional reliability of 95% at the 90%-confidence level when released in the high-drag mode (99/95% desired).
14. Provide greater resistance to impact ricochet than current operational systems.
15. Have potential adaptability to other weapons, such as mines, sonobuoys, modular weapon warheads, etc.
16. Be cost competitive with present systems.

The AIR Program requirements drawn from the JSOR further stated that the retarder systems developed, would be compatible with inventory GP bombs and mines as follows:

Air Force	Navy
500-lb Mk 82	500-lb Mk 82
2000-lb Mk 84	500-lb Destructor Mk 36
750-lb M117 (if developed)	
500-lb Destructor Mk 36	
750-lb M117 Destructor (if developed)	

The two AIR systems developed by Goodyear Aerospace Corporation (GAC) to meet the Improved Bomb Stabilization/Retardation requirements in the JSOR, basically to retard the descent rate of the 500-lb Mk 82 and 2000-lb Mk 84 GP bombs, were the BSU-49/B and BSU-50/B respectively. These systems were designed, tested, and qualified under a joint Government (U.S. Air Force and U.S. Navy) and industry (GAC) engineering effort. Additionally, the BSU-49/B design included techniques to improve the static and dynamic stability of the Mk 82 low-drag mode configuration, and basically, to eliminate the low-drag stability problem (low margin of dynamic stability) in the MAU-93/B conical fins and Snakeye Mk 15 fins. The observed instability rate, under operational release conditions, was 19.7% since their introduction in the Fleet (a period of approximately 20 years) (Reference 13).

Following the development of the BSU-49/B and BSU-50/B, a third AIR system, the BSU-85/B, was developed by GAC for the 1000-lb Mk 83 GP bomb under an engineering development contract with the Navy (see Figure 3-96). The AIR assemblies serve both as a low-drag and high-drag aerodynamic stabilizer, thus providing the pilot with the option of delivering either a low-drag or high-drag Mk 80 series GP bomb. Figure 3-97 illustrates the AIR system in both the low-drag or high-drag configurations.

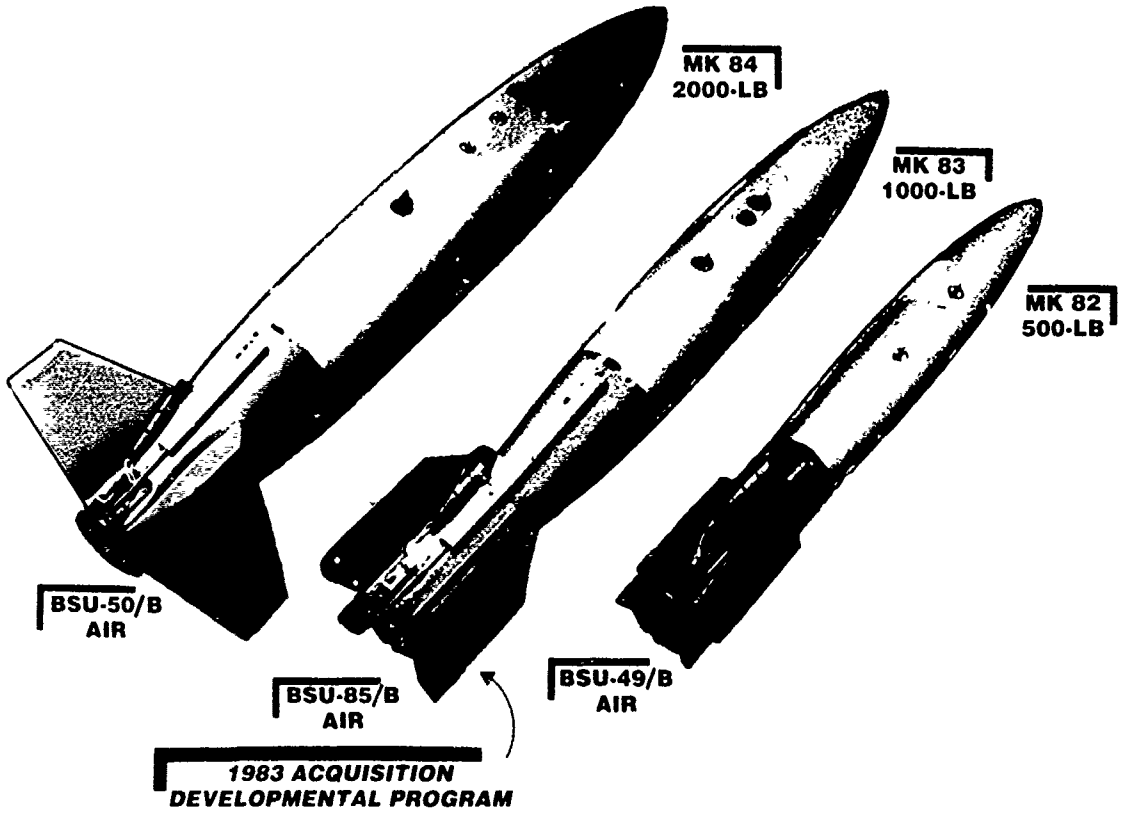


FIGURE 3-96. Air Inflatable Retarders and Stabilizers—Mk 84/BSU-50/B, Mk 83/BSU-85/B, and Mk 82/BSU-49/B.

The AIR system consists of a low-drag stabilizer assembly, a deployable fabric retarder, and a lanyard-operated deployment system. The low-drag stabilizer assembly consists of a welded sheet steel structure or canister, both cylindrical (BSU-49/B) or conical (BSU-50/B and BSU-85/B) in shape with four fixed fins. As a roll generating device, each of the four fins has a 13-deg tab or wedge on the same side of the trailing edge to induce a spin rate—approximately eight times the nutation frequency to dampen excessive pitch or yaw oscillations. The rear portion of the stabilizers forms a weathertight container for the deployable fabric retarder. This tightly woven nylon fabric retarder, sometimes described as a balloon parachute (ballute) or more commonly as an air inflatable retarder, is sewn into a closed parabolic shape that is encompassed, at the aft end, by a hexagonally-shaped boundary layer trip or "burble fence".

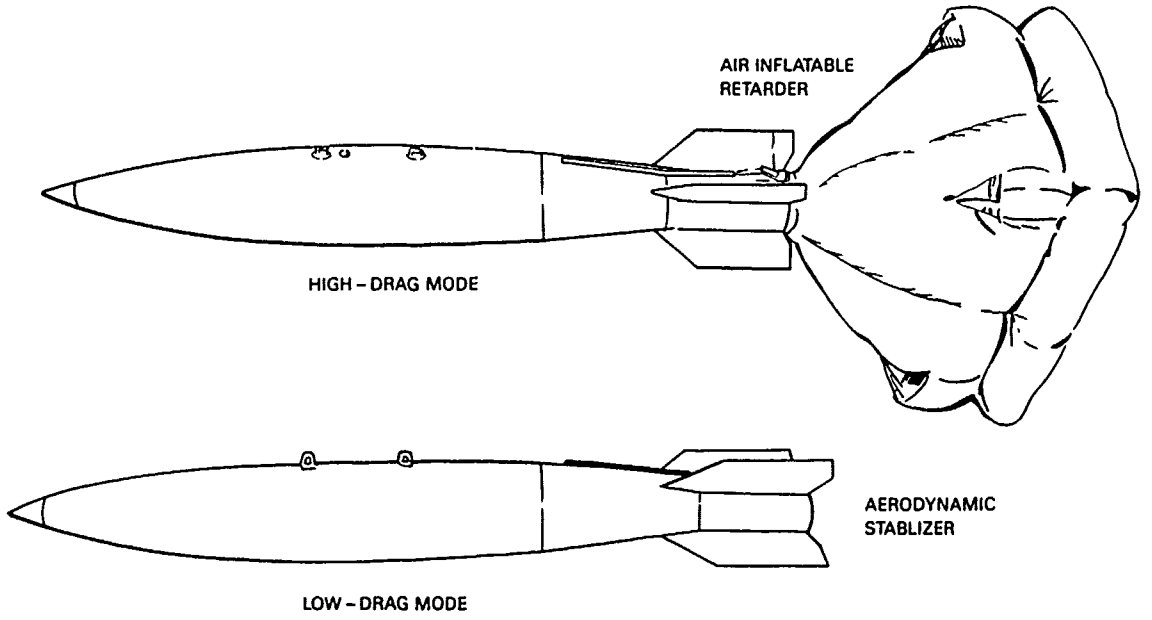


FIGURE 3-97. Dual-Mode Stabilizer and Decelerator BSU-85/B Air Inflatable Retarder.

The AIR unit is stored inside the aft section of the cylindrical or conical stabilizers until it is deployed, whereby it is inflated by ram air through four inlets to form an aerodynamically stable retarder. Four meridian straps surround the inflated retarder and attach it to an internal, structural bulkhead/environmental barrier, in the stabilizer. An aft closure plate is attached to the back of the retarder canister providing an environmental barrier to exterior elements. The closure plate has a spring-loaded release mechanism. Two 20-lb springs (180 deg apart) supply the force to eject the closure cover a sufficient distance so that aerodynamic forces can continue to extract the retarder. Retarder deployment begins as the bomb is released from the aircraft. A delay lanyard, which is attached by a shear link to an arming solenoid of the bomb rack, withdraws a restraining pin in the latching system and allows the springs to eject the aft closure plate rearward. Inflation of the retarder begins as soon as the air inlets are exposed to the air flow during deployment. Cloth check valves under the air inlets (orifices) prevent cross flow during the inflation process. Circular openings in the main body gores allow air to enter and inflate the burble fence. Figure 3-98 illustrates the BSU-85/B AIR system, which incorporates 72% of the BSU-49/B and BSU-50/B production parts, and is typical of the AIR system.

The retarding force of the AIR system, slows and steepens the bomb's descent to the target, allowing the delivery aircraft to attain safe escape from the fragmentation envelope resulting from bomb impact upon the target (Figure 3-99). The unique aerodynamic

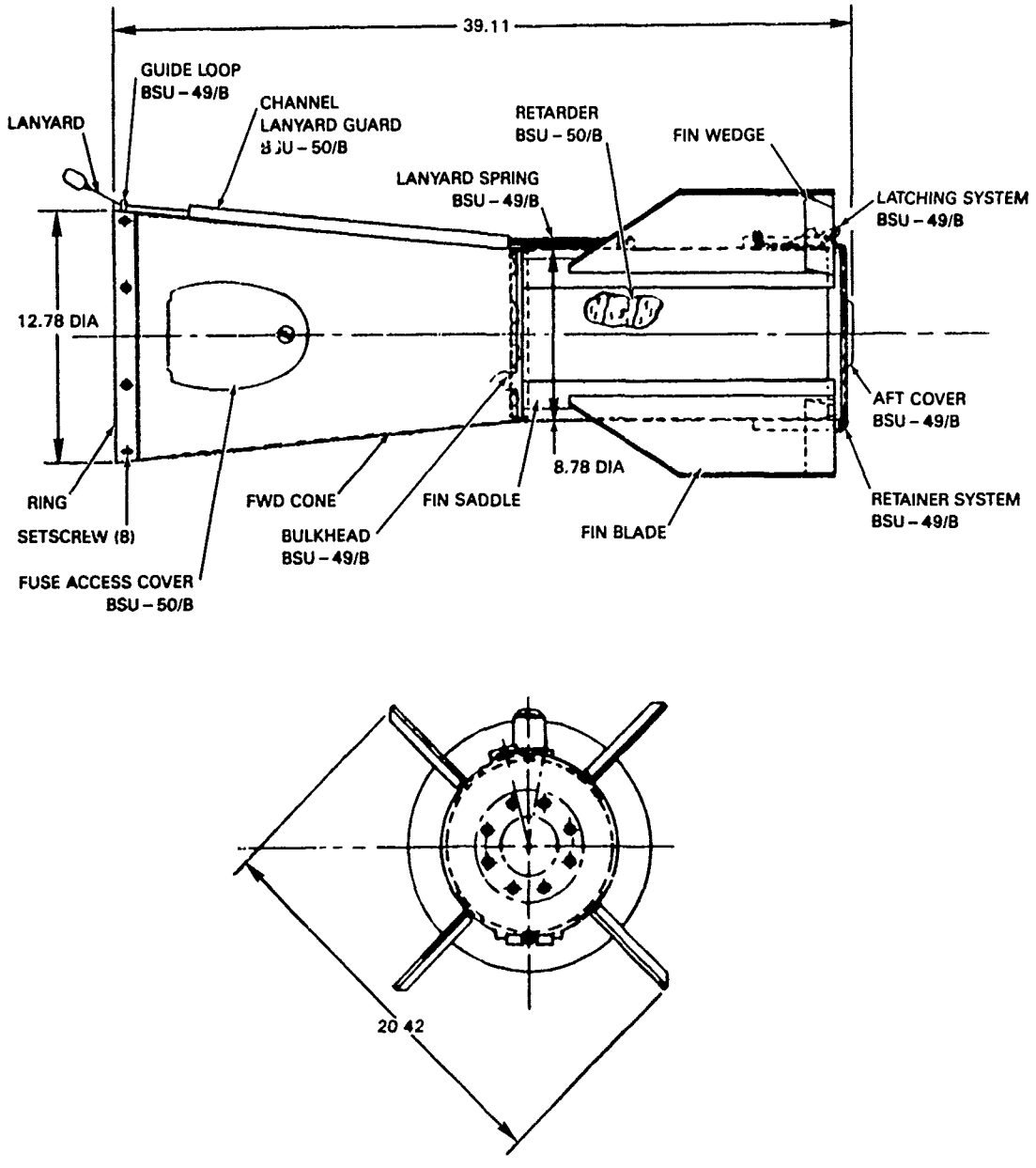


FIGURE 3-98. Mk 83/BSU-85/B AIR System.

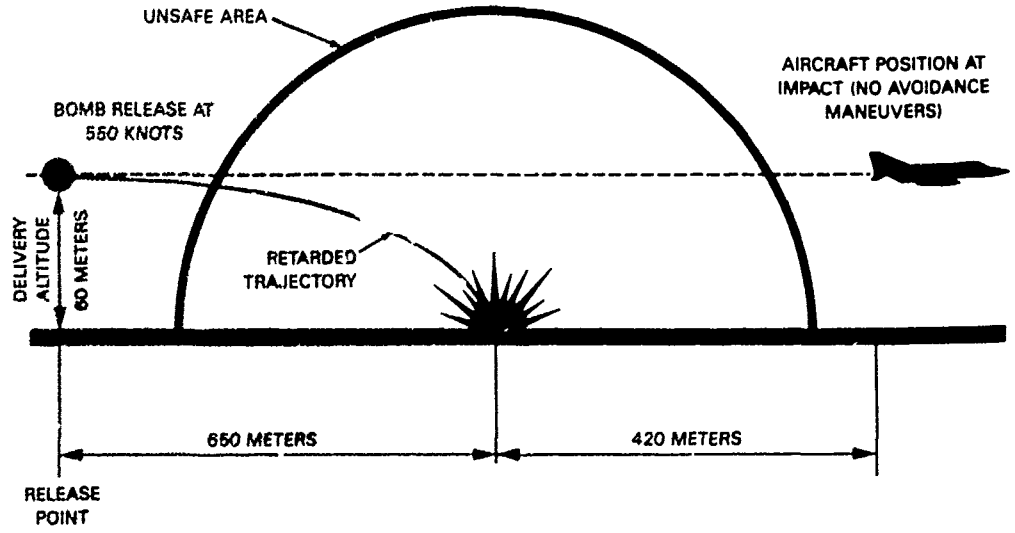


FIGURE 3-99. Typical Low-Altitude Bombing Release Using the AIR System.

characteristic of the AIR shape developed through considerable wind tunnel and U.S. Air Force and Navy advanced development flight tests, during the early 1970s, is the high degree of stabilization it provides throughout the subsonic, transonic, and supersonic aircraft delivery speeds. This latter capability provides more repeatable and accurate bomb trajectories to the target throughout the operational capability of current attack aircraft than previous retardation systems.

The major features of the AIR system are as follows:

1. External, multiple ejection rack or bomb bay carriage for the Mk 82/ BSU-49/B
2. Pylon carriage for the Mk 84/BSU-50/B and Mk 83/BSU-85/B
3. A door in the forward section of the stabilizer to provide access for installing or setting tail fuzes
4. Demonstrated ripple release intervals as low as 60-90 milliseconds for the Mk 82/BSU-49/B
5. Triple ejector rack (TER) or vertical ejector rack (VER) carriage for the Mk 83/BSU-85/B
6. Debris-free release, eliminating risk of foreign object damage to delivery and trailing aircraft

The AIR systems are compatible with the following fuze systems:

1. Mechanical: M904 nose fuze–high and low drag, M905 tail fuze–low drag, and FMU-54/B or A/B–drag-sensing tail fuze.

2. Electrical: Mk 376–drag-sensing tail fuze, FMU-112/B–high-drag-sensing and low-drag tail fuze, and FMU-139/B–high-drag-sensing and low-drag tail fuze.

The AIR system specifications are shown below.

Specifications	BSU-49/B	BSU-50/B	BSU-85/B
STABILIZER			
Diameter	8.75 in.	15.86 x 8.75 in. (cone)	12.85 x 8.75 in. (cone)
Span	15 in.	37 in.	20.32 in.
Length	26 in.	30.5 in.	39.2 in.
Weight	56 lb	96 lb	90 lb
RETARDER			
Drag coefficient times frontal area (C_DA) at Mach 0.6	9.6 ft^2	10.6 ft^2	10.6 ft^2

The AIR systems are packed into shipping and storage containers at the manufacturer's facility, at final assembly. Field maintenance is not required or recommended. The AIR systems have been designed and tested for storage at temperatures ranging from -65 to +160°F at a relative humidity of 95%. When the AIR systems are stored in their specially designed and sealed steel shipping and storage container CNU-241 (BSU-49/B and BSU-50/B), the shelf life is at least 10 years under all weather conditions (Figure 3-100). The CNU-241 can hold 12 BSU-49/B or four BSU-50/B AIR systems. Currently the BSU-85/B fin assemblies are individually packaged into a CNU-419E non-metallic shipping and storage container (Figure 3-101). The Naval Weapons Handling Center (NWHC) at Earle, New Jersey is proposing a metal container to hold six BSU-85/B units similar to the Air Force CNU-241. The specified service life of the AIR systems, after removal from their containers is one year.

The BSU-49/B and BSU-50/B AIR systems have been tested and certified over the full operational airspeed envelopes of the Air Force's A-7, A-10, B-52, F-4, F-111, F-15, and F-16 aircraft. They have a demonstrated reliability of over 95%. Compatibility of the AIR system with the Navy's A-6, A-7, AV-8, F-4, F/A-18, TF/A-18, P-3, and S-3 aircraft was demonstrated during the Mk 83/BSU-85/B development program completed in 1986.

FIGURE 3-100. CNU-241 AIR Shipping and Storage Container.

The advantages of the AIR systems are:

1. Improved low-drag performance over previous Mk 82/MAU-93/B or Mk 15 Mod 5 Snakeye systems
2. Improved high-drag performance over Mk 82/Mk 15 Mod 5 Snakeye retarder system
3. Can be released at speeds from 200 to 700 knots calibrated airspeed (KCAS)
4. Release altitude from 100 to 7000 feet in high-drag mode
5. Release altitude to 50,000 feet in low-drag mode
6. Can be released from straight and level flight or during toss or dive maneuvers

The BSU-49/B and BSU-50/B AIR systems development programs were completed in the 1980-1981 time frame. The low-rate initial production (LRIP) effort of BSU-49/B and BSU-50/B units was completed in 1982. Full-scale production was started in 1983 on both systems. The BSU-85/B development program was started in 1982 and OPEVAL testing was completed in 1987. Navy approval for limited production (ALP) was obtained in February 1986 (Reference 14).

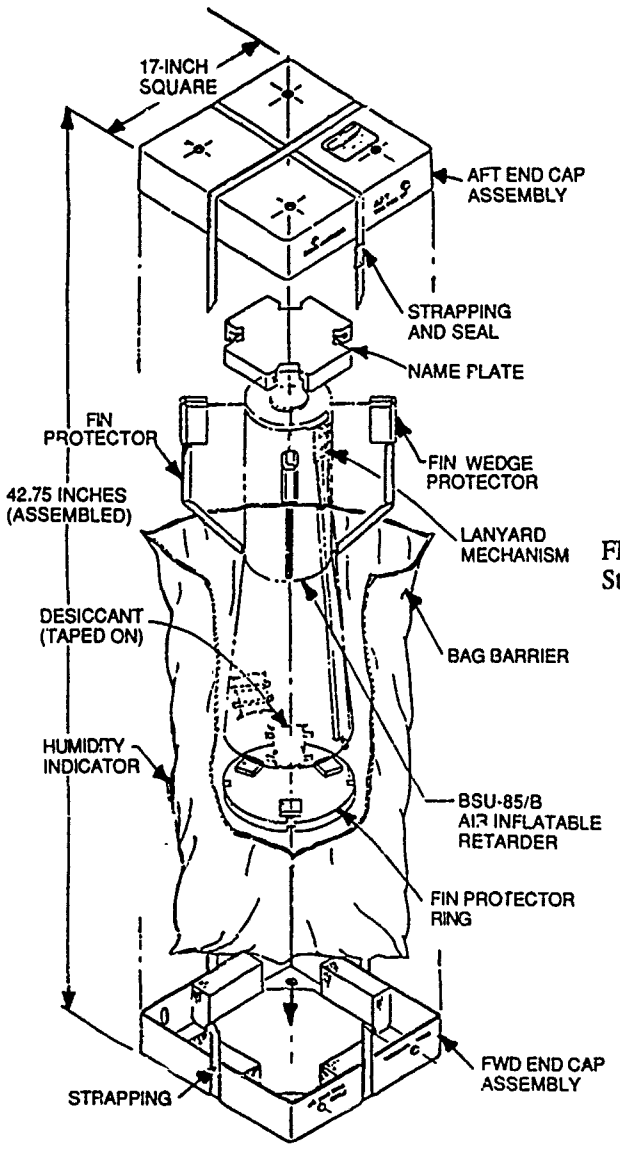


FIGURE 3-101. Fin Shipping and Storage Container, CNU-419/E.

A multi-year competitive contract for BSU-85/B AIR systems was awarded to Irvin Industries in March 1987. In order to continue to procure the BSU-85/B retarders under a multi-year contract, an additional ALP was granted on 7 May 1987 for FY 87 units after a delay in the ongoing OPEVAL testing precluded a programmed Milestone IIIB Approval for Full Production decision (Reference 15). The Test and Evaluation Master Plan (TEMP No. 279-1, Rev 1, 28 August 1987) was revised to reflect Commander, Operational Test and Evaluation Force (COMOPTEVFOR) planning requirements for BSU-85/B Fleet Operational Test and Evaluation (FOT&E) during the fourth quarter of FY 88 and the first quarter of FY 89. This will allow for extension of application/Fleet clearance on the A-6E/F, A-7E, AV-8B, A-4, P-3, and S-3 aircraft after FOT&E. The

FOT&E will verify correction of documentation, human factors, and interoperability OPEVAL issues. The interoperability issue is tied to the availability of fleet-releasable software on the A-6E/F, A-7E, and AV-8B, A-4, P-3, and S-3 aircraft. Lack of fleet-releasable software in all aircraft but the F/A-18 was a limitation in the scope of the OPEVAL. Operational testing of the other TEMP-specified aircraft, with fleet-releasable software, was and is planned for in the FOT&E phase.

EXPLOSIVE MATERIALS FOR U.S. NAVY AIRCRAFT BOMBS

FUNDAMENTALS OF EXPLOSIVES

Included in this section are the various concepts by which explosives are defined, described, and classified. The basic characteristics of explosives as to reactions, sensitivity, and hazards are described and classified.

Basic Concepts and Definitions

The basic definitions of an explosive and an explosion should be understood. These are as follows:

1. Explosive. An explosive is a material, either a pure single substance or a mixture of substances, which is capable of producing an explosion by its own energy.

2. Explosion. An explosion may be defined in a variety of ways. Since this report covers aircraft bombs and their explosive components, an explosion is defined herein as "a chemical decomposition or transformation, with the evolution of heat and the formation of decomposition products, some of which are gaseous." All explosives in military use will produce gas.

In order that ordnance may function at the time and place desired, it is necessary to employ different kinds of explosives, each of which has a specific role—either as a main charge or as a booster charge. Explosives suitable for one purpose may be entirely unsatisfactory for another. Thus, the explosive used to burst a forged steel projectile or bomb case would be unsuitable and highly dangerous if used for ejecting and propelling projectiles out of the weapon or propelling missiles. Similarly, the explosives used in initiators such as in primers and fuzes are so sensitive to shock that only small quantities can be used safely.

High and Low Explosive

Military explosives are divided into two general classes, high explosives and low explosives, according to their rates of decomposition.

High Explosives. The general characteristics and uses of high explosives, both compounds and mixtures, in modern service are summarized in this section. High explosives are usually nitration products of organic substances, such as toluene, phenol, pentaerythritol, amines, glycerin, and starch, and may be nitrogen-containing inorganic substances or mixtures of both. A high explosive may be a pure compound or a mixture of several compounds with additives such as powdered metals (aluminum), plasticizing oils, or waxes that impart desired stability and performance characteristics.

A high explosive is characterized by the extreme rapidity with which its decomposition occurs; this action is known as a detonation. When initiated by a blow or shock, or from the explosion of a suitable primary explosive, it will decompose almost instantaneously, either in a manner similar to an extremely rapid combustion or with rupture and rearrangement of the molecules themselves. In either case, gaseous and solid products of reaction are produced. The disruptive effect of the reaction makes some explosives valuable as a bursting charge, but precludes their use as a propellant for the reason that the gases formed would develop excessive pressures that might burst the barrel of the weapon.

High explosives do not function by burning; in fact, not all of them are combustible, but most of them can be ignited by a flame and in small amounts, generally burn tranquilly, and can be extinguished easily. If heated to a high temperature, by external heat or by their own combustion, they sometimes explode. They differ from primary explosives in not being exploded readily by heat or by shock, and generally in being more brisant and powerful. High explosives exert a mechanical effect upon whatever is near them when they explode, whether they are confined or not.

Low Explosives. Low explosives are mostly solid combustible materials that decompose rapidly but do not normally explode. This action is known as deflagration. Upon ignition and decomposition, low explosives develop large volumes of gases that produce enough pressure to propel a missile in a definite direction. The rate of burning is an important characteristic, which depends upon such factors as combustion gas pressure, grain size and form, and composition. Low explosives do not usually propagate a detonation. Under certain conditions, however, they react in the same manner as high explosives and they may detonate. The single-base, double-base, and composite propellants, as well as black powder mixtures are typical examples of low explosives.

CHARACTERISTICS OF EXPLOSIVE REACTIONS

The most important characteristics of explosive reactions are discussed below.

Velocity. An explosive reaction differs from ordinary combustion in the velocity of the reaction. The velocity of combustion of explosives may vary within rather wide limits, depending upon the kind of explosive substance and upon its physical state. The burning rate of colloidal cellulose nitrate powders used as propellants in modern guns is in the order of 24 centimeters per second at average gun pressures, whereas the velocity of reaction of high explosives range from about 2,000 to 8,500 meters per second.

Heat. An explosive reaction is always accompanied by the rapid liberation of heat. The amount of heat represents the energy of the explosive and hence its potentiality for doing work. It may be supposed that the quantity of heat given off by an explosive reaction is large, but this is not necessarily the case. A pound of coal, for example, yields five times as much heat as a pound of nitroglycerin. However, coal cannot be used as an explosive because it fails to liberate heat with sufficient rapidity.

Gases. The principal gaseous products of the more common explosives are carbon dioxide, carbon monoxide, water vapor, nitrogen, nitrogen oxides, hydrogen, methane, and hydrogen cyanide. Some of these gases are suffocating; some are actively poisonous. The gases from low explosives are rarely dangerous, since they usually escape at once into the open and are dissipated and diluted with air. Generally speaking, the commonly used high explosives produce a large proportion of noxious gases that are particularly dangerous, since under normal conditions of use these gases do not dissipate rapidly. Projectiles or bombs filled with high explosives often burst after penetration into confined spaces from which the gases are not easily evacuated. Some of the gaseous products of explosive reactions are themselves flammable, or form explosive compounds with air. Among these are hydrogen, carbon monoxide, and methane.

Pressure. The high pressure accompanying an explosive reaction is due to the formation of gases which are expanded by the heat liberated in the reaction. The work which the reaction is capable of performing depends upon the volume of the gases and the amount of heat liberated. The maximum pressure developed and the way in which the energy of the explosion is applied depend further upon the velocity of the reaction. When the reaction proceeds at a low velocity, the gases receive heat while being evolved, and the maximum pressure is attained comparatively late in the reaction.

If, in the explosion of another substance the same volume of gas is produced and the same amount of heat is liberated, but at a greater velocity, the maximum pressure will be reached sooner and will be quantitatively greater. However, disregarding heat losses, the work done will be equal. The rapidity with which an explosive develops its maximum

pressure and the ability of this pressure to shatter rather than displace most solid objects in its path is a measure of the quality known as brisance (from the French word "briser" to break or shatter). Simply stated, a brisant explosive is one in which the maximum pressure is attained so rapidly that the effect is to shatter material surrounding or in contact with it.

From a military viewpoint, brisance is of practical importance because it determines the effectiveness of an explosive in fragmenting shells, bombs, mines, etc., and in imparting high velocities to the resulting fragments. As the shattering effect is dependent upon the suddenness with which the gaseous products of an explosive are liberated, the velocity of detonation is at least a major factor in determining brisance. It has been found that there is a general linear relationship between velocity of detonation and brisance, and if the velocity is known it is possible to calculate the brisance or vice versa. Brisance may be calculated by Kast's formula B = f x d x D, where B is the brisance value, f is the "specific energy or force" also called "specific pressure" in kg/cm^2, d is the density of the explosive in g/cc, and D is the detonation velocity in m/sec. More recently, as noted in the Picatinny Arsenal Technical Report TR 2700, Vol. 4, *Encyclopedia of Explosives and Related Items*, dated 1969, C.G. Dunkle stated that the product of the available energy and detonation velocity can be taken as a measure of brisance. Since in comparison of different explosives with respect to brisance, the detonation velocity seems to have the greater weight of the two factors. Brisance has been characterized also by the product of the available energy and the square of the detonation velocity. This relates closely to the detonation pressure which can be expressed by the formula $P = \rho D^2/(\gamma + 1)$, where ρ = loading density, D = detonation velocity, and γ = the polytropic exponent of the detonation products.

Stability. The stability of an explosive is important in determining the length of time it can be kept under normal storage conditions without deterioration and its adaptability to various military uses. For example, an explosive used in underwater munitions should hold up against adverse hygroscopic conditions and remain effective though wet, as in a leaky mine case. A good, general-purpose explosive should withstand reasonable exposures to such extremes as high humidity in a hot climate or cold temperatures of arctic conditions and still retain its full, functional capability.

Ignition Temperatures. There is no one temperature of ignition or detonation in an explosive, for its behavior when heated depends on two factors—the manner of confinement and the rate of heating. It is usually possible, however, to find a small range of temperatures within which a given explosive will ignite or detonate. These so-called ignition temperatures, or explosion temperatures, are useful in setting limits near which it is certainly unsafe to heat an explosive. When an unconfined explosive is heated sufficiently, it will usually catch fire and burn, but detonation can occur either immediately or after an interval of burning. In general, the likelihood of detonation rises rapidly with increasing confinement due to the resultant rise of pressure.

Loading Properties. The adaptability of an explosive to loading requirements is an important factor in fixing its range of usefulness. When projectiles are press-loaded, it is necessary to fill them with a granular explosive. On the other hand, cast-loaded munitions, such as bombs, require an explosive having a relatively low melting point. Where a mixture of several explosives is used, it is necessary that one of them be liquid. Thus, such solid materials as aluminum and RDX can be carried in suspension in molten TNT and cast as a slurry at temperatures far below their own melting points.

Sensitivity of Explosives

The levels at which various types of explosives react to explode when exposed to heat, flame, shock, and friction, form an index of sensitivity which is important in two areas (1) explosive safety during handling and use, and (2) the amount of energy necessary to initiate an explosion.

Sensitivity is an important consideration in selecting an explosive for a particular purpose. For example, the explosive in an armor-piercing projectile or bomb must be relatively insensitive; otherwise the shock of impact would detonate it before it had penetrated to the point desired. Again, if the molecular groups in the explosive are in such unstable equilibrium that the reaction starts spontaneously, or in response to a slight blow, the substance can have no practical application whatever. It was originally considered that the power of an explosive was measured by its sensitivity and that the most powerful explosives were the most sensitive. Investigation has proved that this is not true. TNT is a good example of a very powerful explosive which under ordinary circumstances requires a severe shock to initiate explosion.

Initiation of Explosive Reactions

An explosive reaction is initiated by the application of energy. The preferred method of initiation depends on the characteristics of the individual explosive. The most commonly used methods of initiation are by heat, shock, or influences.

Heat. Low explosives are commonly initiated by the application of heat in some form. Some high explosives will react when sufficient heat is applied, especially if heat is applied suddenly throughout the mass. Initiation by percussion (direct blow) or by friction is simply initiation by heat derived from the energy of these actions.

Shock (detonation). In general, high explosives, such as the main charges of bombs, mines, and torpedoes require the sudden application of a strong shock to initiate the explosive reaction. This shock or detonation is usually obtained by exploding a smaller charge or booster of a more sensitive high explosive that is in contact with or in close

proximity to the main charge. The smaller charge can readily be exploded by heat or shock.

Influence. It has frequently been demonstrated that detonation of an explosive mass can be transmitted to other masses of high explosive in the vicinity without actual contact. It has been generally accepted that such transmission is caused by the passage of an explosive percussion wave from one mass to the other. The second explosion occurring under these conditions is said to be initiated by influence. The result is called a sympathetic explosion. The distance through which this action may take place varies with the kinds of explosive used, the intervening medium, and certain other conditions. The tremendous energy of the percussive wave in an underwater explosion is evidenced by the immediate upheaval of the surface of the water when the explosion occurs. The geyser-like eruption which occurs shortly afterwards is caused by the rise of the gases of the explosion to the surface.

Radio Frequency Hazards To Ordnance (HERO). Many naval explosive weapons are affected by the transmission of radio frequencies, such as the operation of radars, and other high frequency transmitting equipment under certain conditions. Therefore, shipboard personnel must know what weapons are HERO safe, and those that are not, prior to operating high-frequency transmitting equipment.

Classification of Explosives

Explosive substances may be classified by their reaction, composition, or service use.

Classification by Reaction. The terms high and low explosives, previously referred to, serve as a means of classifying explosives by their reaction. Explosive substances include a wide range of mixtures and of homogeneous chemical compounds. Some substances give rise to explosive reactions that are characterized by fairly rapid combustion and are known as burning. or low explosives. In these, oxygen is always present with one or more combustible elements. The oxygen is supplied in such form as to permit oxidation or combustion to proceed without support from outside sources. The reaction in these explosives is a true burning which proceeds from point to point throughout the explosive substance, accelerated by the heat and pressure produced.

Other substances give rise to explosive reactions characterized by molecular rearrangement which proceeds practically instantaneously. This molecular rearrangement may be combined with burning. Such substances are called high explosives. In these, oxygen is usually, but not always, present with combustible elements such as carbon and hydrogen. These elements are usually held in the system in weak bonding radicals, such as the nitrate or nitro groups. The chemical arrangement is generally one of unstable

equilibrium, and the initiating impulse brings about a breaking down of chemical bonds resulting in molecular rearrangement which occurs so rapidly that the evolution of heated gaseous products is practically simultaneous throughout the entire mass.

Classification by Composition. From the standpoint of their composition, explosives may be divided into explosive mixtures and explosive compounds.

1. Explosive mixtures are composed of distinct substances, carefully prepared and mechanically conglomerated in varying proportions. Explosive mixtures must have some oxygen supplier such as nitrate or chlorate, and some combustible such as carbon or sulphur. Black powder is a typical example of an explosive mixture.

2. Explosive compounds are homogeneous substances whose molecules contain within themselves the oxygen, carbon, and hydrogen necessary for combustion. Whereas the characteristics of explosive mixtures can be varied by changing the proportions of the components, the elements constituting an explosive compound are always present in the molecules in the same proportions. Therefore, the nature of the explosive compound cannot be changed by varying the quantities of the constituent elements. Explosive compounds of different characteristics can be obtained, however, by nitrating the basic substances to different degrees. Explosive compounds consist very largely of organic compounds (hydrocarbons) into which the nitrate or nitro groups are introduced by the process of nitration.

Classification by Service Use. Naval explosives may be classified according to the use to which they are put.

1. Propellants and impulse explosives. These explosives are used to propel projectiles from guns, to propel rockets and missiles, launch torpedoes, launch depth charges from projectors, and catapult aircraft. They are all burning or low explosives.

2. Disrupting or bursting explosives. Explosives of this classification are all employed to create damage to the target under attack. They are all of the high explosive type and are used alone or as part of the explosive charge in mines, bombs, depth charges, missile and torpedo warheads, and in projectiles as a burster charge.

3. Initiating explosives. The initiation of an explosive reaction requires the application of energy in some form. Propellants are commonly ignited by the application of flame, while disrupting explosives are set off by a severe shock. Fulminate of mercury, one of the most sensitive service explosives, is well adapted for use as an initiating explosive, because it produces both a flame and a shock when it is exploded. The device used to initiate the burning of a propellant explosive is called a primer. When fired, the primer produces the long, hot flame required to ignite the propellant. The device used to

initiate the reaction of a disrupting explosive is called a detonator. When fired, the detonator produces the shock necessary to initiate the explosive reaction.

4. Auxiliary explosives. Large propellant charges and relatively insensitive disrupting explosives require an intermediate charge, so that the flame or shock of the initiating explosive may be increased to ensure proper reaction of the main explosive charge. The intermediate or auxiliary explosive used with propellants is called an ignition charge and consists of a quantity of flame-producing material sufficient to engulf the propellant grains. The auxiliary explosive used with disrupting explosives used in bombs, mines, etc., is called a booster and consists of a quantity of high explosive more sensitive than the main charge. The booster increases the shock of the detonator to a degree sufficient to explode the main charge.

Hazardous Aspects of Explosive Substances. Explosive substances are dangerous in that they are in a state of readiness to change, by explosion or very rapid burning, into more stable substances. The stimulus necessary to initiate this change will vary depending upon the substance in question. The more common of these stimuli are heat, flame, friction, shock, or combinations of these. The degree of stimulation required also varies depending on the substance in question. Some, such as primary explosives, require very little stimulation before they will explode. Such substances are said to be "sensitive" explosives and are especially hazardous. Other substances, such as main or burster charge explosives, require a much greater stimulation before they will detonate. These substances are said to be relatively "stable" and are less hazardous than sensitive explosives. However, all explosive substances can be made to explode provided the proper stimulus is applied to the required degree. The effect of an explosion needs little amplification. Until the advent of the nuclear weapon, the chemical explosion represented the highest order of military destructive power. Military explosive devices are designed to explode and the stimuli necessary to cause such explosions are usually applied by simple acts which can occur in many ways and during many required operations. Special precautions must be observed, and special techniques in design and use are required in order to safely use military explosives.

What has been said for explosions above applies almost equally to the subject of fire. Many types of military explosives really function by a very rapid burning. Almost all explosives will burn and many very fiercely with the development of intense heat. Ammunition fires can incinerate exposed personnel in a matter of seconds. They can kill by asphyxiation, and in some cases by poisonous fumes, where closed spaces are involved.

Many explosives are poisonous if their vapors or dust are ingested thus making them an industrial hazard where they are manufactured, loaded, and stored. In addition, their smoke, in the case of fire, can also poison and can cause severe dermatitis.

Requirement for an Explosive

In considering the use of high explosives for destructive purposes, the first requirement is to deliver the largest amount of charge possible using the most effective explosive available. This will govern the selection of the burster or main charge. The second requirement is to cause detonation of the burster with maximum effect by an acceptable safe means. This will usually mean using the smallest possible amount of suitable primary explosives. In practice, it is usually found that maximum efficiency can often be achieved by using a very small primary charge to explode a secondary or intermediate charge, which builds up the initiating shock to where full detonation of the burster charge is obtained. Such an intermediate charge is known as a booster. The combined system of the primary charge and booster charge form an explosive train which together with the main charge (bursting charge) form the explosive system of the weapon. Explosive trains are frequently modified by the addition of one or more of the following elements:

1. Delay. A delay is an explosive train component that introduces a controlled time delay in the functioning of the train.

2. Relay. A relay is an element of a fuze explosive train that augments an outside and otherwise inadequate output of a prior explosive component, so as to reliably initiate a succeeding train component. Relays, in general, contain a small single explosive charge and are not usually employed to initiate high-explosive charges.

3. Lead. A lead is an explosive train component that consists of a column of high explosive, usually small in diameter, used to transmit detonation from one detonating component to a succeeding high-explosive component. It is generally used to transmit the detonation from a detonator to a booster charge.

Effects of Explosions

The explosive forces of military weapons used to effect damage are as follows:

1. The force of the expanding gases of an explosion creates a damaging shock wave through the surrounding medium, which may be air, earth, water, or a combination of these. This shock wave fragments and propels the material of its case, or special materials associated with it for that purpose, in all directions. The shock wave also creates secondary missiles by inducing movement of objects in the area through the effects of blast or shock.

2. The thermal effects generated by the explosion on the target or in the target area, which initiates burning.

As the effects of explosives vary somewhat in different mediums in which they are exploded, the explosive to be used depends on the medium in which it will exert its damage. In other words, it may be necessary to optimize the explosive effect in water, in air, or in the earth.

Explosive Efficiency

The efficiency of an explosive is expressed in terms of the total energy exerted, measured by crusher gauges or piezoelectric gauges, and the time within which it occurs. This is usually proportional to the velocity of detonation as measured by a Boulenge chronograph and Mettegang recorder. Brisance, the shattering power of explosives, is usually measured by exploding small charges in coarse sand and checking the amount of the sand which has been pulverized. An explosive of high brisance will usually be one having a high velocity of detonation, but not necessarily having great power. The most efficient explosives will show both good power and high brisance.

Safety and Stability

The requirements for safety in handling and use and the ability of explosives to withstand long periods of storage at reasonable levels of temperature and humidity have kept many otherwise excellent explosive compounds out of military service. Military explosives, in the form in which they are to be used, must meet these criteria and be producible in a form suitable for military use.

Availability and Cost

The raw material and the process for explosive preparation must be available for the production of the explosive in quantity if the explosive is to be of significant military use. It must be able to compete with other materials costwise or be of sufficiently superior characteristics to merit its procurement at a higher cost.

TYPES OF MILITARY EXPLOSIVES USED IN AIRCRAFT BOMBS

The Bureau of Ordnance recommended to the General Board of the Navy Department in 1935, that "the optimum aircraft bomb was a high-capacity type, with a charge-to-weight

ratio from 50 to 75%, for use against unarmored or unprotected targets. With a short delay fuze, it would produce very effective damage to the structure of any target which it hits, and effective damage to the underwater body of targets without torpedo protection in case of a hit alongside" (Reference 4). The Navy also stated that:

1. "The most important type of explosive bomb is the demolition bomb which, as its name indicates, is designed for the demolition of targets. The destructive effect produced by these bombs is the result of detonation of the high-explosive content. This detonation produces a vast amount of blast, the destructive effects of which increase with the amount of explosive in the bomb body. When the detonation takes place above ground, as a result of instantaneous fuze action, metal fragments from the body casing are scattered at high velocities for great distances. Experiments conducted indicate that fragments from the metal case carry destructive effects to much greater distance than blast. However, within a limiting radius blast is far more effective than fragments. Blast is thus considered more desirable than fragments for demolition effect and thin-case demolition bombs carrying the largest practicable percentage of high explosive have as a result been adopted. The blast effect naturally decreases as the distance from the target increases. A direct hit with even a small bomb is immeasurably superior to near hits with considerably larger bombs. The mining effect resulting from the detonation of the explosive below the surface of the earth, obtained through the use of delayed fuze action, is of great importance in demolition bombs to destroy the target directly or undermine its foundation. All bombs in the service at present are the so-called thin-walled type, containing approximately 50%, by weight, of explosive (see Reference 4).

2. "More serious damage can be done by the blast effect of high-explosive bombs than by their fragmentation. When a high explosive bomb is detonated, the charge is instantaneously converted into high-temperature gases which exert a tremendous pressure and burst the bomb body. Upon the release from confinement, the gaseous products of detonation expand suddenly and move outward in all directions at a high velocity, generating shock and pressure waves, and shattering or displacing surrounding material" (see Reference 7).

Since blast effectiveness was paramount in Navy-developed GP bombs, the explosive formulations selected for main charge fills had to have good blast characteristics—i.e., relatively high peak pressures and positive impulses on equal volumetric comparisons. As stated previously, the explosives had to have good "brisant" qualities and a reasonably high velocity of detonation, as well as high peak pressures and positive impulses (power).

In assessing or comparing characteristics of explosives, other factors are considered such as their sensitivity. The first of these is the "Laboratory Impact Sensitivity" in which the ratio of a given weight necessary to detonate the explosive being assessed to the drop height necessary to detonate TNT, expressed on a percentage basis. TNT is given as 100. The second sensitivity test is a scale of "Bullet Impact Sensitivity" with RDX rated as 0 and

TNT as 100. The following main charge explosives will be expressed in relation to TNT and RDX if the data is available. Since the velocity of detonation will vary directly with the density of the cast or pressed explosives, all other factors being constant, it will be given for a definite density. However, if various loading densities values (cast in air, under vacuum, and pressed) are provided, the corresponding detonation velocity will be expressed.

Minol

Minol, a binary explosive developed by the British during World War II, is a castable mixture of TNT, ammonium nitrate (AN) and powdered aluminum. There are three formulations—Minol 1, a 48/42/10 percent ratio; Minol 2, a 40/40/20 percent ratio; and Minol 3, a 42/38/20 percent ratio. Minol 2 is the more commonly used formulation. It can be prepared by adding the dry ingredients to molten TNT at 90°C under agitation. Minol can also be prepared by adding 25 parts of aluminum to 100 parts of 50/50 amatol previously prepared. It is comparable to TNT and Tritonal in sensitivity to initiation, but is more sensitive to shock and less brisant. Minol is unstable in the presence of moisture since the aluminum and ammonium nitrate react with each other. Minol 2 is used as either a main charge or bursting charge in bombs and depth charges, where TNT is in short supply. Its density range is 1.64 to 1.74 gm/cc. Its blast equivalency (relative to TNT) is: **in air**—peak pressure 115, impulse 116, energy 133; **in air confined**—impulse 90; **underwater**—peak pressure 108, impulse 126, energy 140; **underground**—peak pressure 134, impulse 139, energy 147. The velocity of detonation is 20,650 ft/sec at a density of 1.68, if all the ammonium nitrate reacts. The velocity is sensitive to the extent of AN reaction. The Minol bullet impact value is 52. Its laboratory impact value is approximately 67. Its color is gray.

Tritonal

Tritonal is a binary explosive developed and standardized by the United States during World War II. It is a castable mixture consisting of TNT and powdered aluminum. The addition of aluminum to increase the power of explosives was proposed by Escales in 1899 and patented by Roth in 1900 (German Patent 172,327). Tritonal is prepared by adding TNT and aluminum separately in a steam-jacketed melt kettle equipped with a stirrer. Heating of the kettle and mixing of the ingredients are continued until all of the TNT is melted. When the viscosity of the mixture is considered satisfactory (at 81°C), it is poured into bombs or projectiles the same as TNT. The composition of tritonal is 80% TNT and 20% aluminum. Its density range is 1.65 to 1.75 gm/cc. Its blast equivalency (relative to TNT) is: **in air**—peak pressure 110, impulse 115, energy 119; **in air confined**—impulse 130; **underwater**—peak pressure 105, impulse 118, energy 119; **underground**—peak pressure 117, impulse 127, energy 136.

"Studies, directed towards establishment of the optimum amount of aluminum in the TNT/aluminum system have shown that (1) the blast effect increases to a maximum when the aluminum content is 30% (Reference 16); (2) the brisance, as measured by the sand test, passes through a maximum at about 17% aluminum (Reference 17); (3) in fragmentation tests, no gain was observed; additions of aluminum caused a decrease in efficiency over the entire range from 0 to 70% aluminum (Reference 18); and (4) the rate of detonation of cast charges is continually decreased by additions of aluminum up to 40% (Reference 19). For all practical purposes, it was concluded that the addition of 18 to 20% aluminum to TNT improves its performance to a maximum. This conclusion was in agreement with that of the British who performed tests of TNT/aluminum mixtures (Reference 20).

The velocity of detonation of tritonal is 21,245 ft/sec (cast charges) and 21,980 ft/sec (pressed charges). Its bullet impact value is 40; the laboratory impact value is not available (NA) (Reference 21). Its color is gray.

Destex

Destex is a desensitized version of Tritonal, developed by the U.S. Air Force, in which the standardized 80% TNT and 20% aluminum formulation is changed to include the addition of D-2 wax, acetylene carbon black, and lecithin. The final composition is 74.4% TNT, 19.1% aluminum, 4.3% D-2 wax, 1.9% acetylene carbon black, and 0.084% lecithin. The Air Force was seeking a main charge explosive fill that had improved survivability when used in a penetrator type weapon as well as less sensitivity to bullet impact. The use of Destex in the Navy's Harpoon Warhead (WDU-18/B) was recommended by the Naval Air System Command (NAVAIR) in 1971 over the other candidate explosive H-6 (with an internal shock pad). The components of Destex are mixed in a heated kettle (about 92°C). After the TNT melts, a vacuum is applied while the mixture is stirred to a uniform melt. For the Harpoon warhead, the mixture is stirred, then poured directly into the warhead while still under vacuum. A proper liner material such as asphaltic hot melt per MIL-C-3301, between the warhead case and explosive, must be used or an explosion or detonation of Destex will probably occur in a fuel fire test. The velocity of detonation of Destex is 22,040 ft/sec at a density of 1.7 gm/cc. Its bullet and laboratory impact values are not available. It color is gray.

Octol

Octol is a castable binary explosive of 75% HMX and 25% TNT (Type I) or 70% HMX and 30% TNT (Type II). The preparation of Octol entails adding water wet HMX slowly to molten TNT in a steam-jacketed kettle at a temperature of 100°C. The

mixture is heated and stirred until all moisture is evaporated. The composition is cooled to a satisfactory pouring temperature and cast directly into ammunition components or prepared in the form of chips to be stored for later use. The densities of Type I and Type II are 1.81 and 1.80 gm/cc respectively. Its detonation velocity is 27,483 ft/sec at a density of 1.80. Octol's principal use is a high explosive fill for bombs, bomblets, and projectiles. Its laboratory impact value is not given and the bullet impact value is approximately 57. Its color is buff.

Plastic Bonded Explosive (PBX)

PBX is a heterogeneous mixture composed of an explosive filler held together with an organic polymer binder. It is pressable, castable, extrudable, and injection moldable. An explosive consisting of RDX coated with polystyrene, plasticized with dioctylphthalate was initially developed in 1952 for the Atomic Energy Commission by the Los Alamos Scientific Laboratory of the University of California (Contract W-7405-Eng. 36 with the U.S. Atomic Energy Commission, Report No. LA-1448). The specific formulation of 90/8.5/1.5 RDX/polystyrene/dioctylphthalate was subsequently standardized by Los Alamos. This explosive, originally designated as PBX, was redesignated PB-RDX.

There have been many other PBX formulations since 1952, all of which consist of RDX or HMX, a plastic material (plasticizer) to polymerize the mixture and make it more flexible, and other ingredients (which may include aluminum for blast enhancement). The flexibility factor is important since it allows the explosive material to absorb more shock energy before shearing of the crystalline structure occurs, thus provides a less sensitive explosive.

In the aftermath of the catastrophic accidents aboard carriers, which resulted in loss of life and extensive ship damage caused to a large extent, by exploding warheads, bombs, and rocket motors, a panel was established to review carrier operation safety. The panel presented its findings in October 1967 (Reference 22) with one of its major recommendations being the improvement of the cookoff characteristics of current and future weapons, i.e., be afforded fire survivability.

Initially efforts were made to improve in-service air-launched ordnance cook-off times by applying thermal protection. More recently, the Navy has established technical requirements for insensitive munitions (Reference 23). The Russell Report, Reference 22, stated that one of the major factors in the survivability of combat ships was the sensitivity of the ship's munitions and that improvements could be made by using less sensitive energetic materials or by increasing the protection provided to munitions. In accordance with Reference 23, "all U.S. Navy munition will be designed to minimize effects of unplanned stimuli (fuel fires, sympathetic detonation, etc.). They will incorporate

insensitive energetic materials which meet or improve upon published insensitivity standards." The goal for complete transition to insensitive munitions is 1995.

In pursuit of the goals outlined in the Navy's Operational Requirements (OR) for Insensitive High Explosives (IHE) (Reference 24), several aluminized PBXs were evaluated for use in aircraft bombs. The PBXs had about the same air blast, fragmentation, and underwater performance as H-6, the current fill for Navy bombs, and had demonstrated a potential for significantly reducing the sensitivity of munitions to fires and enemy attack (Reference 25).

Sufficient data were available in February 1982 to make recommendation concerning the use of an insensitive PBX as a fill for Navy bombs and to formally notify the Army's Single Manager for Conventional Ammunition (SMCA) at ARRCOM, Rock Island, of the Navy's intentions to load munitions with this type of insensitive explosive. It was not necessary at that time to know which PBX would be eventually selected, as long as the explosive had similar processing and properties/materials requirements. The Naval Sea Systems Command (NAVSEA) in February 1982, recommended that the Naval Air Systems Command officially commit itself to a program to qualify an insensitive aluminized, cast cured PBX for use in either the improved 1000-lb Moderately Hard Target Penetrator Bomb or an improved Mk 80 series bomb and officially apprise the SMCA of such a decision (Reference 25). Type qualification of PBXW-109(Q) redesignated PBXN-109 for the Navy's 1000-lb Mk 83 GP bomb, redesignated as the BLU-110/B bomb in October 1986 (Reference 26), was the first step taken to incorporate a less-sensitive PBX-type explosive material in a GP bomb system. Other PBX explosives are used in projectiles, missiles, bomblets, mines, torpedoes and special applications. The average composition of PBXN-109 is 64% ± 2% RDX, 20% ± 2% aluminum powder (spherical), and 16% ± 2% binder. Its density range is from 1.6 to 1.7 gm/cc. Its detonation velocity is 24,704 ft/sec at a density of 1.60. The laboratory and bullet impact values are not available. Its color is gray.

HMX

HMX (Cyclotetramethylene-Tetra-Nitramine) was discovered as an impurity by-product in the nitration of hexamethylene tetramine to form RDX. Its sensitivity is about the same as RDX, it is seldom used alone in military applications but is mixed with a compound such as TNT. In the Navy, HMX is used as an ingredient in plastic-bonded explosives. Mixtures which also use HMX in their formulation include the octols. The octols, which were developed by the United States, are formed by adding HMX to TNT. There are two formulations of octol currently being used (see p. 188).

TATB

TATB (1, 3, 5 - Triamino - 2, 4, 6 - Trinitrobenzene) was first prepared in 1888 by C. L. Jackson and J. F. Wing, who found the compound insoluble in alcohol, ether, chloroform, benzene, and glacial acetic acid; and soluble in nitrobenzene and aniline. The preparation of TATB as noted in Reference 21 consisted of saturating 200 milliliters of absolute alcohol with ammonia and then 12.5 gm (0.028 mol) of 1, 3, 5 - triamino - 2, 4, 6 - trinitrobenzene was added. The mixture was stoppered and allowed to stand at room temperature for 24 hours. Additional ammonia was bubbled into the mixture, which was then heated under reflex for 30 minutes, filtered hot and the insoluble product collected on a Buchner funnel. Its melting point is about 345°C. The product was washed with water, alcohol and dried. The 4.7 gm of material recovered was recrystallized from nitrobenzene. The disadvantage of the above method was that it could not be used for the preparation of large quantities of TATB. Since it did not seem feasible to develop a new method of preparation, an investigation was made of the amination reactions. An attempt was made to find a modification which would produce high yields of a pure product. The process that evolved from this study is summarized as follows: 1, 3, 5 - trichlorobenzene was nitrated " in one step" to 1, 3, 5 - trichloro - 2, 4, 6 - trinitrobenzene in an 85% yield. The crude nitration product was aminated in benzene with ammonia gas to TATB, in yields of at least 95%. The density range of TATB is from 1.29 to 1.93 gm/cc (crystal form). Its velocity of detonation is 24,600 ft/sec at a density of 1.8 (pressed at 50,000 psi) and 17,650 ft/sec at a density of 1.29. Its laboratory and bullet impact values are not available. Its color is yellow.

DATB

DATB (1, 3 - Diamino, - 2, 4, 6 - Trinitrobenzene), also called 2, 4, 6 - trinitro - 1, 3 - diamino-benzol or 2, 4, 6 - trinitro-phenylenediamine - (1, 3) was first obtained by Noelting and Collin in 1884, and also by Barr in 1888 and J. J. Blanksnia in 1902 by other processes. Later, DATB was prepared in two steps from commercially available starting materials. First M-nitroaniline was nitrated with H_2SO_4-HNO_3 acid mixture to tetranitroaniline. The crude tetranitroaniline was converted by methanolic ammonia to deaminotrinitro-benzene in a high degree of purity. A conversion of 100 parts of M-nitroaniline into 110 parts of DATB was obtained by this method, which could easily be carried out on a commercial scale (Reference 21). The melting point of DATB is 290°C. Is density range is from 1.65 gm/cc (pressed at 50,000 psi) to 1.83 gm/cc (crystal form). Its velocity of detonation is 24,600 ft/sec at a density of 1.65. Its laboratory and bullet impact values are not given. Its color is yellow.

TNT

TNT (Trinitrotoluol) is powerful, brisant, easy to load by casting since its melting point (Grade A) is 80.5°C, stable under all stowage conditions, insensitive enough to stand all normal handling, and even capable of standing bullet impact when cast. The Navy uses it as a booster in a pressed granular form in which it is more sensitive to detonator action.

The velocity of detonation is 22,300 ft/sec at a density of 1.55. Its laboratory impact value is 100. Its bullet impact value is 100. Its color is yellow to buff.

Tetryl

Tetryl (Trinitrophenylmethylnitramine), because of its combination of high power, brisance, and sensitivity, was the standard U.S. booster charge. It was used for main charge loads in small caliber projectiles, but proved too sensitive to withstand the setback in all but 20-mm. It was used as a base charge in compound detonators. This, in effect, made it a small booster in intimate contact with the initiating explosive. The melting point of Tetryl (130°C) is too high to allow it to be melted and cast. It is loaded by being mixed with small quantities of graphite or stearic acid which serve to lubricate it while it is being processed into pellets. Tetryl is quite safe to handle and is extremely stable in stowage. Exposed or loose Tetryl should not be handled because it may cause dermatitis.

The velocity of detonation of tetryl is 24,400 ft/sec at a density of 1.55. Its color is light yellow, but it is usually gray because of the graphite. It is more powerful than TNT. Its laboratory impact value is 45. It bullet impact value is 61.

Explosive D

Explosive D (Ammonium Picrate) was the standard main charge for armor-piercing bombs and projectiles and other Navy projectiles. While its power and brisance are slightly inferior to TNT, it is much more insensitive to shock and will stand impact on armor plate without being deflagrated. It has two other disadvantages: (1) its melting point is too high for it to be melted and cast, and it is therefore loaded by being pressed into cases by a hydraulic ram; and (2) it reacts with metals to form extremely sensitive compounds. This is counteracted by covering the interior of bombs or projectiles with acid-proof lacquer.

Its rate of detonation is 21,300 ft/sec at a density of 1.48. Its power and brisance are about 95% those of TNT. Its laboratory impact value is 99; its bullet impact value is over 100. Its color is yellow or yellow-orange.

RDX

RDX (Cyclonite Cyclotrimethylenetrinitramine) is one of the most powerful and brisant of the military high explosives, and it is considered much too sensitive to use alone. It is about half way between Tetryl and PETN in sensitivity. RDX is being used extensively in mixtures with other explosives and inerts which reduce its sensitivity to a safe range, while the mixtures have a very high brisance and power due to the RDX. It has excellent stowage qualities, but, because of its sensitivity, it is shipped immersed in water like an initiating explosive. The velocity of detonation is 28,000 ft/sec at a density of 1.70. RDX has a laboratory impact value of 34; its bullet impact value is 0. Its color is white.

PETN

PETN (Pentaerythritetetranitrate) resembles RDX in its characteristics. it is somewhat more sensitive, but almost equal in power and brisance. It is appreciably more sensitive to percussion and impact then Tetryl and is, therefore, not used alone as a booster, though it is being used as a base charge in some compound detonators in the way Tetryl is. The tendency of PETN to burn is much less than that of similar explosives. Its main use alone in the service is in primacord. When used alone, PETN is combined with a small quantity of wax to desensitize and lubricate it, and is loaded by pressing. It is important to know that PETN in primacord is very insensitive to flame, shock, and friction, and therefore must be detonated by a cap.

The velocity of detonation of PETN is 26,000 ft/sec. The velocity of detonation of primacord is 20,500 ft/sec. PETN has a laboratory impact value of 22; its bullet impact value, though not given, would be about equal to RDX (0). Its color is white.

Haleite

Haleite (EDNA, Ethylenedinitramine) was an explosive that was probably used in combination with other explosives. It was somewhat more powerful than TNT. Its sensitivity was about the same as Tetryl. Haleite melted at 180°C, but it was reported that it could detonate in the manner of an initiating explosive at that temperature or a little lower. If loaded alone, Haleite would be pressed.

Nitroguanidine

Nitroguanidine is the explosive incorporated in the Navy's new double-based propellant powder, SPCG. It is unusual in being a high explosive that is so cool in its

reaction that it explodes without flash. Nitroguanidine is comparable in strength to TNT, and its sensitivity is of the same order. Its rate of detonation is 24,400 ft/sec at a density of 1.50.

Amatol

Amatol a substitute for TNT, is a mixture of ammonium nitrate and TNT; the percentage of ammonium nitrate, depending upon the availability of TNT, has varied from 40 to 80%. Amatol's power and brisance decrease with the increasing percentages of nitrate, and its sensitivity decreases at the same time. However, Amatol is still a fairly good high explosive, even when the TNT is reduced to 20%. The 80/20 mix cannot be cast, since it is not fluid enough to pour even when TNT is molten, and it therefore must be loaded by extrusion. Amatol has a disadvantage in that it is very hygroscopic and therefore is usually protected by a sealing pour of pure TNT.

The velocity of detonation of Amatol 50/50 is 19,700 ft/sec at a density of 1.54. Its laboratory impact value is 93. Its bullet impact value is about 100. Its color is buff.

Composition B

Composition B is intended to be used as a more powerful replacement for TNT in the loading of some of the large size GP bombs and in fragmentation bombs. Composition B will be used where an explosive with more power and brisance is of tactical advantage, and there is no objection to a slight increase of sensitivity.

Composition B-1 is a mixture of 59% RDX, 40% TNT, and 1% wax. Composition B-2 is a mixture of 60% RDX, and 40% TNT. The TNT cuts down the sensitivity of the RDX to a safe range and lowers the melting point to 81°C, allowing the material to be cast-loaded.

Composition B might be detonated (low order) by bullet impact, but it is almost as insensitive as TNT in this respect. It has an extremely high shaped-charge efficiency. Its velocity of detonation is 24,500 ft/sec at a density of 1.60. Its total energy of blast in air is about 116% of that of TNT. Composition B has a laboratory impact value of 79, and a bullet impact value of 79. Its color is yellow to brown.

Torpex

Torpex was one of the explosives developed during World War II to be used mainly in underwater ordnance. The original Torpex formulation (Torpex 1) was a mixture of

45% RDX, 37% TNT, and 18% aluminum powder (1% wax added). Torpex 2 was a mixture of 42% RDX, 40% TNT, and 18% aluminum powder (1% wax added). It is used in mines, torpedo war heads, and depth bombs. Torpex is more sensitive than TNT; its bullet impact and drop test sensitivities are of the same order as those of Tetryl. It was quite stable in stowage, though it produces gas, causing pressure in the case. Torpex is insensitive enough to stand all normal handling. Its melting point was low enough for it to be cast-loaded. Its velocity of detonation is 24,000 ft/sec at a density of 1.72. Torpex is 141% as powerful as TNT. Its laboratory impact value is 53; its bullet impact value is 48. Its color is slate gray.

DBX

DBX (Depth Bomb Explosive) was another aluminized RDX mixture, and its name suggested its intended use. DBX is 21% RDX, 21% aluminum nitrate, 40% TNT, and 18% aluminum. It was designed to replace Torpex, which it closely resembled in sensitivity, strength, brisance, and energy of shock in water, but half of the strategic RDX material in Torpex was replaced by ammonium nitrate in DBX. It was not used much, as the supply of RDX was adequate to meet the demand. DBX could be cast, though its melting range of 98-105°C was about the upper limit. This explosive is no longer in use.

HBX

HBX was a mixture designed to replace Torpex in depth bombs. It was loaded in the Flat Nose Bomb AN-Mk 54 Mod 1. HBX is 40% RDX, 38% TNT, 17% aluminum powder, and 5% desensitizer. Tests indicated that it was about 98 to 100% as powerful as Torpex, that it was definitely less sensitive than Torpex in both laboratory and bullet impact, that it was slightly more sensitive in these respects than TNT, and that it would be about the same order as Composition B.

A difficulty with Torpex and HBX was that they produce gas and build up pressure in the case during stowage. It had been discovered that 0.5% by weight of calcium chloride added to the mixture would absorb all the moisture and eliminate the production of gas. HBX explosive formulation is no longer in use.

A later modification of the basic HBX formulation, to increase its air blast capabilities, was designated HBX-6 or more commonly called H-6 (p. 146). H-6 is currently the standard main charge in the Navy's Mk 80 Series GP Bombs

Composition A

Composition A is a mixture of 91% RDX and 9% plasticizing oil. The oil content is sufficient to desensitize the mixture and lubricate it enough to allow it to be pressed into antiaircraft shells, which will probably be its principal use. Composition A is less sensitive than TNT in both drop and bullet impact tests. It is appreciably more brisant and powerful, as is indicated by its velocity of detonation of 27,000 ft/sec at a density of 1.62. Composition A has a laboratory impact value of 105. Its bullet impact value is over 100. Its color may be white or buff, depending upon the color of the oil.

Tetrytol

Tetrytol was a mixture of Tetryl and TNT (70/30 was a frequent ratio). It was designed to obtain a Tetryl booster that may be cast. This mixture was slightly less powerful and less sensitive than Tetryl. Its particular use was in burster tubes for chemical bombs, in demolition blocks, and in cast shaped charges. Tetrytol could not be used where the loaded item was immersed in hot explosive, as are the auxiliary boosters in the loading of Army bombs, because the tetrytol will be remelted by the heat and separation will result. It was approved for use in all other boosters. This explosive no longer in use.

Pentolite

Pentolite is a mixture of TNT and PETN, usually 50/50. Its chief uses have been in small shell loading, in grenades, and in cast shaped charges. Pentolite has a very high shaped-charge efficiency. It is not as stable as TNT in stowage, and separation of PETN may occur. Efforts should be made to keep it cool. The sensitivity of Pentolite is such that it cannot be drilled, and the fuze cavities in shells that must be drilled are poured with 90/10. Pentolite is about the same sensitivity as Tetryl in drop tests, and more sensitive than Torpex to bullet impact. Its brisance and power are equivalent to Composition B. At a density of 1.65, its rate of detonation is 24,000 ft/sec. Pentolite has a laboratory impact value of 47, and a bullet impact value of 48.

Ednatol

Ednatol was a mixture of 57% EDNA and 43% TNT, designed to ease the shortage of RDX. It was intended that Ednatol would be used as a substitute for Composition B in large GP bombs and fragmentation bombs. Ednatol was somewhat more powerful than TNT and comparable in sensitivity. Ednatol becomes soft enough to pour at 80°C and, therefore, could be cast. It was entirely stable in stowage.

PTX-1

PTX-1 was a ternary explosive intended for loading in shells, bombs, grenades, mines, demolition blocks, and shaped charges. It was a mixture of 30% RDX, 50% Tetryl, and 20% TNT. This mixture resulted in an explosive equal to Composition B and Pentolite, and superior to Tetrytol and Ednatol. PTX-1 was less sensitive than Tetrytol and more stable.

PTX-2

PTX-2 was another ternary explosive mixture. It consisted of 43.2% RDX, 28% PETN, and 28.8% TNT. It was slightly more sensitive in drop and bullet impact tests than Composition B, but a little less sensitive than Pentolite. PTX-2 was more brisant than any of the binary mixtures now used, which would include Composition B, and was about 10% more effective than Tetryl as a booster. It was intended to be used as a booster, as a main charge for fragmentation ammunition, and as an explosive for shaped charges. The melting point of PTX-2 was such that it could be cast.

Composition C

Composition C-4 is the only one of the Composition C series now in production, though small quantities of C-3 still may be found in the field. C-4 contains 91% RDX and 9% nonexplosive plasticizer. The plasticizer contains 2.1% polyisobutylene, 1.6% motor oil, and 5.3% di(2-ethylhexyl)sebacate. C-3 contains 77% RDX, 3% Tetryl, 4% TNT, 1% nitrocellulose, 5% MNT (Mononitrotoluol), and 10% DNT (Dinitrotoluol). The last two, while they are explosives, are oily liquids and plasticize the mixture. The essential difference between Composition C-3 and Composition C-2 is the substitution of 3% Tetryl for 3% RDX, which improves the plastic qualities. Composition C-1 was 88.3% RDX and 11.7% plasticizing oil. The changes were made in order to obtain a plastic composition that would meet the requirements of an ideal explosive for demolition applications, maintain its plasticity over a wide range of temperatures, and not exude at 77°C.

Composition C-4 is about 1.15 times as powerful as TNT. Its velocity of detonation is 26,377 ft/sec at a density of 1.59. Its laboratory impact value is approximately 98. Its bullet impact value is over 100. Its color is light brown.

PEP-3

PEP-3 (a plastic explosive) was a mixture of 86% PETN and 14% plasticizing oil. PEP-3 was about 90% as powerful and brisant as Composition C, but its stowage stability and plastic range were much better. Its sensitivity was about the same as Composition C, though it had less tendency to burn. This explosive is no longer in use.

Picratol

Picratol is a mixture of 52% Explosive D and 48% TNT. Picratol's stability is about equal to that of Explosive D and TNT. It has a rate of detonation of 22,875 ft/sec at a normal loading density of 1.625. Brisance tests, peak pressure tests, and impulse tests indicate that Picratol's destructive force is somewhat less than that of TNT, but greater than that of Explosive D.

Cyclotol

Cyclotol is a generic name for RDX and TNT mixtures. Cyclotols such as the 60% RDX and 40% TNT mixture, designated as Composition B, were developed as replacements for Pentolite. Cyclotols do not have Pentolite's resistance to flame, however are considerably less sensitive.

Composition CH-6

The development of the RDX Composition CH-6 was reported in the NAVORD Report [illegible] 6880, dated 15 June 1960, by L. D. Hampton, Naval Ordnance Laboratory (now the Naval Surface Weapons Center), White Oak, Md. (Reference 27). The manufacturing process is as follows: dissolve polyisobutylene in 35 parts of toluene; $CaCl_2$ in water. A water slurry of RDX (10 parts of water by weight) is heated to 348°K and the polyisobutylene/toluene solution is added. A mixture of graphite and sodium stearate (previously mixed with 13 parts by weight of water) is added to the RDX slurry. The $CaCl_2$ solution is added to the mix to precipitate calcium stearate onto the RDX. Toulene is distilled off and the slurry is cooled to 323°K. The mixture is filtered, washed with water and dried at 343°K. CH-6 is frequently press-loaded into a booster holder. The basic composition of CH-6 is 97.5% RDX, 1.5% calcium stearate, 0.5% graphite, and 0.5% polyisobutylene. It is currently used in boosters and leads. It can be cast in air, under vacuum, and pressed (4000 to 64,000 psi) with resultant densities ranging from 1.45 to 1.72 gm/cc. The velocity of detonation range is 24,490 to 28,050 ft/sec at these respective densities.

PRIMARY EXPLOSIVES—DETONATORS, PRIMERS, AND IGNITERS

Primary explosives are sometimes referred to as "initiating explosives." Under normal conditions, they will not burn, but will detonate if ignited. Their strength and brisance are inferior, but are sufficient to detonate high explosives. Because of their sensitivity, primary explosives are used in munitions for initiating and intensifying high-order explosions. Mercury fulminate, lead azide, lead styphnate, and diazodinitrophenol are examples of such explosives.

Detonators. A detonator is an explosive train component that can be activated by either a nonexplosive impulse or by the action of a primer and is capable of reliably initiating high-order detonation in a subsequent high-explosive component of the train. When activated by a nonexplosive impulse, a detonator performs the function of a primer. In general, detonators are classified in accordance with the method of initiation such as percussion, stab, electric, friction, flash, or chemical.

Primers. A primer is a relatively small and sensitive initial explosive train component which, on being actuated, initiates functioning of the explosive train and will reliably initiate high explosive charges. In general, primers are classified in accordance with the method of initiation such as percussion, stab, electric, friction, or chemical.

Igniters. These are ignition elements which vary somewhat in their characteristics according to their designated functions as follows:

1. A device containing a readily burning composition, such as black powder, used to amplify the initiation of a primer in the functioning of a fuze.

2. A device containing a spontaneously combustible material, such as white phosphorus used to ignite the fillers of incendiary bombs and flamethrower fuels at the time of dispersion or rupture of the bomb casing.

3. A device used to initiate burning of the fuel mixture in a rocket combustion chamber.

Hazards of Primary Explosives and Initiating Devices

Primary explosives and the basic devices in which the explosives are used are very sensitive to shock, heat, flame or spark, and friction. The degree of sensitivity to these influences will vary somewhat depending on the primary explosive involved; however, these explosives all exhibit sufficient sensitivity to such influences to be considered very sensitive. In addition, lead azide and mercury fulminate will both react to certain different metals and alloys to form compounds more sensitive than the original explosive. Electric

detonators, primers, and igniters are subject to actuation by electromagnetic radiation and firing by the discharge of static electrical charges. Initiating devices are those ammunition elements by which ammunition is caused to function. Therein lies not only their value but also their basic hazardous characteristics.

Characteristics of Initiating Explosives

The general characteristics of the basic initiating explosives as used in the naval service are as follows:

Lead Styphnate. There are two forms of lead styphnate—that which appears as six-sided monohydrate crystals and that which appears as small rectangular crystals. Its color varies from yellow to brown. Lead styphnate is particularly sensitive to fire and the discharge of static electricity and, when dry, can be readily detonated by static discharges from the human body. The longer and narrower the crystals, the more susceptible the material is to static electricity. Lead styphnate does not react with metals and it is less sensitive to shock and friction than mercury fulminate or lead azide. Lead styphnate is only slightly soluble in water and methyl alcohol and may be neutralized by a solution of sodium carbonate. Its density is 3.02 gm/cc (crystal). Its velocity of detonation is 17,060 ft/sec at a density of 2.9. Its laboratory impact value is approximately 8.

Lead Azide. Lead azide may be used where a detonation is caused from flame, but mercury fulminate is generally preferred where the cap is to be set off by a firing pin. Lead azide is a crystalline, cream-colored compound which is practically insoluble in water. When lead azide is stored in water, however, care must be taken to assure that the water is free of bacteria-forming impurities which may react with the dextrinated lead azide to form a gas. Rooms in which lead azide is handled shall be washed thoroughly and regularly with a desensitizing solution. Lead azide shall not be exposed to copper, zinc, or alloys containing such metals because of the possible formation of other azides which are more sensitive than the original lead azide. Its density (crystal) is 4.80 gm/cc and dextrinated is 4.38 gm/cc. Its velocity of detonation is 17,000 ft/sec at a density of 4. The laboratory impact value of lead azide is approximately 8, similar to mercury fulminate. Lead azide does have a distinct advantage over mercury fulminate in being completely stable in stowage at elevated temperatures. Its color is white.

Mercury Fulminate. Mercury fulminate is an initiating explosive that may be used as either a primer or a detonator. Mercury fulminate is white when pure, but ordinarily has a faint brownish yellow or grayish tint. It is a heavy, practically nonhygroscopic, crystalline solid. When dry, mercury fulminate is very sensitive and may be detonated by flame, friction, or percussion, and in turn detonate a booster; or it may be mixed with other materials to form a primer composition and used to ignite a propellent charge. The same precautions given for lead azide and lead styphnate shall be used as guides in handling

mercury fulminate. Mercury fulminate either wet or dry shall not be permitted to come into contact with certain materials such as aluminum, magnesium, zinc, brass, or bronze. Its melting point is much too high for it to be cast, and it is loaded by being pressed into caps. Mercury fulminate has one disadvantage for military use because it will decompose in stowage at tropical temperatures; at the end of about three years, it may be rendered useless. Compared to high explosives, mercury fulminate has lower power and brisance, a fact which is indicated by its velocity of detonation of 16,500 ft/sec at a density of 4.0. Its laboratory impact value is 8.

DDNP (Diazodinitrophenol). Diazodinitrophenol is a yellowish brown powder which is soluble in acetic acid, acetone, strong hydrochloric acid, and most of the solvents, but insoluble in water. A solution of cold sodium hydroxide may be used to destroy it. DDNP is desensitized by immersion in water and does not react with water at normal temperature. Its melting point is 157°C. This is an initiating explosive which has been used for some time in commercial detonating caps and is now being used to some extent in military types. DDNP is more insensitive to shock than mercury fulminate and lead azide, though it may be detonated by a sharp blow. It will, therefore, probably be used only where it will be set off electrically or by miner's safety fuze. DDNP has an advantage in being more powerful than other initiating explosives and being comparable in strength to Tetryl. If unconfined, flame will cause DDNP to flash but will not detonate it. This characteristic, combined with insensitivity to shock, makes DDNP much more safe to handle. Its density (crystal) is 1.63 gm/cc. Its apparent density is 0.27 gm/cc and when pressed (at 3000 psi) is 1.14 gm/cc. The velocity of detonation of DDNP is 14,435 ft/sec at a density of 0.9 and 22,637 ft/sec at a density of 1.6. The laboratory impact value is approximately 16.

INSENSITIVE MUNITIONS REQUIREMENTS

New main charge explosives are being evaluated as possible replacements for current H-6 (Navy) and Tritonal (Air Force) bomb fills to meet Insensitive Munitions requirements as stated in NAVSEAINST 8010.5 "Technical Requirements for Insensitive Munitions," dated 22 May 1985 (Reference 23). These requirements are as follows:

1. All U.S. Navy munitions will incorporate insensitive energetic materials which meet or improve upon published insensitivity standards. The goal for complete transition to insensitive munitions is 1995.

2. Where technology is not available to comply with the insensitive munitions policy through the use of insensitive energetic materials, methods of protecting the munition and ways to mitigate damage to ships and aircraft shall be identified for implementation.

3. Fleet readiness and operational capability will be maintained in all elements of the insensitive munitions program.

Every effort will be made to define realistic threats to naval ships and to design munitions to meet operational requirements with the most practical and least sensitive energetic material available.

A series of new, main-charge insensitive high-explosive compositions have been formulated and are now being or have been evaluated for bomb fills, namely:

1. **Air Force**

   a. TNTO—TNT/NTO/aluminum/wax
   b. AFX-400 Series—the composition of these explosives is basicaily ethylene diamine dinitrate and phase stabilized ammonium nitrate (with KNO_3) which is known as EAK. Other additives include aluminum and RDX.
   c. AFX-900 Series—Nitroguanidine (NQ)/RDX/aluminum/wax
   d. AFX-1100 Series—TNT/aluminum/wax (63/20/17% weight)
   e. Undesignated—NQ/TNT/aluminum/wax (50/30/10/10% weight)
   f. Undesignated—NQ/TNT/aluminum/RDX/wax (50/30/10/5/5% weight)

2. **Air Force and Navy**

   a. Undesignated—NQ/TNT/aluminum/wax (45/25/20/10% weight)

3. **Navy**

   a. ADNBF (NWC)—7 Amino-4, 6-dinitro-benzo-furoxan (ADNBF)/ aluminum
   b. NTO (NSWC/W.O.)—nitro-trioxazalone (NTO)

Also, new, less sensitive, booster explosive compositions have been formulated, and are now being or have been tested and qualified for bomb fuze applications. These new booster explosive formulations are

1. **Navy**

   a. PBXN-202 (PBXC-13) (NWC)—RDX/EVA
   b. PBXW-7 (NSWC/W.O.)—TATB/RDX/VITON (binder)
   c. PBX C-18 (NWC)—ADNBF/EVA (binder)
   d. PBXC-17 (NWC)—HMX/EVA
   e. Not designated (NWC)—TATB/HMX/EVA

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