AMC PAMPHLET

AMCP 706-244

THIS IS A REPRINT WITHOUT CHANGE OF ORDP 20-244

RESEARCH AND DEVELOPMENT OF MATERIEL

ENGINEERING DESIGN HANDBOOK

AMMUNITION SERIES

SECTION 1, ARTILLERY AMMUNITION—GENERAL

WITH TABLE OF CONTENTS, GLOSSARY AND INDEX FOR SERIES

HEADQUARTERS, U. S. ARMY MATERIEL COMMAND SEPTEMBER 1963

HEADQUARTERS
UNITED STATES ARMY MATERIEL COMMAND
WASHINGTON 25, D.C.

30 September 1963

AMCP 706-244, Section 1, Artillery Ammunition--General, forming part of the Ammunition Series of the Army Materiel Command Engineering Design Handbook, is published for the information and guidance of all concerned.

(AMCRD)

FOR THE COMMANDER:

SELWYN D. SMITH, JR.
Major General, USA
Chief of Staff

OFFICIAL:

R. O. DAVIDSON
Colonel, GS
Chief, Administrative Office

DISTRIBUTION: Special

FOREWORD

The ARTILLERY AMMUNITION SERIES is being issued as an interim publication of the Ordnance Engineering Design Handbook, a comprehensive sequence of publications planned to treat the entire field of Ordnance design. When the Handbook was begun it was found to be impractical to integrate into it the series relating to Artillery Ammunition already in preparation under the direction of Picatinny Arsenal. Although they were similar, the objectives of the two projects were not identical. The subject breakdown adopted for the Handbook would have necessitated redistribution of the material of this series throughout several of the planned volumes of the Handbook, with consequent delay in publication of much of the material. It was therefore decided to issue this material intact as an interim publication to make it available as early as possible. The material appearing in this series will be gradually superseded as pertinent volumes of the Ordnance Engineering Design Handbook become available.

Material for this series was prepared by the Technical Writing Service of the McGraw-Hill Book Company, under Contract DAI-28-017-501-ORD-(P)-912. Technical supervision and much of the basic information were furnished by Picatinny Arsenal. Engineers from other Ordnance Design Centers also supplied much information, and aided in the review. In fact, so many persons have given time and energy to this project that it has been difficult to compile a complete list of acknowledgements.

The following were responsible for the conception and direction of the project.

ARTILLERY AMMUNITION SECTION, ARTILLERY AMMUNITION AND PACKING DEVELOPMENT LABORATORY, SAMUEL FELTMAN AMMUNITION LABORATORIES, PICATINNY ARSENAL

Alfred F. Teitscheid	Chief, Artillery Ammunition Branch
Wilder R. Carson	Chief, Artillery Ammunition Branch
Roy H. Wood	Chief, Artillery Ammunition Laboratory A

MAJOR CONTRIBUTORS

George Demitrack	Picatinny Arsenal	Interior Ballistics, Propellants
Lars Enequist	Ballistics Research Laboratory	Lethality Criteria
Henry P. Hitchcock	Ballistics Research Laboratory	Exterior Ballistics
Dr. Robert H. Kent	Ballistics Research Laboratory	Exterior Ballistics
Charles Lenchitz	Picatinny Arsenal	Thermodynamics of Explosive Materials
Prof. Arthur F. MacConochie	Prof. of Mechanical Engineering, University of Virginia	Manufacturing Methods
Arnold O. Pallingston	Picatinny Arsenal	Physical Testing of Explosive Materials
Richard E. Todd	Picatinny Arsenal	Quality Control
Col. Herman U. Wagner, USA (Retired)		General Contributor and Consultant
Murray Weinstein	Picatinny Arsenal	Physical Testing of Explosive Materials
Dr. Lewis Zernow	Ballistics Research Laboratory	Shaped Charge Theory, Blast
Col. Herman H. Zornig, USA (Retired)		Ordnance Specialist and Consultant

GENERAL ASSISTANCE

Kenneth H. Abbott	Watertown Arsenal	Kinetic Energy Ammunition
Theodor Advokat	Picatinny Arsenal	Special Purpose Shell
Norman E. Beach	Picatinny Arsenal	Chemical Testing of Explosive Materials
Donald R. Beeman	Picatinny Arsenal	Head Ammunition Design Branch

GENERAL ASSISTANCE (cont)

Willard R. Benson	Picatinny Arsenal	Lethality Theory
Warren Blittersdorf	Frankford Arsenal	Cartridge Case Design, Manufacturing Methods
Joseph I. Bluhm	Watertown Arsenal	Rotating Bands
William Byrne	Frankford Arsenal	Cartridge Case
John E. Capell	Picatinny Arsenal	Ammunition Design Standards
Herbert N. Cohen	Picatinny Arsenal	Pyrotechnics
Corwin S. Davis	Picatinny Arsenal	Chief Propellant Section
Abraham L. Dorfman	Picatinny Arsenal	Pyrotechnics
Cyrus G. Dunkle	Picatinny Arsenal	Shaped Charge Ammunition
Leonard H. Eriksen	Picatinny Arsenal	Explosives Chemistry Laboratory
Harold N. Euker	Frankford Arsenal	AP Shell
Patrick Falivene	Picatinny Arsenal	Propellant Ignition
Arthur P. Field	Picatinny Arsenal	Inspection
Al Fox	Frankford Arsenal	Manufacturing Methods
Leo J. Frey, Jr.	Picatinny Arsenal	Special Purpose Shell
Robert Frye	Picatinny Arsenal	Head Chemical Branch
Andrew J. Galko	Picatinny Arsenal	GB Shell
Thomas Hall	Picatinny Arsenal	HEP Shell
Dr. David Hart	Picatinny Arsenal	Head Pyrotechnics Laboratory
Floyd Hill	Ballistics Research Laboratory	Tank Vulnerability
Sidney Jacobson	Picatinny Arsenal	Kinetic Energy Ammunition

GENERAL ASSISTANCE (cont)

William Josephs	Picatinny Arsenal	Propellants
Kurt Kupferman	Picatinny Arsenal	Shaped Charge Ammunition
Robert G. Leonardi	Picatinny Arsenal	Primer Ignition
William L. Lukens		Formerly in charge of Ammunition Design Branch, Picatinny Arsenal
Ulysses S. MacDonald	Picatinny Arsenal	Inspection
James R. McKay	Picatinny Arsenal	Special Purpose Shell
Harold Markus	Frankford Arsenal	AP Shell
Anthony Muzicka	Watervliet Arsenal	Rifling and Gun Chambers
Jacob H. Niper	Picatinny Arsenal	Inspection
Karl G. Ottoson	Picatinny Arsenal	Asst. Chief, Chemical Test Section
Lawrence W. Pell	Picatinny Arsenal	High Explosives
Ballard E. Quass	Picatinny Arsenal	Special Purpose Shell
Lt. Richard Rhiel	D & P S Aberdeen Proving Grounds	Plate Penetration Monograms
Dr. William H. Rinkenbach		Formerly in charge of Picatinny Arsenal
Gilbert E. Rogers	Picatinny Arsenal	General Artillery Ammunition Design
Max Rosenberg	Picatinny Arsenal	Ammunition Design
William M. Rowe	Picatinny Arsenal	HEP Shell
Samuel Sage	Picatinny Arsenal	Chief, High Explosives Section
Marvin B. Schaffer	Picatinny Arsenal	Canister Shell
Arthur B. Schilling	Picatinny Arsenal	Foreign Ammunition

GENERAL ASSISTANCE (cont)

Robert M. Schwartz	Picatinny Arsenal	General Ammunition Design
William F. Shirk	Picatinny Arsenal	Canister Shell
Morgan Smith	Ballistics Research Laboratory	Aircraft Vulnerability
Joseph V. Sperazza	Ballistics Research Laboratory	Blast Theory
Joseph Sterne	Ballistics Research Laboratory	Lethality, Fragmentation
Theodore W. Stevens	Picatinny Arsenal	High Explosives
Noah A. Tolch	Ballistics Research Laboratory	Lethality, Fragmentation
Paul B. Tweed	Picatinny Arsenal	High Explosives
Robert J. Vogel	Picatinny Arsenal	Assistant, Research and Development Section
Leo Volkheimer	Picatinny Arsenal	WP Shell
Stanley Wachtell		Chief, Physical Test Section
Garry Weingarten	Picatinny Arsenal	Head, Chemical Research Section Pyrotechnics Laboratory
Edward Wurzell	Picatinny Arsenal	Interior Ballistics

PREFACE

This series is a compilation of available data on the design of artillery ammunition. It is intended to introduce the graduate engineer to the art of ammunition design and to serve as a ready reference for the practicing artillery ammunition designer.

Information contained in these publications has been obtained from development reports and drawings of ammunition items, from proof firing records, and from research reports by United States and British government agencies. The information obtained from these sources was corroborated and supplemented by means of direct interviews and correspondence with personnel of U. S. government and private research and design agencies.

This series consists of six sections. Section 1 is an introduction to the general subject of ammunition and its design. It is primarily intended to familiarize newcomers to the field with the nomenclature and classification of ammunition items. For convenience in publication, the features applying to the entire series, such as Table of Contents, Glossary and Index, have been bound with Section 1.

Section 2 is concerned with terminal ballistics, or the production of effect by the various types of ammunition. Section 3 deals with the control of flight, and exterior ballistic design of both fin-stabilized and spin-stabilized rounds.

Section 4, on design for projection of ammunition, includes the design of propellants for desired interior ballistic characteristics, stress analysis, and the design of cartridge case, gun chamber, and rifling and rotating bands.

Section 5 describes the inspection aspects of artillery ammunition design. It is included to acquaint the designer with dimensioning practices and the nature of the limitations placed on design by the requirements of gaging and quality control.

Section 6, on manufacturing methods, has been included to give the neophyte designer some insight into the overall problem of the manu-

facture of metal parts of ammunition items, since methods of manufacture impose limitations upon the design of such items.

Much effort has been spent in locating and verifying this data. However, in spite of this, it is probable that valuable sources have been overlooked and that a certain percentage of the information is already obsolescent because of the rapid advances being made in the field. It is hoped that the users of the Artillery Ammunition Series will inform the Office of Ordnance Research, Box CM, Duke Station, Durham, North Carolina, of any omissions or errors that they may notice.

table of contents

GLOSSARY

A

ABSOLUTE DEVIATION: The shortest distance between the center of the target and the point where a projectile hits or bursts.

ABSOLUTE ERROR: Shortest distance between the center of impact or the center of burst of a group of shots and the point of impact or burst of a single shot within the group.

ACCURACY LIFE: The estimated average number of rounds that a particular weapon can fire before its tube becomes so worn that its accuracy tolerance is exceeded.

ACCURACY OF FIRE: The measurement of the precision of fire expressed as the distance of the center of impact from the center of the target.

ADIABATIC FLAME TEMPERATURE: The temperature a combustible system would attain if all the energy of combustion went into the formation of gas without energy loss to the surroundings.

AMATOL: High explosive made of a mixture of ammonium nitrate and trinitrotoluene; sometimes used as a bursting charge in high-explosive projectiles.

AMMONAL: High-explosive substance made of a mixture of ammonium nitrate, trinitrotoluene, and flaked or powdered aluminum. Ammonal is sometimes used as a bursting charge in high-explosive projectiles, and produces bright flashes on explosion.

AMMUNITION DATA CARD: Identification card prepared for each individual lot of ammunition manufactured, giving the type and composition of the ammunition, and identifying its components by lot number and manufacturer. When necessary, it may also include instructions for handling the ammunition.

AMMUNITION IDENTIFICATION CODE: Code symbol (for example, P5HBA) assigned to each ammunition item for identification and to facilitate the supply of ammunition to the field. The first two characters refer to the pertinent ordnance catalog, and the remaining three characters to the weapon group, type and model, and packaging. In small arms ammunition the grade is indicated.

AMMUNITION LOT NUMBER: Code number that identifies a particular quantity of ammunition from one manufacturer. The number is assigned to each lot of ammunition when it is manufactured.

ANGLE OF DEPARTURE: Angle between the line of sight and the axis of the bore of a gun at the instant the projectile leaves the muzzle. Angle of departure is the sum of the angles of site, elevation, and vertical jump.

ANGLE OF FALL: Angle between the horizontal and the tangent to the trajectory at the point at which a projectile falls.

ANGLE OF IMPACT: Acute angle between the tangent to the trajectory at the point of impact of a projectile and the plane tangent to the surface of the ground at the point of impact; angle at which a projectile strikes the ground or a target.

ANGLE OF INCIDENCE: Angle at which a projectile strikes a surface; acute angle between the tangent to the line of impact of a projectile and the perpendicular to the surface of the ground at the point of impact. It is the complement of the angle of impact.

AREA TARGET: Target for gunfire or bombing covering a considerable space, such as ammunitions factory, airport, or freight yard. An area target differs from a point target, which is a particular object or structure.

ARMING: As applied to fuzes, the changing from a safe condition to a state of readiness for initiation. Generally a fuze is caused to arm by acceleration, rotation, clock mechanism, or air travel, or by combinations of these.

ARMOR: Protective covering, especially metal plates used on ships, tanks, motor vehicles, etc.

ARMOR-PIERCING: A term applied to bullets and projectiles designed to pierce armor plate.

ARMOR-PIERCING CAPPED: Term applied to armor-piercing projectiles which have a steel cap in front of the projectile point, to assist in defeating face-hardened armor plate.

AUTOMATIC (Self-Acting): Moving or acting by itself. After the first round is fired, an automatic weapon fires, extracts, ejects, and reloads without application of power from an outside source, repeating the cycle as long as the firing mechanism is held in the proper position. Automatic action involves repeating the cycle of operation, as distinguished from semi-automatic, which is restricted to one complete cycle at a time.

AUTOMATIC FEED MECHANISM: Mechanism in an automatic gun that puts fresh shells into the chamber in position for firing.

B

BACK-BLAST: Rearward blast of gases from the breech of recoilless weapons and rockets upon the burning of the propellant charge. It is sometimes referred to as breech-blast.

BALLISTIC CAP: Cap for projectile, designed to improve its ballistic efficiency.

BALLISTIC COEFFICIENT: Measure of the ability of a missile to overcome air resistance.

BALLISTIC CONDITIONS: Conditions which affect the motion of a projectile in the bore and through the atmosphere, including muzzle velocity, weight of projectile, size and shape of projectile, rotation of the earth, density of the air, elasticity of the air and the wind.

BALLISTIC CURVE: Actual path or trajectory of a bullet or shell.

BALLISTIC DENSITY: Computed constant air density that would have the same total effect on a projectile during its flight as the varying densities actually encountered.

BALLISTIC EFFICIENCY: Ability of a projectile to overcome the resistance of the air. Ballistic efficiency depends chiefly on the weight, diameter, and shape of the projectile.

BALLISTIC LIMIT: Velocity at which a given type of projectile will perforate a given thickness and type of armor plate at a specified obliquity.

BALLISTIC MORTAR: Instrument used to determine the relative energy obtainable from explosive materials.

BALLISTICS: The science of the motion of projectiles.

BALLISTIC TEMPERATURE: A computed constant temperature that would have the same total effect on a projectile traveling from the gun to the target as the varying temperatures actually encountered.

BALLISTIC WAVE: Audible disturbance or wave caused by the compression of air ahead of a projectile in flight.

BALLISTIC WIND: Assumed constant wind that would have the same total effect on a projectile traveling from the gun to the target as the varying winds actually encountered.

BALLISTITE: Smokeless powder used as a propelling charge in small-arms and mortar ammunition.

BALLOTING: The bounding from side to side of a projectile in the bore of a gun.

BASE EJECTION SHELL: Type of special purpose shell which functions by expelling its filler out of the base of the shell. Expulsion is usually achieved by a small charge of propellant, called an expelling charge.

BASE LINE: Line of known length and direction between two points whose locations are known; used in fire control.

BASE PLUG: Seal in base of projectile.

BASE OF TRAJECTORY: Straight horizontal line from the center of the muzzle of a weapon to the point in the downward curve of the path of a projectile that is level with the muzzle.

BASE SPRAY: (See SPRAY.)

BIOLOGICAL AGENT: Viruses, any of certain classifications of micro-organisms and toxic substances, derived from living organisms used to produce death or disease in man, animals, and growing plants.

BIOLOGICAL WARFARE: Tactics and techniques of conducting warfare by use of biological agents.

BLACK POWDER: A sensitive, easily ignitible explosive mixture, which produces dense smoke; few remaining military uses, such as igniters, expelling and blank-fire charges. Black powder was used as a propellant before the advent of so-called smokeless powder.

BLANK AMMUNITION: Ammunition containing power but no projectile. Blank ammunition is used in training, in signaling, and in firing salutes.

BLAST: Sudden air pressure created by the discharge of a gun or the explosion of a charge.

BLASTING CAP: Small cylindrical case with a thin wall in which is enclosed a sensitive explosive, such as mercury fulminate, used as a detonator to set off another explosive charge. The explosive in the blasting cap is fired either by a burning fuse or by electricity. Also called a detonator.

BLAST CUBE: Angle iron frame covered with aluminum sheets; used for testing effectiveness of blast.

BLAST TUBE: Device used for the study of shock waves, and for calibration of air-blast gages.

BLASTING MACHINE: Small hand-powered generator for electrically firing one or more detonators or squibs to explode or ignite munitions or series of munitions.

BLOWBACK: Escape, to the rear and under pressure, of gases formed during the firing of a gun. Blowback may be caused by a defective breech mechanism, a ruptured cartridge, or a faulty primer.

BOAT-TAIL: Rear end of a projectile that is tapered or cone-shaped, and not cylindrical, as in a projectile having a square base.

BOOSTER: High-explosive element, sufficiently sensitive to be actuated by small explosive elements in a fuze, and powerful enough to cause detonation of the main explosive filling.

BORE: The cylindrical, and usually rifled, portion of the gun tube, or barrel interior, extending from the forcing cone to the muzzle. Bore is used both for the inside surface of the barrel or tube of a gun, with its rifling, and for the cylindrical space enclosed by that portion of the tube.

BORE IMPRESSION: Impression of the bore of a gun tube, made with a plastic substance in order to determine the condition of the rifling.

BORESAFE FUZE: Type of fuze having an interruptor in the explosive train that prevents a functioning until after the projectile has cleared the muzzle of a weapon.

BOURRELET: Finely machined band or ring of metal just behind the ogive of a projectile, designed to support the front portion of the projectile by riding the lands as the projectile travels through the bore of a gun.

BOW WAVE: (See BALLISTIC WAVE.)

BREECH: The rear part of the bore of a gun, especially the opening that permits the projectile to be inserted at the rear of the bore.

BREECH-BLAST: (See BACK-BLAST.)

BREECHBLOCK: Movable steel block that closes the rear part of the barrel in a firearm.

BRIDGE WAVES: Mach waves caused by the interaction of two shock waves to form a third that bridges the volume between the original two.

BRISANCE: Shattering power of high explosives.

BURNING (of propellant): (See LINEAR BURNING RATE.)

BURST: Explosion of a projectile in the air, or when it strikes the ground or target.

BURSTER: Explosive charge used to break open and spread the contents of chemical projectiles, bombs, or mines.

BURSTER TUBE: Tube that holds the burster in a chemical projectile.

BURSTING CHARGE: Quantity of explosive which breaks the casing of a projectile to produce demolition, fragmentation, or chemical action. (See EXPLOSIVE CHARGE.)

C

CALIBER: (1) Diameter of the bore of a gun. In rifled gun bores the caliber is obtained by measuring between opposite lands. A caliber .45 revolver has a barrel with a land diameter 45/100 of an inch. (2) Diameter of a projectile. (3) Unit of measure used to express the length of the bore of a weapon. The number of calibers is determined by dividing the length of the bore of the weapon, from the breech face of the tube to the muzzle, by the diameter of its bore. A gun tube whose bore is 40 feet (480 inches) long and 12 inches in diameter is said to be 40 calibers long.

CANISTER: (1) Metal cylinder containing metal fragments which are scattered when the cylinder breaks. (2) Cylinder containing materials for special terminal effects, such as smoke, propaganda leaflets, chaff, etc.

CANNISTER AMMUNITION: Shell containing preformed metal fragments which are dispersed by the centrifugal force caused by the shell's rotation.

CANNELURE: (1) A ring-like groove in the jacket of a bullet which provides a means of securely crimping the cartridge case to the bullet; analogous to the crimping groove in artillery ammunition. (2) Ring-like groove for locking the jacket of an armor-piercing bullet to the core. (3) Ring-like groove in the rotating band of a projectile, intended to lessen the resistance offered to the gun riflings. (4) Groove around the base of the cartridge case, where the extractor takes hold.

CANNON: (1) Fixed or mobile weapon, larger than small arms, that ejects its projectile by the action of an explosive. Cannon include guns, howitzers, and breech-loading mortars. (2) That portion of such a weapon required to fire a projectile (that is, tube, breech mechanism, and firing mechanism), as contrasted to that portion which supports the weapon and which is called the carriage or mount.

CANT: A leaning or tilt, to one side, of any object; militarily, the sidewise tilting of a gun.

CAP: (1) Nosepicce on a projectile. (2) (See BLASTING CAP.)

CARTRIDGE: Round of ammunition wherein the propellant and primer are contained in a casing and in which the propellant, primer, and projectile are assembled, stored, shipped, and issued as a complete unit.

CARTRIDGE BAG: Cloth bag holding the propelling charge for some types of cannon.

CARTRIDGE CASE: Container that holds the primer and propellant, and to which the projectile may be affixed.

CAST LOADING: Loading of HE shell by the pouring of molten high-explosive filler into shell body.

CAVITY CHARGE: (See SHAPED CHARGE.)

CENTER OF BURST: Point in the air about which the bursts of several projectiles, from rounds fired under like conditions, are evenly distributed.

CENTER OF BURST ERROR: Distance between the target and center of burst.

CENTER OF DISPERSION: Theoretical center of hits or bursts that would have been made if an unlimited number of shots had been fired with the same data. Actually it has to be considered the center of impact or bursts of all shots already fired.

CHAFF: Electromagnetic-wave reflectors in the form of narrow metallic strips, used for creating echoes with which to confuse the enemy; also called window.

CHAFF SHELL: Hollow projectile containing a filler of chaff. (See CHAFF.)

CHAMBER: Part of a gun in which the charge is placed; in a cannon, that space between the obturator or breechlock and the forcing cone. Nominally it is the space occupied by the cartridge case.

CHAMBER CAPACITY: Space available for gas expansion when the projectile is seated in position; measured from the face of the closed breechblock, around the base of the projectile, to the rear of the rotating band (or obturator). In fixed ammunition, it is the volume of the cartridge case behind the projectile.

CHEMICAL AGENT: Solid, liquid, or gas whose chemical properties produce lethal, injurious, or irritant effects; a screening or colored smoke; or an incendiary agent. (War gases, smokes, and incendiaries are the three main groups.)

CHOKING GAS: Casualty producing gas which causes irritation and inflammation of the bronchial tubes and lungs. Phosgene is an example of this type of gas.

CHORD: Straight line parallel to the centerline of the projectile from the leading edge to the trailing edge of a fin; the length of that line.

CHRONOGRAPH: Instrument for measuring and graphically recording small intervals of time; frequently used for measuring velocity of projectiles.

CLASSIFICATION OF DEFECTS: Enumeration of possible defects of a product classified according to their importance.

CLOSED BOMB: Apparatus used for determining the thermochemical characteristics of combustible materials. Also called closed chamber; bomb calorimeter.

COEFFICIENT OF FORM: Factor introduced into the ballistic coefficient of a projectile, based on its shape.

COLORED MARKER SHELL: Projectile containing a colored dye which is ejected by a burster charge; used for spotting, marking, and signaling.

COMPLETE PENETRATION: (1) In the Army, penetration obtained when the projectile in the target or light through the target can be seen from the rear of the target. (2) In the Navy, penetration obtained when the projectile passes through the target intact or a major portion of the projectile passes through.

COMPLETE ROUND: (1) A complete round of separate-loading artillery ammunition consists of a primer, propelling charge, and (except for blank ammunition) a projectile. (2) A complete record of fixed or semi-fixed ammunition comprises a primer, propelling charge, cartridge case, and a projectile.

COMPUTED MAXIMUM PRESSURE: For any type of gun, the theoretical value of maximum pressure computed by interior ballistics formulas. When a new gun of the type in question is fired under standard conditions, with a propelling charge that will give a projectile its rated muzzle velocity, this is the pressure which should be developed.

CONFINEMENT: Degree of physical restriction to passage of detonation wave through explosive material.

COOK-OFF: Functioning of a chambered round of ammunition, initiated by the heat of the weapon.

COPPER CRUSHER GAGE: Device used to measure pressure developed in gun chamber by measuring the deformation of a copper cylinder.

COPPERING: Metal fouling left in the bore of a weapon by the rotating band or the jacket of a projectile.

CORDITE: Double-base powder in the form of cords, composed of guncotton, nitroglycerin, and mineral jelly, used by some foreign nations as a propellant in rounds of ammunition.

COUNTERRECOIL: Forward movement of a gun returning to firing position after recoil.

CROSS-WIND FORCE (LIFT): Component of air resistance in a direction perpendicular to the motion of the center of gravity, in the plane of yaw.

CRYSTAL DENSITY: Maximum density attainable for a given substance.

D

DECELEROTOR: Device for slowing the rotation of parachute-containing projectile, before ejection of the parachute.

DEFLAGRATION: Rapid reaction (explosion) with evolution of considerable heat, accompanied by some disruptive effect but less violent than a detonation.

DEGRESSIVE GRANULATION: Propellant grain which burns with a continually decreasing surface until the grain is completely consumed.

DELAY FUZE: Fuze that has a delay element incorporated in the fuze train, permitting the missile to penetrate the target a distance corresponding to the delay. Such fuzes are used to permit penetration of the target before detonation, or for mining effect.

DESIGN PROCEDURE: Outline of steps to follow in designing an item.

DETERRENT: Material diffused into the surface of propellant grains to control burning.

DETONATE: Explode suddenly and violently.

DETONATING AGENT: Explosive used to set off another explosive. Fulminate of mercury and tetryl are used as detonating agents to set off other less sensitive explosives.

DETONATING CHARGE: Charge used to set off a high-explosive charge.

DETONATING CORD: Flexible fabric tube containing a filler of high explosive that is set off by a blasting cap or by an electric detonator. It has an extremely high rate of explosion, and is used to set off other high-explosive charges. The detonating cord currently in use is known commercially as primacord.

DETONATING EXPLOSIVE: (See HIGH EXPLOSIVE.)

DETONATION: Extremely rapid reaction with evolution of considerable heat accompanied by considerable violently disruptive effect and intense shock wave. (See also DEFLAGRATION.)

DETONATION FRONT: (See WAVE FRONT.)

DETONATION RATE: Velocity at which the detonation wave travels through an explosive material.

DETONATION WAVE: (See SHOCK WAVE.)

DETONATOR: Sensitive explosive used to set off an explosive train, as well as the mechanism and container connected therewith.

DEVLOPED MUZZLE VELOCITY: The actual muzzle velocity produced by any gun.

DOUBLE-BASE POWDER: (See DOUBLE-BASE PROPELLANT.)

DOUBLE-BASE PROPELLANT: Propellant whose principle active ingredients are nitrocellulose and nitroglycerin. (See PROPELLANT.)

DRAG: Component of air resistance in the direction opposite to that of the motion of the center of gravity of a projectile.

DRILL AMMUNITION: Ammunition without an explosive charge, used in training and practice.

DUMMY PROJECTILE: Shell that has no explosive charge. Dummy projectiles are used for practice and training purposes.

E. C. BLANK FIRE: (See E. C. SMOKELESS POWDER.)

E. C. SMOKELESS POWDER: Orange or pink explosive powder, resembling coarse sand. It is used as a charge in small arms, in blank cartridges. Also called blank-fire powder or E. C. blank fire.

ECCENTRICITY: Distance from center line to center of gravity of projectile.

ELASTIC STRENGTH PRESSURE: The computed internal gas pressure in a gun which, at the section under consideration, will stress the metal in some layer of the wall tangentially, up to the minimum elastic limit which is prescribed for the metal from which the member is made.

ELECTRIC PRIMER: Metallic device containing a small amount of a sensitive explosive or charge of black powder which is actuated by energizing an electric circuit. It is used for setting off explosive or propelling charges.

ELECTRIC SQUIB: Commercial flash-fuze device for electrical firing of burning type munitions such as smoke pots. It consists essentially of a small tube sealed with sulfur, containing a small charge of powder compressed around a fine resistance wire. There are three types: open-end, flash-vented, and closed-end.

EQUAL SECTION CHARGE: Propelling charge made up of a number of charges equal in size. The number of sections used determines the muzzle velocity and range of the projectile.

EQUATION OF STATE: An equation relating the volume, temperature, and pressure of a system.

EROSION: Wearing away of a bore due to combined effect of gas washing, scouring, and mechanical abrasion. Due to the high temperatures and velocities, and chemical action, the bore diameter becomes enlarged.

EXPELLING CHARGE: Quantity of propellant used in special purpose shell to eject the contents of the shell.

EXPLOSIVE: Substance which, when subjected to heat, impact, friction, or other suitable initial impulse, undergoes an explosion that is a very rapid chemical transformation, forming other more stable products entirely or largely gaseous, whose combined volume is much greater than that of the original substance. Explosives are classified as high-explosive or low-explosive, according to the rate of the transformation. (See HIGH EXPLOSIVE and LOW EXPLOSIVE.)

EXPLOSIVE CHARGE: Predetermined quantity of explosive required to produce a specific effect. (See BURSTING CHARGE; EXPELLING CHARGE; PROPELLING CHARGE.)

EXPLOSIVE D: Ammonium picrate, a high-explosive charge that is not easily set off in transportation, or in handling, etc. Sometimes it is used as a bursting charge in armor-piercing projectiles.

EXPLOSIVE TRAIN: That portion of a fuze or fuze system consisting of explosive components, such as primer, detonator, booster, etc., necessary to cause functioning of a warhead or destructor.

EXTERIOR BALLISTICS: The branch of ballistics which deals with the motion of the projectile after leaving the gun.

F

FIN: Light metal portion of a mortar shell, bomb, and some rockets, designed for stabilizing and controlling them while in flight.

FIN STABILIZATION: Method of stabilizing a projectile, bomb, or missile during flight by the fitting of fins.

FIXED AMMUNITION: Ammunition with primer and propellent powder contained in a cartridge case permanently crimped or attached to a projectile, that is loaded into a weapon as a unit.

FIXED ROUND: Round of fixed ammunition.

FLAME TEMPERATURE. (See ADIABATIC FLAME TEMPERATURE.)

FLASH REDUCER: Any material for use with a propelling charge to reduce its muzzle flash.

FLAT TRAJECTORY: Trajectory with little curvature, produced by a projectile with a high velocity.

FLECHETTE: Stabilized fragment having a pointed nose and finned tail; dart.

FORCE: A term, convenient in interior ballistics theory, which is defined as the product of the number of mols of gas per gram of propellant and the adiabatic-constant-volume flame temperature.

FORCING CONE: Tapered beginning of the lands at the origin of the rifling of a gun tube. The forcing cone allows the rotating band of the projectile to be gradually engaged by the rifling thereby centering the projectile in the bore.

FORM COEFFICIENT: Factor used in form functions to describe the ratio of burning surface to fraction burned.

FORM FUNCTION: Mathematical expression relating burning rate to propellant grain geometry.

FRAGMENTATION: The breaking and scattering in all directions of the pieces of a projectile, bomb, or grenade.

FULMINATE OF MERCURY: (See MERCURY FULMINATE.)

FUZE: Device used to initiate a detonation under the conditions desired.

G

GILDING METAL: Copper-zinc alloy (brass) used for rotating bands.

GRANULATION: Size and shape of grain of propellant.

GRAVIMETRIC DENSITY: Weight of the propellant (in lb per $in.^3$) divided by the volume occupied by the propellant (includes the air space in and around propellant grains).

G-SERIES WAR GASES: Group of persistent blood and nerve poisons which are highly toxic and practically odorless. GA, GB, and GD are members of the G-series.

GUNCOTTON: Nitrocellulose containing 13 percent or more of nitrogen.

H

HANGFIRE: Temporary failure or delay in the action of a primer, igniter, or propelling charge. For a few seconds it cannot be distinguished from a complete failure, or misfire.

HANGFIRE TEST: Test to determine uniformity and promptness of fire of a type of ammunition.

HC MIXTURE: Solid, nonpersistent screening smoke that, when burning, produces a grayish white smoke having a sharp, acrid odor, which is toxic if released in sufficient quantities in enclosed places; used in bombs, shell, grenades, and smoke pots. The smoke is cool burning as contrasted with white phosphorous, and tends to cling to the earth.

HEAT OF COMBUSTION: Heat evolved in the complete oxidation of a substance at constant pressure and 25°C. The test is usually accomplished calorimetrically by burning a gram of sample in a combustion bomb containing one cc of water under a pressure of 30 atmospheres of pure oxygen.

HEAT OF EXPLOSION: Heat evolved in burning a sample in a combustion bomb under a pressure of 25 atmospheres of helium, or other inert gas. (Products of explosion vary with the oxygen balance of the sample.)

HEAT OF FORMATION: Heat of formation of a compound is equal to the sum of the heats of formation of the products of combustion, minus the heat of combustion of the compound. ΔH_f (reactants) = $\Sigma \Delta H_f$ (products) - ΔH_c.

HEAT OF REACTION: Heat evolved when a sample is burned in a combustion bomb in one atmosphere of helium or other inert gas. (Products of this reaction are dependent on the oxygen balance of the sample.)

HEAT SHELL: (See HIGH-EXPLOSIVE ANTITANK SHELL.)

HEAT TEST: Accelerated stability test of an explosive material.

HEP SHELL: (See HIGH-EXPLOSIVE PLASTIC SHELL.)

HIGH-ANGLE FIRE: Fire delivered at elevations greater than the elevation of maximum range, its range therefore decreasing as the angle of elevation is increased. Mortars deliver high-angle fire.

HIGH EXPLOSIVE: Explosive which undergoes an extremely rapid chemical transformation, thereby producing a high order detonation and shattering effect. High explosives are used as bursting charges for bombs, projectiles, grenades, mines, and for demolition.

HIGH-EXPLOSIVE ANTITANK (HEAT) SHELL: Ammunition for defeat of armour by use of a shaped charge.

HIGH-EXPLOSIVE PLASTIC (HEP) SHELL (or, SQUASH-HEAD SHELL): Shell with deformable nose, designed to contain a plastic explosive, for use against armor; shock transmitted through the armor causes the back of armor plate to spall.

HIGH-EXPLOSIVE SHELL: Projectile with a bursting charge of high explosive, used against personnel and materiel.

HYGROSCOPICITY: The tendency of a substance to absorb any available moisture from its surroundings; specifically the absorption of water vapor from the atmosphere.

HYPERVELOCITY: Muzzle velocity of an artillery projectile of 3,500 feet per second or more.

HYPERVELOCITY ARMOR-PIERCING (HVAP) AMMUNITION: Ammunition which embodies a core of hard, dense material (such as tungsten carbide) within a shell of light material, such as aluminum. Its light overall weight permits it to be fired safely at very high velocities. The velocity is rapidly lost, but at short ranges it is effective against armor.

HYPERVELOCITY ARMOR-PIERCING DISCARDING SABOT (HVAPDS) AMMUNITION: Ammunition which embodies a hypervelocity, armor-piercing, subcaliber projectile within a discarding sabot. (See SABOT.)

HYPERVELOCITY ARMOR-PIERCING DISCARDING SABOT FIN-STABILIZED (HVAPDSFS) AMMUNITION: Ammunition which embodies a hypervelocity, armor-piercing, subcaliber, fin-stabilized projectile within a discarding sabot. (See SABOT.)

I

IGNITER: Device containing a ready burning composition, usually a form of black powder, used to amplify the ignition of a propelling charge by a primer. Also sometimes used to amplify the initiation of a primer in the functioning of certain types of fuzes and burster charges.

IGNITER TRAIN: Step-by-step arrangement of charges in pyrotechnic bombs, shells, etc., by which the initial fire from the primer is transmitted and intensified until it reaches and sets off the main charge. An explosive bomb, projectile, etc., uses a similar series, called an explosive train.

IGNITIBILITY: Statement of the ease with which the burning of a substance may be initiated.

IGNITING MIXTURE: Explosive mixture used as a fuze in pyrotechnic signals.

IGNITING PRIMER: Primer designed to be initiated by flame from another primer. Sometimes used in subcaliber guns so as to permit drill or practice with the regular primer.

IGNITION CARTRIDGE: Igniter in cartridge form which may be used alone or with additional propellant increments as a propelling charge for certain mortar ammunition.

ILLUMINATING SHELL: Projectile with a time fuze that sets off a parachute flare at any desired height; used for lighting up an area.

IMPACT FUZE: Fuze designed to function on impact.

INCENDIARY: (1) Chemical agent used primarily for igniting combustible substances with which it is in contact by generating sufficient heat to cause ignition. (2) Filling for incendiary munitions such as shells, bombs, grenades, and flame throwers. (3) Munition with flammable filling and means of release and/or ignition.

INCREMENT: A package of propellant, forming part of the full propelling charge, which may be removed to reduce the velocity or range. (See MULTISECTION CHARGE.)

INITIAL AIR SPACE: Volume of gun chamber not occupied by propellant when gun is loaded for firing.

INITIAL VELOCITY: (See MUZZLE VELOCITY.)

INITIATOR: Small quantity of very sensitive and powerful explosive used to start the detonation of another less sensitive explosive. Mercury fulminate, lead azide, and tetryl are the principle high explosives used as initiators.

INSTANTANEOUS FUZE: One which will burst the projectile on the outside of a hard surface (such as a concrete emplacement) before penetration or ricochet. This fuze will give some crater on hard ground. (See SUPERQUICK FUZE.)

INTERIOR BALLISTICS: Subdivision of ballistics which deals with that part of the phenomena within the chamber and bore of a weapon associated with imparting kinetic energy to missiles. (See BALLISTICS.)

ISOBARIC ADIABATIC FLAME TEMPERATURE: Adiabatic flame temperature attained in a constant pressure system. (See ADIABATIC FLAME TEMPERATURE.)

ISOCHORIC ADIABATIC FLAME TEMPERATURE: Adiabatic flame temperature attained in a constant volume system. (See ADIABATIC FLAME TEMPERATURE.)

J

JOLT AND JUMBLE TESTS: Tests intended to simulate the shocks various components of ammunition are subjected to in transportation and handling.

JUMP: The movement which the tube of the gun describes under the shock of firing, but before the projectile leaves the muzzle. Usually expressed as an angle.

K

KINETIC ENERGY AMMUNITION: Ammunition whose effectiveness is dependent upon its high density (mass) and high velocity.

L

LANDS: Raised portion between grooves in the bore of a rifled gun.

LATERAL DEVIATION: Horizontal distance between the point of impact or burst and the gun-target line.

LEAD AZIDE: Very sensitive high explosive used in small quantities to initiate other less sensitive high explosives.

LEAFLET SHELL: Usually consists of standard-base ejection smoke shell, of any caliber, with smoke canisters removed and propaganda substituted therefor.

LIFTING PLUG: Threaded eyebolt which fits into the fuze cavity, permitting heavy shells to be handled by means of a winch.

LINEAR BURNING RATE: The distance normal to any burning surface of the propellant grain burned through in unit time. This property depends upon the chemical composition, and is not a function of geometry.

LINER: (1) Inner tube, in a cannon, which bears the rifling and which may be replaced when worn out. (2) Cone of material used as an integral part of shaped charge liner.

LIVE AMMUNITION: Ammunition containing explosives. This is in contrast to drill ammunition (dummy ammunition), which contains no explosives and is used in training.

LOADING DENSITY: Ratio of weight of propellant (in lb per $in.^3$) to available chamber volume.

LONG-DELAY FUZE: One which will burst the projectile after complete penetration into hard ground. There is a variation in the time element in long-delay fuzes required for different uses. (This is a question to be determined by the Ordnance Dept.)

LOW EXPLOSIVE: Explosive which undergoes a relatively slow chemical transformation, thereby producing a deflagration or an explosion, the effect ranging from that of a rapid combustion to that of a low order detonation. It is suitable for use in igniter trains and certain types of propellants. (See PROPELLANT.)

LOW ORDER DETONATION: Incomplete detonation of the explosive charge in a bomb, projectile, or other similar high explosive. (See DETONATION.)

LOWER ACCEPTABLE MEAN MAXIMUM PRESSURE: For any type gun, that value of the maximum pressure which is specified in the propellant specification as the lower limit for the average of the maximum pressures that are developed by an acceptable smokeless propellant in propelling charges which will impart the specified muzzle velocity to the specified projectile. Smokeless propellant in propelling charges which in acceptance tests develops an average maximum pressure lower than this value is considered as having failed to pass the test.

M

MACH NUMBER: Ratio of the velocity of a body to that of sound in the same medium.

MACH WAVE: Supersonic shock wave.

MAGNUS FORCE: (1) Force normal to the plane of yaw, caused by the spin. (2) Force arising from interaction of a spinning body and the windstream when the body is yawing.

MAGNUS FORCE, CENTER OF: Vanishing point of Magnus moment.

MAXIMUM PRESSURE: The maximum value of the pressure exerted by the propellant gases on the walls of a gun during the firing of the round.

MAXIMUM SKY BRIGHTNESS: Worst possible sky condition for observing pyrotechnic signals; usually uniform clouds or overcast.

MEPLAT: Flat nose.

MERCURY FULMINATE: Sensitive explosive that is set off by friction, impact, or heat, and detonates. Mercury fulminate is used to set off other explosives in projectiles, mines, or bombs.

METAL FOULING: Deposit of metal, which collects in the bore of a gun, that comes from the jackets or rotating bands of projectiles.

MISFIRE: (1) Failure to fire or explode properly. (2) Failure of a primer or the propelling charge of a projectile to function, wholly or in part. Misfire may be contrasted with hangfire, which is delay in any part of a firing charge.

MULTISECTION CHARGE: Propelling charge in separate-loading or semifixed ammunition that is loaded into a number of powder bags. Range adjustments can be made by increasing or reducing the number of bags used, as contrasted with a single-section charge, in which the size of the charge cannot be changed.

MUZZLE BLAST: Sudden air pressure exerted in the vicinity of the muzzle of a weapon by the rush of hot gases and air on firing.

MUZZLE BRAKE (also called a RECOIL BRAKE): Device attached to the muzzle of a gun which utilizes escaping gases to reduce the effective recoil force of the gun tube on the carriage or mount. In some designs it eliminates or reduces muzzle flash.

MUZZLE FLASH: Undesirable luminous ignition of unburned propellant gases issuing from the muzzle of a gun. The gases ignite upon mixture with atmospheric oxygen.

MUZZLE VELOCITY: Speed of a projectile at the instant it leaves the muzzle of a gun.

MUZZLE WAVE: Compression wave or reaction of the air in front of the muzzle of a weapon immediately after firing.

N

NERVE GAS: (See G-SERIES WAR GASES.)

NITROCELLULOSE: Explosive substance formed by the nitration of cotton, or some other form of cellulose. Used as the base of most U. S. propellants. Specific grades of nitrocellulose (see PYROCELLULOSE and GUNCOTTON) depend on the degree to which the cellulose is nitrated.

NITROCOTTON: (See GUNCOTTON.)

NITROGUANIDINE (nitrated aminomethanamidine): Used as an additional base of propellant; used as a "cool propellant" because of its low flame temperature which does not erode gun bores nor produce as much luminous flash as single base (nitrocellulose) propellants.

NITROGLYCERINE: Nitrated ester of glycerol in which the OH radicals are replaced by NO_2; used as primary base of British propellants and as gelatinizing agent of U. S. propellants, but not used as primary base of U. S. propellants because its high flame temperature accelerates bore erosion.

NITROGEN MUSTARD GASES: Group of blister gases similar to mustard gas with varying chemical properties and little or no odor; gases affect eyes, nose, and lungs.

NONDELAY FUZE: Fuze that functions as a result of inertia of firing pin (or primer) as missile is retarded during penetration of target. The inertia causes the firing pin to strike the primer (or primer the firing pin), initiating fuze action. This type of fuze is inherently slower in action than the superquick or instantaneous fuze, since its action depends upon deceleration (retardation) of the missile during penetration of the target.

NORMAL CHARGE: Propelling charge employing a standard amount of propellant to fire a gun under ordinary conditions, as compared with a reduced charge or a supercharge used in special circumstances.

NORMAL FORCE: (1) Component of air resistance perpendicular to the axis of the projectile in the plane of yaw (exterior ballistics). (2) Any force perpendicular to a given line or surface (general).

NORMAL IMPACT: Striking of a projectile against a surface that is perpendicular to the line of flight of the projectile.

NOSE SPRAY: (See SPRAY.)

NUTATION: A small periodic oscillation about the motion of precession.

O

OBTURATION: Any process that prevents the escape of gases from the tube of a weapon during the firing of a projectile.

OBTURATOR: A device for making the tube of a weapon gas-tight, preventing any escape of gas until the projectile has left the muzzle.

OGIVE: The shape of the head of the projectile, often a convex solid of revolution generated by an arc of a circle whose center lies on the side of the axis of revolution opposite to the arc.

OPTIMUM CHARGE: Web and propellant weight combination which produces maximum velocity at a specified pressure.

OVERTURNING MOMENT (of a projectile in flight): Couple about an axis through the center of gravity, perpendicular to the plane of yaw.

OXYGEN BALANCE: Ratio of self-contained oxygen to fuel in a propellant or explosive.

P

PARASHEET: Parachute-like device made from a single flat piece of material, or as few pieces as its size will permit; avoids cost of complex gore construction of parachute.

PEAK PRESSURE: Instantaneous maximum pressure developed in the gun chamber by burning propellant; pressure immediately preceding an expanding shock wave.

PERCUSSION COMPOSITION: High-explosive powder that is ignited in some types of firearms by the blow of the firing pin against the primer cap.

PERCUSSION FUZE: (See IMPACT FUZE.)

PERCUSSION PRIMER: Cap or cylinder containing a small charge of high explosive that may be set off by a blow. A percussion primer is used in all fixed and semifixed ammunition and in certain types of separate-loading ammunition to ignite the main propelling charge.

PERFORATION: Passage of a missile completely through an object.

PERMISSIBLE INDIVIDUAL MAXIMUM PRESSURE: For any type gun, that value which should not be exceeded by the maximum pressure developed by any individual round under any service condition.

PERMISSIBLE MEAN MAXIMUM PRESSURE: For any type gun, that value which should not be exceeded by the average of the maximum pressures developed in a series of rounds fired under any service conditions.

PHOSGENE: Colorless choking gas having an odor of new-mown hay or fresh corn; causes choking and coughing, and injuries to the lungs.

PICRIC ACID (trinitrophenol): High explosive, more powerful than trinitrotoluene, used widely in the form of mixtures with other nitro compounds.

PIEZOELECTRIC CRYSTAL: Crystalline material possessing the property that, when it is mecahnically compressed or stretched in certain directions, electrical charges in direct proportion to the mechanical strain appear on the crystal surfaces.

PITCH (of rifling): Reciprocal of the twist. (See TWIST.)

PLANFORM: Shape of plan view of fins.

PLASTIC EXPLOSIVE: Explosive which, within normal ranges of atmospheric temperature, is capable of being molded into desired shapes.

PLUNGING FIRE: Gunfire that strikes the earth's surface at a high angle.

POINT-BLANK RANGE: Distance, to a target, that is so short that the trajectory of a bullet or projectile is practically a straight, rather than a curved, line. Point-blank range is one for which no superelevation is needed.

POINT DETONATING FUZE: Fuze, located in the nose of a projectile, which is initiated upon impact.

POWDER: Term sometimes loosely used for "propellant" or "propelling charge."

POWDER TRAIN: (1) Train, usually of compressed black powder, used to obtain time action in older fuze types. (2) Train of explosives laid out for destruction by burning.

PRACTICE AMMUNITION: Ammunition used for target practice, ammunition with a propelling charge, but with either an inert filler or a low-explosive filler to serve as a spotting charge.

PRECISION: The quality of having small dispersion about the mean.

PRECESSION: A change in the direction of the axis of a rotating body. In this handbook, precession means the slow motion without nutation.

PRESSURE, CENTER OF: The point where the resultant force caused by air resistance intersects the axis of the projectile.

PRIMACORD: Flexible fabric tube containing a filler of high-explosive PETN (pentareythritetetranitrate) that is used to transmit a detonation from a detonator to a booster or bursting charge. Primacord is the trade name for the type of detonating cord currently in use.

PRIMER: Device used to initiate the functioning of an explosive or igniter train. It may be actuated by friction, blow, heat, pressure, or electricity.

PRIMER-DETONATOR: Assembly consisting of a primer and a detonator. It may also include a delay element.

PRIMER SEAT: Chamber in the breech mechanism of a gun that uses separate-loading ammunition, into which the primer is set.

PROBABLE ERROR: An error of such magnitude that the probability of making an error greater than it in any given observation is just equal to the probability of making one less than it, both probabilities being one-half.

PROCEDURE, DESIGN: Outline of steps to follow in designing an item.

PROGRESSIVE GRANULATION: Propellant grain which burns with a continually increasing surface until the grain is completely consumed.

PROJECTILE: Object, such as a bullet or shell, that is propelled from a weapon by an explosive propelling charge.

PROOF AMMUNITION: Ammunition incorporating solid, blunt-nosed, steel or cast iron shot of inexpensive manufacture; used in proof firing of guns; used to simulate the weight of projectile designed for the gun in adjusting the charge weight of propellant.

PROPAGANDA SHELL: (See LEAFLET SHELL.)

PROPELLANT: Explosive material whose rate of combustion is low enough, and its other properties suitable, to permit its use as a propelling charge.

PROPELLING CHARGE: Explosive charge that is burned in a weapon to propel a projectile therefrom (see PROPELLANT). Burning of the confined propelling charge produces gases whose pressure forces the projectile out.

PROXIMITY FUZE: Fuze designed to detonate a projectile, bomb, mine, or charge when activated by an external influence in the close vicinity of a target.

PYROCELLULOSE: Nitrocellulose containing 12.60 percent nitrogen.

PYROCOTTON: (See PYROCELLULOSE.)

PYRO POWDER: Straight nitrocellulose powder; smokeless propelling charge consisting of a nitrocellulose that has a smaller nitrogen content than guncotton; single-base propellant.

PYROTECHNICS: Ammunition containing chemicals that produce a smoke or brilliant light in burning, used for signalling, marking, spotting, illuminating, etc.

PYROXYLIN (collodion): Nitrocellulose containing 8-12 percent nitrogen.

Q

QUALITY ASSURANCE: System of assuring that material accepted is in accordance with requirements, including inspection and test procedures, acceptance criteria, etc.

QUICKNESS (propellant burning): Rate of change of pressure within the close chamber with respect to time.

R

RAM: (1) To push into position. (2) To seat a projectile in the bore of a gun.

RAMMER: (1) Device for driving a projectile into position in a gun. It may be hand- or power-operated or a part of the receiver mechanism. (2) Tool used to remove live projectiles from the bore of a gun.

RATED MAXIMUM PRESSURE: For any type gun, that value of the maximum pressure which is specified in the propellant specification as the upper limit of average pressure which may be developed by an acceptable propellant in the form of propelling charges which will impart the specified muzzle velocity to the specified projectile. The smokeless propellant in propelling charges which, in the acceptance test, develops an average maximum pressure exceeding this value is considered as having failed to pass the test.

RELATIVE FORCE: Ratio of observed maximum pressure developed by a propellant under test to the maximum pressure developed by a standard propellant under identical test conditions.

RELATIVE QUICKNESS: Ratio of the quickness (dP/dt) of a test propellant to the quickness of a standard propellant, measured at the same initial temperature and loading density in the same closed chamber.

REMAINING VELOCITY: Speed of a projectile at any point along its path of flight. Remaining velocity is usually measured in feet per second.

RICOCHET: Glancing rebound of a projectile after impact.

RIFLE: (1) Any firearm that has rifling in the bore designed to give a spin to the projectile for greater accuracy of fire and longer range (not extensively used in this manner, except for shoulder arms). (2) Cut spiral grooves (rifling) in the bore of a gun in order to give a spin to the projectile so that it will have a greater accuracy of fire and longer range.

RIFLING: Spiral grooves in the bore of a weapon designed to give a spin to the projectile for greater accuracy and carrying power. Rifling includes both the grooves and the ridges between, called lands.

ROTATING BAND: Soft metal band around a projectile near its base. The rotating band makes the projectile fit tightly in the bore by centering the projectile, thus preventing escape of gas, and giving the projectile its spin as it engages in the rifling.

ROUND: (1) All the parts that make up the ammunition necessary in firing one shot (also called COMPLETE ROUND). (2) One shot fired by a weapon.

ROUND OF AMMUNITION: (See ROUND.)

S

SABOT: (1) Lightweight carrier in which a subcaliber projectile is centered to permit firing the projectile in the larger caliber weapon. The carrier fills the bore of the weapon from which the projectile is fired; and its light weight permits it to be safely fired at very high velocities. It is normally discarded a short distance from the muzzle, in which case it is known as a discarding sabot.

SAFETY WIRE: Wire set into the body of a fuze to lock all movable parts into safe position so that the fuze will not be set off accidentally. It is pulled out just before loading.

SCABBING: Breaking off of fragments in the inside of a wall of hard material due to the impact or explosion of a projectile on the outside.

SCREENING SMOKE: Chemical agent which, when burned, hydrolyzed, or atomized, produces an obscuring smoke; used to deny observation and reduce effectiveness of aimed fire.

SEMIFIXED AMMUNITION: Ammunition in which the cartridge case is not permanently fixed to the projectile, so that the zoned charge within the cartridge case can be adjusted to obtain the desired range; loaded into the weapon as a unit.

SEMIFIXED ROUND: Round of semifixed ammunition.

SENSITIVITY: Measure of the response of an explosive material to initiation by heat, friction, or impact.

SEPARATED AMMUNITION: Ammunition in which the cartridge case is not fixed to the projectile, so that the zoned charge within the cartridge case can be adjusted to obtain the desired range; loaded into the weapon as a unit.

SEPARATE-LOADING AMMUNITION: Ammunition in which the projectile, propelling charge, and primer are not held together in a shell case, as in fixed ammunition, but are loaded into a gun separately.

SEPARATING BURST: Method of ejecting the contents of a projectile by means of a charge of propellant that breaks the projectile, into two approximately equal parts, along a specially designed circumferential shear joint.

SERVICE AMMUNITION: Ammunition intended for combat rather than for training purposes.

SETBACK: Rearward jerk, caused by inertia, of parts of a projectile when it is fired.

SHAPED CHARGE: An explosive so shaped and designed as to concentrate its explosive force in a single direction.

SHELL: Hollow projectile filled with explosive, or chemical or other material, as opposed to shot, which is a solid projectile.

SHELL-DESTROYING TRACER: Tracer with an igniter element, placed between the explosive in an antiaircraft projectile and the tracer element, that is designed to detonate the explosive after the projectile has passed the target point but is still high enough to be harmless to ground troops.

SHOCK WAVE: Rapid expansion of the hot gases resulting from detonation of an explosive charge.

SHORT DELAY FUZE: One which will burst a projectile on ricochet, preferably about 6 to 10 feet above ground. Some crater effect will be obtained on hard ground.

SHOT: (1) A solid projectile. (2) Pellets, small balls, or slugs used in shotgun shells, canisters, and some other types of ammunition.

SHRAPNEL: Artillery projectile which contains small lead balls that are propelled by a powder charge in the base, set off by a time fuze. Shrapnel has been replaced almost entirely by high-explosive shells. Wounds called shrapnel wounds usually are due to shell fragments rather than to shrapnel.

SHRINKAGE: Contraction of propellant grain from wet (green) dimensions (as it comes from the graining dye) to the dry dimensions after solvent extraction and evaporation.

SIDE SPRAY: (See SPRAY.)

SIGNALING SMOKE: Any type of smoke, but usually colored smoke from a hand or rifle grenade, or from a pyrotechnic signal, used for conveying a message.

SINGLE-BASE POWDER: (See SINGLE-BASE PROPELLANT.)

SINGLE-BASE PROPELLANT: Propellant whose principle active ingredient is nitrocellulose.

SINGLE-SECTION CHARGE: Propelling charge in separate-loading ammunition that is loaded into a single bag. A single-section charge cannot be reduced or increased for changes of range, as a multisection charge can be.

SMOKE SHELL: Any projectile containing a smoke-producing chemical agent that is released on impact or burst. Also called smoke projectile. Smoke may be white or colored. (See COLORED MARKER SHELL.)

SMOKELESS POWDER: (See SMOKELESS PROPELLANT.)

SMOKELESS PROPELLANT: Propellant explosive from which there is a minimum amount of visible smoke on firing.

SMOOTH-BORE: Having a bore that is smooth and without rifling; shotguns and mortars are commonly smooth-bore.

SPALL: Fragments broken from either surface of an armor plate as the result of penetration, impact of a projectile, or detonation against the plate.

SPECIFIC DENSITY: Mass per unit volume. In interior ballistics it is usually distinguished from loading density and gravimetric density, which see.

SPIN: Angular velocity about the axis of the projectile.

SPIN-DECELERATING MOMENT: A couple about the axis of the projectile which diminishes spin.

SPIN-STABILIZATION: Method of stabilizing a projectile during flight by causing it to rotate about its own longitudinal axis.

SPRAY: Fragments of a bursting shell. The nose, side, and base sprays are the fragments thrown forward, sideways, and rearward, respectively.

SQUASH-HEAD SHELL: (See HIGH-EXPLOSIVE PLASTIC SHELL.)

SQUIB: Small pyrotechnic device which may be used to fire the igniter in a rocket or for some similar purpose; not to be confused with a detonator, which explodes. (See ELECTRIC SQUIB.)

STABILITY: Measure the ability of an explosive material to be stored for long periods.

STABILITY TEST: Accelerated test to determine the suitability of an explosive material for long-term storage.

STABILIZER: Material added to propellent colloid to inhibit, or reduce, decomposition in storage.

STACKED CHARGE: Powder charge in which the powder grains lie end to end within the powder bag.

STANDARD ATMOSPHERE: Values of temperature and pressure determined by NACA, based on the yearly averages at 40° N latitude. At sea level T = 59°F; P = 29.92 in. Hg; lapse rate = 3.6°F per 1,000 ft altitude. Various other standards have been defined, but this is the standard used in this handbook.

STANDARD BALLISTIC CONDITIONS: Set of ballistic conditions arbitrarily assumed as standard for the computation of firing tables.

STANDARD DEVIATION: The root-mean-square of the deviations from the mean.

STANDARD TRAJECTORY: Path through the air that it is calculated a projectile will follow under given conditions of weather, position, and materiel, including the particular fuze, projectile, and propelling charge that are used. Firing tables are based on standard trajectories.

STANDOFF: Distance between a shaped charge round and its target at the instant of functioning.

STAR: Pyrotechnic signal that burns as a single light.

STAR GAGE: Instrument for measuring the diameter of the bore of a gun.

STAR SHELL: (See ILLUMINATING SHELL.)

STOWAGE: (1) Method of placing cargo in a vessel to prevent damage, shifting, etc. (2) Method of placing equipment and supplies in a vehicle to provide availability and operating room. (3) Equipment when stowed.

STRIKER: Part of the firing mechanism of a gun, mine, mortar, etc., that hits the primer; hammer or firing pin of a gun.

STRIKING VELOCITY: Speed of a projectile at the point of impact.

SUBCALIBER: Of a caliber smaller than standard.

SUPERQUICK FUZE: Fuze that functions immediately upon impact of the missile with the target. Action of this type of fuze is the quickest possible: the firing pin is driven into the primer immediately upon first contact of the missile; functions at the surfaces of the target. Also called instantaneous fuze.

SUPERSENSITIVE FUZE: Fuze that will set off a projectile when it strikes even a very light target, such as an airplane wing.

SUPPLEMENTAL CHARGE: Filler, which is normally TNT, used in deep cavitied projectiles to fill void between ordinary fuze and booster combination and bursting charge.

SURVEILLANCE: Observation, inspection, investigation, test, study, and classification of ammunition, ammunition components, and explosives in movement, storage, and use with respect to degree of serviceability and rate of deterioration.

SWELL DIAMETER: Maximum diameter of the ogive extended to the place where its generating arc is parallel to the center line.

SYMPATHETIC DETONATION: Explosion caused by the shock of another explosion nearby.

T

TERMINAL BALLISTICS: The branch of ballistics which deals with the ultimate effect produced by a projectile.

TERMINAL VELOCITY: Remaining speed of a projectile at the point in the downward path of the projectile where the projectile is level with the muzzle of the gun. The speed at the point of impact is called the striking velocity.

TETRYL: Sensitive explosive used especially in caps and boosters to detonate less sensitive explosives, and as the explosive filler in some types of projectiles.

THERMATE: Standard incendiary agent used as filling for incendiary munitions. Mixture of thermite (iron oxide and aluminum) and other oxidizing agents; it burns at about 4,300°F.

THERMIT: Thermite, commerical welding mixture of iron oxide and aluminum; used as an incendiary for some munitions.

TNT: (See TRINITROTOLUENE.)

TRACER: Element of a type of ammunition containing a chemical composition which burns visibly in flight. Tracer is used for observation and adjustment of fire, for incendiary purposes, and for signaling. Ammunition containing tracers is called tracer ammunition.

TRAJECTORY: Path of projectile, missile, or bomb in flight.

TRAJECTORY CHART: Diagram of a side view of the paths of projectiles fired at various elevations, under standard conditions. The trajectory chart is different for different guns, projectiles, and fuzes.

TRAUZL TEST: Method of determining relative energy available from an explosive material by measurement of the volume expansion of a lead test block.

TRIMONITE: High explosive used as a substitute for trinitrotoluene as a bursting charge. Trimonite is a mixture of picric acid and mononitronaphthalene.

TRINITROPHENOL: (See PICRIC ACID.)

TRINITROTOLUENE (TNT): High explosive widely used as explosive filler in projectiles and by engineers; trinitrotoluol.

TRINITROTOLUOL: (See TRINITROTOLUENE.)

TRIPLE-BASE PROPELLANT: Propellant whose principal active ingredients are nitrocellulose, nitroglycerin, and nitroguanidine. (See PROPELLANT.)

TRIPLE POINT: Intersection of the original shock wave, the reflected shock wave, and the Mach stem.

TUBE: The inner cylinder of a built-up gun, usually extending from the inner face of the breechblock to the muzzle.

TWIST: Inclination of the spiral grooves to the axis of the bore of a weapon. The degree of twist is the determing factor in the speed of rotation of the projectile.

V

VACUUM STABILITY TEST: (See STABILITY TEST.)

W

WAVE FRONT: Surface which is the locus of all molecules having motion in identical phase in a propagating wave.

WEB; WEB SIZE; WEB THICKNESS: Alternative terms describing the minimum distance between any two specified burning surfaces of a propellant grain.

WEB RANGE: Tolerance of web thickness to allow for manufacturing limitation.

WINDSHIELD: (See BALLISTIC CAP.)

WHITE PHOSPHORUS (WP): Yellow, waxy solid which ignites spontaneously when exposed to air. It is used as a filling for various projectiles as a smoke-producing agent, and has an incendiary effect. White phosphorus may be mixed with a xylene solution of synthetic rubber to form plasticized white phosphorus.

WP: (See WHITE PHOSPHORUS.)

Y

YAW: Angle between the axis of the projectile and the tangent to the trajectory.

INDEX

SECTION 1

ARTILLERY AMMUNITION — GENERAL

TYPES AND CLASSIFICATION OF COMPLETE ROUNDS

1-1. Complete Rounds. The term "artillery ammunition" refers to ammunition, excepting rockets and shotgun shells, used in weapons having a bore diameter of more than 0.60 inch. A complete round of artillery ammunition comprises all of the components necessary to fire a weapon once and to cause the projectile to function at the desired time and place. These components are, in general, the projectile, the fuze, the propelling charge, and the primer. Dependent upon both the type of propelling charge and the method of loading into the weapon, complete rounds of artillery ammunition are known as fixed, semifixed, separate loading, or separated. Figure 1-1 illustrates these types of ammunition and their component parts.

1-2. Components of a Complete Round.

Projectile. The projectile is the effect-producing assembly which is ejected from the weapon by the gas pressure developed by the burning propelling charge. Other terms used in specific nomenclature of certain items, in place of "projectile," are "shell" and "shot."

Fuze. A fuze is a mechanical or electrical device assembled to a projectile to cause it to function at the time and under the circumstances desired.

Propelling Charge. The propelling charge consists of a quantity of propellant in a cartridge case, cloth bag, or both.

Primer. A primer is used to initiate the burning of a propelling charge. It consists essentially of a small quantity of sensitive explosive and a charge of black powder.

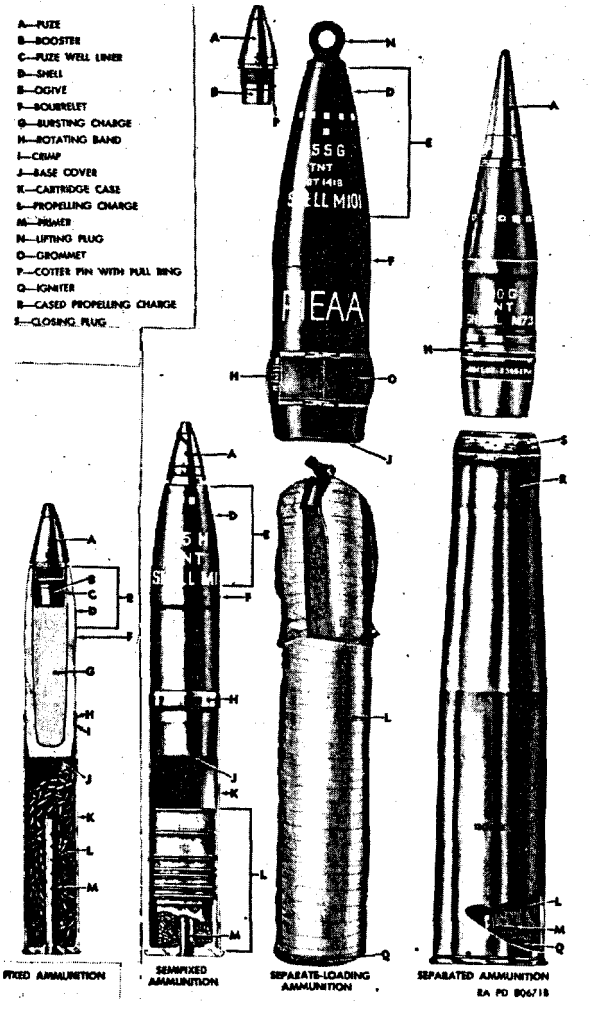

Figure 1-1. Ammunition terms — complete rounds

1-3. Fixed Ammunition. Complete rounds in which the propelling charge is fixed, that is, not adjustable, and which are loaded into the weapon in one operation, are known as "fixed" ammunition. As usually designed, the propelling charge is loose in the cartridge case, which is crimped rigidly to the projectile. In a few cases, however, the charge is contained

in a bag inside the cartridge case. For certain calibers, rounds of fixed ammunition are termed "cartridges."

1-4. Semifixed Ammunition is characterized by an accessible propelling charge, which may be adjusted for zone firing. Like fixed ammunition, it is loaded into the weapon as a unit. The cartridge case is a free fit over the projectile. The propelling charge is divided into bagged sections, each containing a definite quantity of propellant.

1-5. In Separate-Loading Ammunition, the separate components — projectile, propelling charge, and primer — are loaded into the weapon separately, because the ammunition is too heavy and bulky to be handled as a unit. Ammunition larger than 105-mm caliber falls into this category.

1-6. Separated Ammunition is characterized by the arrangement of the propelling charge and the projectile for loading into the gun. The propelling charge, contained in a primed cartridge case that is sealed with a closing plug, and the projectile, are loaded into the gun in one operation. Separated ammunition is used when the ammunition is too large to handle as a fixed unit.

1-7. Classification of Ammunition. Ammunition may be classified according to use as service, practice, blank, or drill. In addition, it may be classified according to type of filler as explosive, chemical, or inert.

1-8. Service Ammunition is used in combat. Dependent upon the type of projectile, it may be high-explosive (HE), high-explosive antitank (HEAT), armor-piercing (AP), armor-piercing capped (APC, with or without explosive filler), hypervelocity armor-piercing (HVAP, HVAPDS, or HVAPDSFS), high-explosive plastic (HEP), incendiary, illuminating, marking, propaganda, chaff, or liquid-filled shell.

1-9. Practice Ammunition is fired for effect in simulated combat, and is also used in training in marksmanship. The projectile in this type of ammunition may have a small quantity of low-explosive filler to serve as a spotting charge, or the filler may be inert. The projectile may be an empty cast-iron shell.

1-10. Blank Ammunition is provided in small and medium calibers for saluting and simulated fire. This ammunition has no projectile.

1-11. Drill Ammunition is used for training in handling and loading. It is completely inert.

1-12. Proof Ammunition. Proof ammunition is used for testing of guns and propellant charges. The projectile is ordinarily a blunt-nosed solid steel shot of the same weight as the high-explosive projectile which is to be fired from the gun. The propellant charge weight is adjusted to give the pressure desired for the test that the round is designed for.

TYPES OF PROJECTILES

1-13. High-Explosive (HE) Shell have projectiles of forged steel, comparatively thin walls, and a large bursting charge of high explosive. HE shell are used against personnel and materiel targets, producing blast effect and fragmentation at the target. HE shell may have a time-, impact-, inertia-, or proximity-type fuze, according to the action desired.

1-14. High-Explosive Antitank (HEAT) Shell. This is a special shell used against armored targets. Its effect is dependent upon the formation of an ultra-high-velocity jet of metal caused by the action of the hollow charge on the metal liner.

1-15. Armor-Piercing (AP) Ammunition. The armor-piercing projectile has a nose of forged high-carbon nickel-chrome steel, and is intended to penetrate the armor of a tank by the energy of impact. The nose may be ogival, or blunt truncated, and must be hard enough to penetrate armor, yet tough enough to withstand cracking or shattering upon impact; it may have an aluminum windshield to provide better ballistic characteristics. The body of an AP shot must be capable of withstanding bending stresses, and also the gouging action of the edges of the hole. The base must have enough strength to smash through the plate if caught by the side of the hole, or should be so designed that it will break off from the body without injuring the forward part.

1-16. Hypervelocity Armor-Piercing (HVAP) Shot is lighter than the other armor-piercing projectile of the same caliber, and it is fired

at higher velocities. The HVAP shot has a pointed cylindrical core of tungsten carbide. The core has great density and hardness. This type of projectile is obsolescent and is being replaced by more modern types, such as HVAPDS.

1-17. Hypervelocity Armor-Piercing Discarding Sabot (HVAPDS) Ammunition. This type of ammunition consists of a subcaliber projectile comprising a carbide core in a light alloy or steel sheath. The subcaliber projectile is placed inside a full-caliber carrier (called a "sabot") designed to impart velocity and spin to the projectile. As it leaves the gun, the sabot is discarded by the action of centrifugal force, air resistance, or both, allowing the projectile to proceed toward the target unimpeded. Generally made of aluminum, magnesium-zirconium alloy, or plastic, sabots are of three types: pot type, petal type, and latch type. (See Section 2.)

1-18. Hypervelocity Armor-Piercing Discarding Sabot Fin-Stabilized (HVAPDSFS) Shot. The HVAPDSFS shot is a fin-stabilized kinetic energy projectile designed for extremely high muzzle velocities. It is characterized by an extremely high length-over-diameter ratio. Its long thin appearance has led to its being referred to as the "arrow" projectile. It may be fired from either rifled or unrifled barrels by means of a sabot. It is currently in the development stage and has given some very promising results.

1-19. High-Explosive Plastic (HEP) Shell are unique in antitank warfare, as they attempt to defeat tanks without penetrating the armor. The explosive is made in a molded plastic form and flattens out when the projectile strikes the target. The detonation of the explosive on the face of the armor causes a rupture on the opposite side. This ruptured portion is known as a spall, which causes damage inside the tank, dependent on the velocity and mass of the spall. The mass and velocity of the spall depends on the quality and thickness of the armor, and the mass, type, and shape of the explosive filler. This shell has not yet been fully developed, and little of the theory is known. A more complete description of available theory and design is given in Section 2.

1-20. Canister Ammunition consists of slugs (small cylinders from bar stock), steel balls, or flechettes (stabilized fragments with pointed nose and finned tail), contained by various methods within the shell. The canister projectile consists of a heavy steel base, designed to withstand the firing stresses, and a thin steel tube packed with preformed missiles. As the canister projectile leaves the weapon, the steel case containing the missiles is split open by centrifugal force, and the missiles are distributed in a random pattern. The missiles inflict damage, since a velocity is imparted to them by a propellant charge. A more complete description of canister packing and design is given in Section 2.

1-21. Pyrotechnic - Type Ammunition comprises a group of shells which perform varied functions, but possess certain design similarities. These shells, which are fired from mortars, howitzers, or guns, are made to function by base ejection, separating burst, or explosive burst. In general, they are modifications of the HE shell of the same caliber. Pyrotechnic-type ammunition, grouped together by design similarity, include: illuminating shell, propaganda shell, colored smoke shell, and chaff shell; WP shell, and liquid-filled shell; and colored marker shell. The complete description and design of these shells is given in Section 2.

PROJECTILE COMPONENTS

1-22. The Ogive is the curved portion of the projectile from the point to the bourrelet. The curve of the ogive is usually the arc of a circle whose center is located in a line perpendicular to the axis of the projectile, and whose radius generally is 6 to 11 calibers in length.

1-23. The Bourrelet is an accurately machined cylindrical surface, of diameter slightly larger than the body, that bears on the lands of the bore. The bourrelet centers the projectile in the bore and guides it in its travel through the bore.

1-24. The Rotating Band is a cylindrical ring of comparatively soft material, usually copper, gilding metal, or soft iron, pressed into a knurled or roughened groove near the base of the projectile. When the gun is fired, the

rotating band is engraved by the rifling and imparts spin to the projectile. The band may also be welded to the projectile by the "welded overlay" method.

1-25. Base Cover. Shell containing high explosives usually are provided with a base cover to prevent the hot gases of the propelling charge from coming in contact with the explosive filler of the projectile through possible flaws in the metal of the base.

1-26. Body. The main portion of the projectile ordinarily is called the body. The term "body diameter," however, is used to designate the dimension of the cylindrical portion of the projectile between the bourrelet and the rotating band. In order to prevent contact with the bore, the body diameter is smaller than the diameter of the bourrelet or the rotating band.

1-27. Tracer. For observation of fire, some shell are fitted with a tracer in the base. In some antiaircraft gun projectiles, the tracer ignites a pellet that, after burning a prescribed number of seconds, detonates the explosive filler, should the fuze fail to operate against a target. This type of tracer is known as "shell destroying" (SD).

1-28. Lifting Plug and Grommet. The lifting plug and grommet do not play any part in the firing of the projectile but are included on the larger caliber shell merely for shipping and handling purposes. The lifting plug is an eye bolt that fits into the threaded fuze cavity in the nose of the shell and permits the shell to be handled by means of a winch. The grommet is a rubber-lined steel covering placed over the rotating band to protect it from damage resulting from rough handling. Both are removed before the projectile is used.

FUZES, BOOSTERS, AND DETONATORS

1-29. Introduction. A fuze is a device used with ammunition to cause it to function at the time desired, and under the circumstances desired. Artillery fuzes are classified according to their location on the projectile as base detonating or point detonating. They also are classified according to their method of functioning, as time, impact, or proximity (VT), or may be a combination of these.

1-30. Time Fuzes usually contain a graduated time element in the form of a compressed black powder train, or a mechanism with a gear train like a clock, which may be set to function at a predetermined time after firing.

1-31. Impact Fuzes are classified according to the quickness of action after impact as superquick, nondelay, or delay. See figure 1-2 for action of ammunition at the target according to the quickness of action. Superquick fuzes produce a burst immediately upon impact, before any penetration occurs, thus giving maximum surface effect. Nondelay fuzes are inertia-operative, and burst the projectile on a hard surface before complete penetration or ricochet. Delay fuzes allow penetration of material targets before bursting, or allow air bursts in ricochet fire. The time of action of impact fuzes is measured from the instant of its impact on a target, whereas the time of action of time fuzes is measured from the instant the weapon is fired. An impact fuze intended to function on impact with a very light material target, such as an airplane wing, is called supersensitive.

1-32. Proximity (VT) Fuzes. In effect, VT (Variable Time) fuzes are automatic time fuzes. Without "setting" or adjustment, they detonate the missiles that carry them on approach to the target. Artillery VT fuzes are essentially combination self-powered radio transmitting and receiving units. In flight, the armed fuze broadcasts radio waves. Unlike radar waves, the radio waves are sent continuously and are nondirectional. The radio wave fronts, which are reflected back from airplane, ground, or water to the moving missile, interact with the transmitted wave. When this interaction of transmitted and reflected waves, which results in ripples or beats, reaches a predetermined intensity, it trips an electronic switch. The switch then permits an electric charge that is stored in the firing capacitor to flow through an electric firing squib. The VT fuzes can be used only in deep-cavity shell.

1-33. General Description of Fuzes. In general, modern fuzes consist of a connected series (train) of small explosive charges, together with a striker or firing-pin device for initiating the action of the first charge in the train. The mechanism and explosive elements are held in a body or housing. In modern point-detonating

Figure 1-2. Action of ammunition at the target

(PD) fuzes, the housing is shaped for best ballistics. In impact fuzes now in use, the explosive train usually consists of a small but highly sensitive explosive charge, such as lead azide, in turn followed by a still larger and still less sensitive explosive charge, such as tetryl. Such charges function by successive detonation—hence the term detonating fuzes.

When delay action is desired by the use of a black powder pellet, the initial charge is a primer mixture, which passes a flame to the black powder and, in turn, to a detonator. Black powder is used exclusively in the time train of powder-train time fuzes, and for the magazine charge of both powder-train and mechanical types of time fuzes. Black powder that has been compressed to great density burns slowly, the rate of combustion decreasing as the density increases. In the functioning of a fuze, each charge by its action initiates the next charge in the train. The final charge in the fuze causes the detonation of the booster, which in turn detonates the bursting charge of the shell.

1-34. Bore Safety. To prevent accidental arming during handling and shipping, safety devices, such as a safety wire or a cotter pin, are used when required. In certain types of fuzes, the mechanisms are arranged so that the fuzes are said to be "boresafe" (detonator-safe). A boresafe fuze is one in which the explosive train is interrupted so that, while the projectile is still in the bore of the weapon, premature action of the bursting charge is prevented if any of the more sensitive elements (primer or detonator) function.

1-35. Methods of Arming. A fuze is said to be armed when it is ready to detonate the shell, that is, when all parts are in, or are free to move to, their proper positions in order that the fuze may operate in its intended manner. The principal forces used in arming fuzes are inertia and centrifugal force. In some fuzes, both of these forces are used to activate safety devices; in others, only one is used. Centrifugal force occurs in spinning projectiles. This force may be utilized to actuate gear trains and to move safety devices into their proper positions in fuzes and boosters.

1-36. Boosters. Since the bursting charges of high-explosive shell are relatively insensitive to shock, a comparatively large detonating charge is necessary to ensure a high order detonation of the bursting charge. The use of more sensitive explosives, such as mercury fulminate or lead azide, in the quantities required for the purpose would create excessive hazards in handling and firing; therefore, such explosives are used only in small amounts as initiating and intermediate detonating charges. A separate charge of somewhat less sensitivity, usually tetryl, is provided for detonating the high-explosive charge of the shell. Because its function is to increase or "boost" the effectiveness of the explosive train, this charge is known as a booster charge. The booster charge may be incorporated in the fuze itself, or may be encased in thin metal or plastic which is screwed permanently to the fuze and handled as a unit with the fuze.

1-37. Detonators. A detonator is used in the explosive train to create or transmit a detonation wave to the booster charge, booster lead, or burster. Three types of detonators are used. One contains a primer mixture as the upper layer, for initiation by stab action of a firing pin. Another contains lead azide as the upper layer, for initiation either by flame action from a separate primer, delay pellet, time-train ring, or by detonation of a separate detonator. The third type contains a fine wire or other high-resistance electric circuit in contact with a heat-sensitive primer mixture. Passage of an electric current through the resistance circuit generates heat, which initiates detonation in the primer mixture. Most detonator cups and disks are made of aluminum.

EXPLOSIVES FOR AMMUNITION

1-38. General. To deliver the projectile at the target, and to cause it to function properly on arrival, it is necessary to employ different kinds of explosives, each of which has a specific function in a round of ammunition. The characteristics of the various types of explosives are given in Section 2. The arrangement of a series of explosives, beginning with a small amount of sensitive explosive and ending with a large amount of comparatively insensitive explosive, is called an explosive train.

1-39. Classification of Explosives. Explosives are divided into two basic groups — propellants (low explosives) and high explosives. The propellant reacts by burning, at a rate which depends upon such factors as pressure, grain form, grain size, and composition. The high explosive is used for its detonating properties, which result from the motion of a detonation wave traveling through the high-explosive charge at an extremely high velocity.

1-40. Propellants are used to eject the projectile from the weapon at a prescribed velocity. Those currently used have a nitrocellulose and/or nitroguanidine base. These propellants are distinguished by such terms as single base (those with nitrocellulose), double base (with nitrocellulose and nitroglycerin), or triple base (nitrocellulose, nitroglycerin, and nitroguanidine). Propellants may be called flashless and/or smokeless, but these terms are relative, not absolute.

1-41. High Explosives, because of their extremely rapid rate of detonation, have a powerful disruptive action. The high explosives that are most sensitive to impact are used as initiators in primers or detonators, whereas the high explosives less sensitive to impact are used as bursting charges in shell.

PROPELLING CHARGES

1-42. General. Propelling charges consist of the propellant (essentially nitrocellulose plus other ingredients) with an igniter of black powder, assembled in a suitable container. Generally, in fixed, semifixed, and separated rounds, the full igniter charge is present in a tube attached to the percussion element of the primer. In certain cases, however, such as ammunition for the 75-mm rifle, a supplementary igniter charge is located in the forward end of the cartridge case. In separate-loading rounds, the igniter charge is assembled in a bag sewed to the base end of the propelling-charge bag, and in some cases includes a core running through the center of the propelling-charge bag. See figure 1-1 for representative types of propelling charges.

To control the burning of propellant powder to obtain the desired performance in a particular weapon, the powder is manufactured in several types of grains. For a complete description of the various propellants, their grain types and their characteristics, refer to Section 4.

1-43. Flashless and Smokeless Characteristics. Whether the ammunition upon firing has flashless or smokeless characteristics, or both, depends chiefly upon the chemical composition of the propellant, the design of the ignition system, and the characteristics of the weapon in which the ammunition is fired. Variable factors that must be allowed for in the original design of the flashless-smokeless ammunition are firing temperature, degree of wear of weapon, and weather conditions.

1-44. A Cartridge Case, made of drawn brass or steel, serves as the container for the propelling charge in the instance of fixed and semifixed artillery ammunition. The case has a profile and design to conform to the chamber of the weapon for which the case is intended. The head of the case is relatively thick and has a flange to permit mechanical extraction and to

seat the round in the gun. These rounds used in automatic guns usually have cartridge cases with extracting grooves instead of flanges or rims. The cartridge case holds the primer, the propelling charge, and the projectile (except for separated types), so that the assembly can be inserted into the weapon in one operation. A secondary function is to provide for obturation. The case is sufficiently thin to be expanded by the pressure of the burning gases to a tight fit against the side of the weapon chamber, thereby preventing the escape of gas to the rear.

1-45. The Propelling Charge in a Round of Fixed Ammunition is usually loose powder in the cartridge case. In some instances, where the charge is not large enough to fill the case completely, a distance wadding, usually a cardboard disk and cylinder or felt pads, is inserted in the neck of the cartridge case, between the powder charge and the base of the projectile. In some instances, the same function may be served by enclosing the charge in a cloth bag inside the case. Where the primer charge is insufficient for satisfactory ignition of the propelling charge, a supplementary igniter charge of black powder may be attached to the distance wadding to supplement the primer ignition.

1-46. The Propelling Charge in a Round of Semifixed Ammunition is in cartridge bags in the cartridge case. Since the cartridge case is loosely fitted to the projectile, some of the bags of powder may be removed prior to firing to provide for zone firing.

1-47. The Propelling Charge in Separated Ammunition. In "separated" ammunition, the separately loaded propelling charge is loosely contained in a cartridge case, which is closed by a "closing plug" made of palmetto pulp, plastic, or cork. An igniter may be placed around the primer to ensure proper ignition.

1-48. Mortar Propelling Charges are made up of several removable parts or "increments" to provide for zone firing. Each increment consists of a charge of smokeless propellant encased in a cotton bag. The bag has a buttonhole at each end to enable it to be fastened to the cartridge housing of the mortar round. The round, as received in the field, has the maximum number of increments fastened to it. The gunner adjusts for zone firing by removing the increments that are not desired.

1-49. Cartridge Bags form a suitable and convenient means of containing the smokeless powder charge in separate-loading ammunition. Cartridge-bag cloth normally is made of silk; bags made of rayon sometimes are used to replace silk. Only certain ash-free grades of this fabric are suitable; other grades might leave smoldering fragments in the bore of the cannon after firing. The products of combustion of smokeless powder are inflammable when mixed with the requisite amount of air. A reignition of gases known as a "flareback" could occur in the presence of these smoldering particles.

Cartridge igniter bags are made of silk, and the cloth is similar to cartridge-bag cloth, except that it is more closely woven in order to prevent the black ignition powder from sifting through. To date no suitable substitutes for silk have been found.

For a further discussion of the propelling charges, and a description of propelling charges for particular guns, refer to Section II, chapter 3, of reference 3, and also Section 4 of this handbook.

1-50. Primers and Ignition Charges. A primer is used in a propelling-charge explosive train as the component that initiates burning of the propelling charge by a flame. Such primers vary in size and complexity, depending upon their type and the quantity of propelling charge to be ignited. For example, the propelling charge of 20-mm rounds is so small, relatively, that the primer is merely a sensitive element assembly that is inserted directly into the primer pocket of the cartridge case. In larger caliber rounds, the primer contains a sensitive element of primer mixture or other explosive, plus a primer charge of black powder to ensure proper ignition of the larger propellant charges. Where sufficient black powder cannot be loaded into the primer body to ensure proper ignition, a separate bag of black powder, called an igniter charge assembly, is placed with the propellant.

Primers may be classified by method of ignition as percussion, initiated by a sharp blow from a firing pin in the weapon; or electric, initiated by sending a small electric current through a resistance wire embedded in an explosive, or through a conductive primer mixture.

GENERAL DESIGN REQUIREMENTS

1-51. Unique Functioning. The unique function of ammunition must be considered in the design of complete rounds and their components. Practically all ammunition items are required to function only once. This one time, they must function as intended, with a very high degree of certainty. Usually, they are used without any previous preparation or adjustment, after subjection to handling and storage that may have gone on for periods of years, sometimes under very adverse conditions.

This peculiarity of function imposes certain design requirements of a restrictive nature, such as:

1. Ruggedness
2. Corrosion prevention
3. Prevention of deterioration of materials.

On the other hand, this peculiarity makes it possible to neglect certain other factors that ordinarily must be given consideration, such as:

1. Wear
2. Fatigue
3. Permanent deformation of certain parts as a normal consequence of its functioning.

1-52. Quantity Production Requirements. Another general characteristic of nearly all ammunition components is that they are made in large quantities. Quantity production makes it economical to provide special tools, automatic or semi-automatic machines, and other special mass production equipment for their manufacture, loading, assembly, inspection, testing, and the like. In the design of ammunition components, their forms, dimensions, and tolerances must be kept in mind for mass production purposes.

1-53. Forces Acting on Projectiles in Handling. Normally, projectiles are subject to rough handling. They may be dropped, or they may roll and tumble against each other, both in shipment and in use. Some of the areas of the projectile that may be subject to damage as a result of this handling are listed below, together with the nature of the damage that might be expected.

1. Rotating bands — indentations or scars.
2. Fins — breaking or bending.
3. Setback arming devices becoming armed.
4. Explosive elements — primers and detonators are liable to detonation if subjected to severe shock deformation or movement.
5. Chemical fillers — leakage.

Such damage can be minimized by proper choice of materials, by the avoidance of sharp corners or edges subject to breakage, and by proper packing.

1-54. Design Considerations From Storage Requirements. Since ammunition may be stored for long periods of time, under adverse conditions of temperature and humidity, the following factors must be considered.

1. Malfunctioning or loss of accuracy caused by extremes of temperature.
2. Malfunctioning or loss of accuracy resulting from exposure to dust or sand.
3. Malfunctioning or loss of accuracy resulting from exposure to rain or snow, and immersion in water.
4. Stability of explosives and other chemically reactive material.
5. Resistance of metal parts to corrosion.
6. Resistance of nonmetallic materials to deterioration.

BIBLIOGRAPHY

1. Hayes, T. J., "Elements of Ordnance," John Wiley and Sons, New York, 1938.
2. Ammunition, General, TM 9-1900, War Department Technical Manual, June 1945.
3. Artillery Ammunition, TM 9-1901, Department of the Army Technical Manual, September 1950.

ENGINEERING DESIGN HANDBOOK SERIES

The Engineering Design Handbook Series is intended to provide a compilation of principles and fundamental data to supplement experience in assisting engineers in the evolution of new designs which will meet tactical and technical needs while also embodying satisfactory producibility and maintainability.

Listed below are the Handbooks which have been published or submitted for publication. Handbooks with publication dates prior to 1 August 1962 were published as 20-series Ordnance Corps pamphlets. AMC Circular 310-38, 19 July 1963, redesignated those publications as 706-series AMC pamphlets (i.e., ORDP 20-138 was redesignated AMCP 706-138). All new, reprinted, or revised handbooks are being published as 706-series AMC pamphlets.

General and Miscellaneous Subjects

Number	Title
106	Elements of Armament Engineering, Part One, Sources of Energy
107	Elements of Armament Engineering, Part Two, Ballistics
108	Elements of Armament Engineering, Part Three, Weapon Systems and Components
110	Experimental Statistics, Section 1, Basic Concepts and Analysis of Measurement Data
111	Experimental Statistics, Section 2, Analysis of Enumerative and Classificatory Data
112	Experimental Statistics, Section 3, Planning and Analysis of Comparative Experiments
113	Experimental Statistics, Section 4, Special Topics
114	Experimental Statistics, Section 5, Tables
134	Maintenance Engineering Guide for Ordnance Design
135	Inventions, Patents, and Related Matters
136	Servomechanisms, Section 1, Theory
137	Servomechanisms, Section 2, Measurement and Signal Converters
138	Servomechanisms, Section 3, Amplification
139	Servomechanisms, Section 4, Power Elements and System Design
170(C)	Armor and Its Application to Vehicles (U)
270	Propellant Actuated Devices
290(C)	Warheads--General (U)
331	Compensating Elements (Fire Control Series)
355	The Automotive Assembly (Automotive Series)

Ammunition and Explosives Series

175	Solid Propellants, Part One
176(C)	Solid Propellants, Part Two (U)
177	Properties of Explosives of Military Interest, Section 1
178(C)	Properties of Explosives of Military Interest, Section 2 (U)
210	Fuzes, General and Mechanical
211(C)	Fuzes, Proximity, Electrical, Part One (U)
212(S)	Fuzes, Proximity, Electrical, Part Two (U)
213(S)	Fuzes, Proximity, Electrical, Part Three (U)
214 (S)	Fuzes, Proximity, Electrical, Part Four (U)
215(C)	Fuzes, Proximity, Electrical, Part Five (U)
244	Section 1, Artillery Ammunition--General, with Table of Contents, Glossary and Index for Series
245(C)	Section 2, Design for Terminal Effects (U)
246	Section 3, Design for Control of Flight Characteristics
247(C)	Section 4, Design for Projection (U)
248	Section 5, Inspection Aspects of Artillery Ammunition Design
249(C)	Section 6, Manufacture of Metallic Components of Artillery Ammunition (U)

Ballistic Missile Series

Number	Title
281(S-RD)	Weapon System Effectiveness (U)
282	Propulsion and Propellants
284(C)	Trajectories (U)
286	Structures

Ballistics Series

140	Trajectories, Differential Effects, and Data for Projectiles
160(S)	Elements of Terminal Ballistics, Part One, Introduction, Kill Mechanisms, and Vulnerability (U)
161(S)	Elements of Terminal Ballistics, Part Two, Collection and Analysis of Data Concerning Targets (U)
162(S-RD)	Elements of Terminal Ballistics, Part Three, Application to Missile and Space Targets (U)

Carriages and Mounts Series

341	Cradles
342	Recoil Systems
343	Top Carriages
344	Bottom Carriages
345	Equilibrators
346	Elevating Mechanisms
347	Traversing Mechanisms

Materials Handbooks

301	Aluminum and Aluminum Alloys
302	Copper and Copper Alloys
303	Magnesium and Magnesium Alloys
305	Titanium and Titanium Alloys
306	Adhesives
307	Gasket Materials (Nonmetallic)
308	Glass
309	Plastics
310	Rubber and Rubber-Like Materials
311	Corrosion and Corrosion Protection of Metals

Surface-to-Air Missile Series

291	Part One, System Integration
292	Part Two, Weapon Control
293	Part Three, Computers
294(S)	Part Four, Missile Armament (U)
295(S)	Part Five, Countermeasures (U)
296	Part Six, Structures and Power Sources
297(S)	Part Seven, Sample Problem (U)