Downloaded from http://www.everyspec.com

DARCOM PAMPHLET DARCOM-P-706-253

LEVEL

AD A079666

DDC FILE COPY

ENGINEERING DESIGN HANDBOOK

BREECH MECHANISM DESIGN

Accession For	
NTIS GRA&I	
DDC TAB	
Unannounced	
Justification	
By	
Distribution/	
Availability Codes	
Dist	Avail and/or special
A	

DDC
RECEIVED
JAN 18 1980
A

US ARMY MATERIEL DEVELOPMENT AND READINESS COMMAND

FEB [redacted] 79

79 29 1392673

Downloaded from http://www.everyspec.com

UNITED STATES DEPARTMENT OF COMMERCE
National Technical Information Service
5285 Port Royal Road
Springfield, Virginia 22161

Date 16 January 1979

NTIS Control # 015264

TO: Defense Documentation Center - DDC/TC
Cameron Station
Alexandria, Virginia 22314

FROM: NTIS, Input Branch
5285 Port Royal Road
Springfield, Virginia 22161

ADA079666

Report # DARCOM-P-706-253 ADA #

Title: "Breech Mechanism Design"

Subject report is /_/ Standard Process /X/ STG report. STG - Special Technology Group. /_/ Computer Product. /X/ Follow up date 24 Jan.

/_/ The report will be accessioned by DDC. The form noting the ADA number is returned.

/_/ The report has been assigned the ADA number noted above and is returned to NTIS for processing.

/_/ DDC will not process the report. It is returned to NTIS.

Mag Tape Price
PC & MF Price 12.50
Stock Quantity 109
Comments: Bin-800
field 4 - PC E05
MF E05

Source A DARC field 3
Source Share 6.50
NTIS- 6.00

Signature (for billing)

Copy when completed to
Finance Branch.

DOD Report Action Request
(Replaces NTIS-164 5-72)

Dottie Adams
processor

~~Please return this form to NTIS-Input~~
~~attention: Dottie Adams~~

Downloaded from http://www.everyspec.com

DEPARTMENT OF THE ARMY
HEADQUARTERS US ARMY MATERIEL DEVELOPMENT AND READINESS COMMAND
5001 Eisenhower Avenue, Alexandria, VA 22333

DARCOM PAMPHLET
No. 706-253

February 1979

ENGINEERING DESIGN HANDBOOK
BREECH MECHANISM DESIGN

TABLE OF CONTENTS

Downloaded from http://www.everyspec.com

TABLE OF CONTENTS (cont'd)

Downloaded from http://www.everyspec.com

TABLE OF CONTENTS (cont'd)

Downloaded from http://www.everyspec.com

TABLE OF CONTENTS (cont'd)

Paragraph *Page*

CHAPTER 3.
DESIGN CRITERIA AND PROCEDURES—INITIATION THROUGH PROTOTYPE

Downloaded from http://www.everyspec.com

TABLE OF CONTENTS (cont'd)

Downloaded from http://www.everyspec.com

TABLE OF CONTENTS (cont'd)

Downloaded from http://www.everyspec.com

LIST OF ILLUSTRATIONS

Downloaded from http://www.everyspec.com

LIST OF ILLUSTRATIONS (cont'd)

Downloaded from http://www.everyspec.com

LIST OF ILLUSTRATIONS (cont'd)

Downloaded from http://www.everyspec.com

LIST OF TABLES

Downloaded from http://www.everyspec.com

PREFACE

The Engineering Design Handbook Series of the US Army Materiel Development and Readiness Command is a coordinated series of handbooks containing basic information and fundamental data useful in the design and development of Army materiel and systems. The handbooks are authoritative reference books of practical information and quantitative facts helpful in the design and development of Army materiel so that it will meet the tactical and the technical needs of the Armed Forces.

This handbook has been prepared as an aid to engineers designing breech mechanisms. Fundamental design information not readily attainable elsewhere is presented along with requirements and problem areas that are unique to breech mechanisms.

The material presented in this handbook is composed of data and design information gathered from many sources; however, treatment is limited to one of condensation and summary because of the subject scope. References appear at the end of each chapter for guidance in acquiring additional information. A glossary has been provided at the end of the handbook.

When reference is made to Military Specifications, regulations, or other official directives, it is done to reveal the existence of these documents. In this respect, the user should obtain the current editions for applications.

This handbook was prepared by IIT Research Institute under subcontract to the Engineering Handbook Office of the Research Triangle Institute, Research Triangle Park, NC, prime contractor to the US Army Materiel Development and Readiness Command for the Engineering Design Handbook Series. Members of the Benet Weapons Laboratory—a US Army Armament and Development Command organizational element located at Watervliet Arsenal—provided guidance, review of the text material, and support by furnishing source data and references. Major contributions to the preparation of this handbook were made by Mr. Frank Bartos and Mr. Milton Nusbaum, IIT Research Institute.

The US Army DARCOM policy is to release these Engineering Design Handbooks in accordance with DOD Directive 7230.7, 18 September 1973. Procedures for acquiring Handbooks follow:

a. All Department of Army (DA) activities that have a need for Handbooks should submit their request on an official requisition form (DA Form 17, 17 January 1970) directly to:

Commander
Letterkenny Army Depot
ATTN: SDSLE—AJD
Chambersburg, PA 17201.

"Need to know" justification must accompany requests for classified Handbooks. DA activities will not requisition Handbooks for further free distribution.

b. DOD, Navy, Air Force, Marine Corps, nonmilitary Government agencies, contractors, private industry, individuals, and others—who are registered with the Defense Documentation Center (DDC) and have a National Technical Information Service (NTIS) deposit account—may obtain Handbooks from:

Defense Documentation Center
Cameron Station
Alexandria, VA 22314.

Downloaded from http://www.everyspec.com

c. Requestors, not part of DA nor registered with the DDC, may purchase unclassified Handbooks from:

National Technical Information Center
Department of Commerce
Springfield, VA 22161.

Comments and suggestions on this Handbook are welcome and should be directed to:

US Army Materiel Development and Readiness Command
5001 Eisenhower Avenue
Alexandria, VA 22304.

DA Form 2028, Recommended Changes to Publications, which is available through normal publication supply channels, may be used for comments/suggestions.

Downloaded from http://www.everyspec.com

Topics include: Breech Mechanism Types, Design Constraints -- Ammunition constraints, weapon interfaces, Breech and subassemblies, Functional requirements, Design requirements; Design Criteria and Procedures -- Initiation through prototype, Development Criteria and Procedures, and Production Planning.

CHAPTER 1
INTRODUCTION
SECTION I. GENERAL CONSIDERATIONS

1-1 HANDBOOK SCOPE

This handbook is devoted to a description of a rational design sequence and methodology needed to take a particular breech mechanism from conception—as prompted by military needs and technical requirements generated for a given weapon—to the stage of acceptance and production. Major divisions of the handbook provide information and guidance on the various design interrelationships involved.

The designer should keep in mind that the sole purpose of a weapon system is to provide the firepower needed to meet the system requirements. The breech mechanism is one of several key subassemblies in the cannon subsystem which in turn is one of several that make up the total weapon system. One particularly important function which this handbook serves is to assist engineers, without prior breech mechanism design experience, in the design of this significant cannon subassembly. Normally, the design may be best achieved by a team of engineers comprised of a group of multidisciplinary specialists, each with competence in a specific area related to the breech mechanism. These areas include: configuration innovation; design analysis (kinematic, kinetic, stress, weight, and reliability); material selection; maintenance; production; and cost. This group should also include an experienced technical manager to assure that each member has equal stature and responsibility, and that their particular expertise is applied consistently. The design team has a responsibility which starts with the breech mechanism concept and continues throughout the service life of the weapon system. Section III of this chapter describes design responsibility and the team approach more fully.

Subject content and scope of the handbook deserve a degree of definition as early as possible. Specifically, the handbook contents are limited to breech mechanisms of crew-served, "large caliber", land based guns and howitzers, including self-propelled weapons and tank guns. The treatment is oriented toward design guidance, design examples, and engineering data as practical. Breech mechanism design for mortar, recoilless, and other weapon types has been left for coverage in subsequent handbooks.

The meaning of "large caliber" weapon has different connotations among the various handbook users. Because it is a less than rigorously defined term and undoubtedly no single definition will enjoy full consensus, further discussion of "large caliber" is provided in par. 1-2. On the basis of Army weapons previously or presently in existence, an overall range from 37 mm to 280 mm bore diameter can be offered for reader guidance; but the upper limit of caliber easily extends to 16 in. bore, if seacoast or railroad artillery is included.

However, in the context of this handbook, emphasis is justifiably placed on more current weapon applications and first-line equipment — having a caliber range of about 105 mm to 8 in. (203.2 mm). Of course, weapons within the broader size range are also covered wherever they provide information significant to breech design. Weapons no longer in use and ones having future potential comprise such inputs.

The subject of breech mechanism design entails a large number of topics; accordingly, detailed, comprehensive coverage in one convenient volume is an impossibility. Therefore a generalized approach is used, as suitable, in order to make the discussions applicable to a number of

Downloaded from http://www.everyspec.com

similar cases. Users of this handbook should not expect to find complete, step-by-step procedures on every conceivable breech design problem or applications they might encounter (e.g., antiaircraft or antitank artillery, *per se*). The assumption is made that the handbook users are competent to modify the given procedures to make them applicable to specific cases.

1-2 TERMINOLOGY WITH RESPECT TO CALIBER

The approach is taken in this handbook to arrive at the designation "large caliber" weapon—and more particularly to its lower and upper bounds. Refs. 1 to 3 are in general agreement that a bore diameter larger than 30 mm (1.181 in.) constitutes a "large caliber" weapon; this size limit is also given in the basic definition of both "gun" and "howitzer". The lower bound of weapon size under consideration here is further related to the administratively set maximum bore of 40 mm for small arms (Ref. 2).

The upper bound of "large caliber" weapon size is difficult to set. Certainly, historic evidence shows the existence of extremely large bore weapons in former times. In World War I, European armies commonly employed railway artillery and siege guns of fantastic calibers. Even as late as World War II, operational use of an 800 mm (31.5 in.) railway gun can be cited (Ref. 4). The foregoing examples, however, are extreme and special cases. Even though such weapons show virtually no theoretical size limit, they are of little significance toward realistic breech mechanism design.

On the other hand, practical design limits are numerous as well as stringent. Today, the multiple constraints of mobility, maintainability, and reliability—coupled with drastically different tactical concepts and specific weapon missions—impose the realistic upper bound on weapon size. A practical size limit of 8 in. (203 mm) is not likely to be exceeded by military requirements of the foreseeable future.

The various elements of the breech system are individually treated at appropriate points of the handbook. A glossary of technical and ordnance terms used in the handbook and requiring separate definition appears at the end of the volume.

1-2.1 BREECH MECHANISM DEFINITION

The handbook glossary provides terminology definitions for the important components and mechanisms which comprise a breech mechanism. Webster's Third New International Dictionary provides the following definitions:

1. Breech. The part of a cannon or other firearm at the rear of the bore.
2. Breechblock. The block in breech-loading firearms that closes the rear of the bore against the force of the charge.
3. Breech mechanism. The mechanism for opening and closing the breech of a breech-loading firearm, especially of a heavy-caliber gun.

The purpose of the handbook may be better served by the definition that follows. The totality of devices and components: for closing the rear end of a gun after loading (likewise for convenient access after firing); for firing the round of ammunition that has been inserted; for containing and sealing the tremendous pressure developed; and for removing any ammunition components not projected—all comprise the breech mechanism.

The forward and rear ends of a weapon are referred to commonly as "muzzle end" and "breech end", respectively. The muzzle is the end of the gun tube from which the projectile emerges and the breech end is that into which the round of ammunition is inserted.

1-2.2 BREECH MECHANISM FUNCTIONS

The two basic functions of a large caliber weapon breech mechanism are diametrically opposed. The mechanism must, on the one hand,

Downloaded from http://www.everyspec.com

open and be accessible for conveniently receiving each new round of ammunition — also for extracting any remnants of the previous firing. On the other hand, it must be able to close rapidly and at the same time provide adequate structural integrity to contain the high propellant pressures developed in the weapon chamber.

These primary functions are part of a definite sequence in which the breech mechanism elements operate. The operational cycle consists of a number of actions occurring in succession, which must be accomplished simply and economically, yet with a high degree of reliability. Functional sequence is similar for the weapons under consideration here, however, some variations do exist.

The functions of the breech mechanism are performed by six major subassemblies and a safety provision:

1. Breech ring
2. Breechblock
3. Operating mechanism
4. Firing mechanism
5. Obturating mechanism
6. Extracting mechanism
7. Safety interlocks.

1-3 TYPICAL OPERATIONAL CYCLE

Assume that the breech is empty and the breechblock has been opened; an operating cycle then can be conveniently described beginning with the ammunition loading function. For smaller weapons, ammunition is inserted into the breech by hand; but as weapon caliber becomes larger, assist devices are generally necessary.

The breech is closed behind a new round by the breechblock. The method of closing varies according to breech and ammunition type, weapon application, etc., as detailed later. However, operating mechanisms produce rotary, pivot, slide, or hinge motions in the block. In smaller caliber weapons the breechblock moves at right angles to the chamber axis to cover or uncover the chamber opening. This kind of breech, broadly termed the slide block type, generally has been associated with weapon sizes to 120 mm bore for reasons elaborated in Chapter 1, Section II. Similarly, larger caliber weapons (approximately 155 mm and over) have traditionally used the rotary (screw block) type of closure—where the block is first unlocked by a limited rotation then swung out of the breech recess.

The firing function occurs with the initiation of the primer, after the breech has been closed and locked. Firing mechanisms operate on the principle of percussion or electrical activation, or a combination of the two. During firing, an obturation step comes into play, in which the chamber is sealed against escape of the propellant gases. The device for prohibiting the loss of gases can be either a part of the breech or a part of the ammunition. In smaller caliber weapons traditionally associated with metal cased ammunition, the case itself performs the sealing function; no separate obturating device is required in the breech. Larger caliber weapons have traditionally used separate loading rounds, which have no cartridge case; therefore, such breeches require an obturating mechanism. (Relations between weapon size and ammunition type are treated later.)

After firing, there is a recoil-counterrecoil action in which momentum is exchanged between the stationary and moving parts of the weapon. This is a potential source of energy for actuating the breech and is used in a number of large caliber weapon applications. For guns working in enclosed fighting spaces (tanks, self-propelled weapons), a scavenger device or a bore evacuator usually is employed to purge the chamber of propellant residue or noxious fumes — between successive shots. However, evacuators can only be used if the breech is opened automatically during the last part of the counterrecoil. This particular problem regarding personnel protection rarely exists in guns that are not enclosed.

In manually operated weapons, at this point the breech can be unlocked and opened to permit an extraction function to end the operating cycle. This step removes spent ammunition parts left in

Downloaded from http://www.everyspec.com

the breech. For cased ammunition, extraction of a full size cartridge case is involved; but only a small primer case has to be extracted for separate loading ammunition. Thus, the complexity of the extractor device varies approximately with case size.

SECTION II. BREECH MECHANISM TYPES

1-4 APPLICATION CONSIDERATIONS

The breech mechanism comprises an unquestionably vital subsystem of the overall weapon, but nevertheless it is a subgroup of that larger end item. Thus, breech mechanism classification must include consideration of the total weapon characteristics and the intended mission(s) of the weapon. Important application factors of the overall weapon which bear on breech mechanism design are:

1. Type of ammunition to be fired
2. Gross form taken by the weapon; i.e., towed weapon, self-propelled weapon, or tank (see Fig. 1-1).

Ammunition type exerts great influence on breech design. Obviously, the diversity in weapon applications—antiaircraft, antitank, and tank guns for direct-fire missions; howitzers and maximum range guns for indirect-fire support—requires the use of several kinds of ammunition. In turn, a particular ammunition type is related to the rate of fire, loading task, crew size, and extent of automation required in the breech mechanism. As full recognition of ammunition influences on breech design, pars. 1-4.3, 1-7.2, and Chapter 2, Section I, are devoted to detailed coverage of pertinent ammunition-breech relationships.

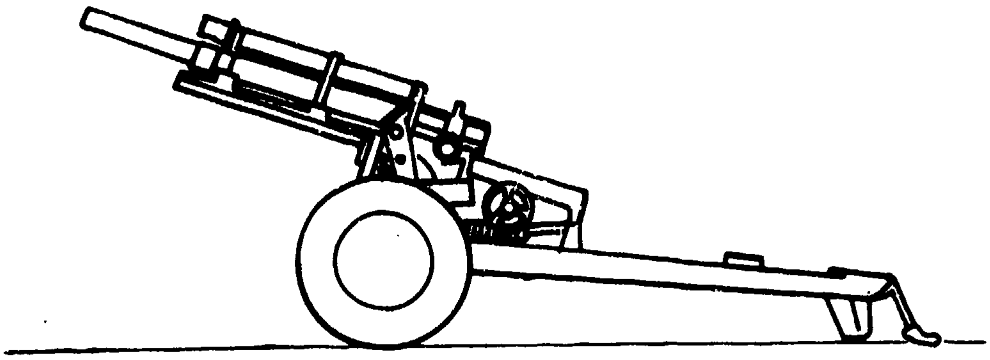
1-4.1 TOWED WEAPONS

Despite the many advances of materiel modernization, towed weapons have retained a definite place within Army requirements. Even without motive power of their own, they can provide offsetting qualities which maintain their useful role. Versatility in employment ability, to closely accompany or support troops, and ability to provide good firing rates with simple breech mechanisms are among the positive attributes of this weapon category. Technical developments are also well utilized in towed weapons; availability of newer materials with better physical properties coupled with optimum design applications has resulted in weight reductions without sacrifice in performance. One very significant example of lighter weight weapon design is the 105 mm Howitzer, M102 (see Table 1-1) which now makes helicopter transportability a routine operation. Designs that can provide the additional feature of "air mobility" further reduce the traditional disadvantage associated with towed weapons.

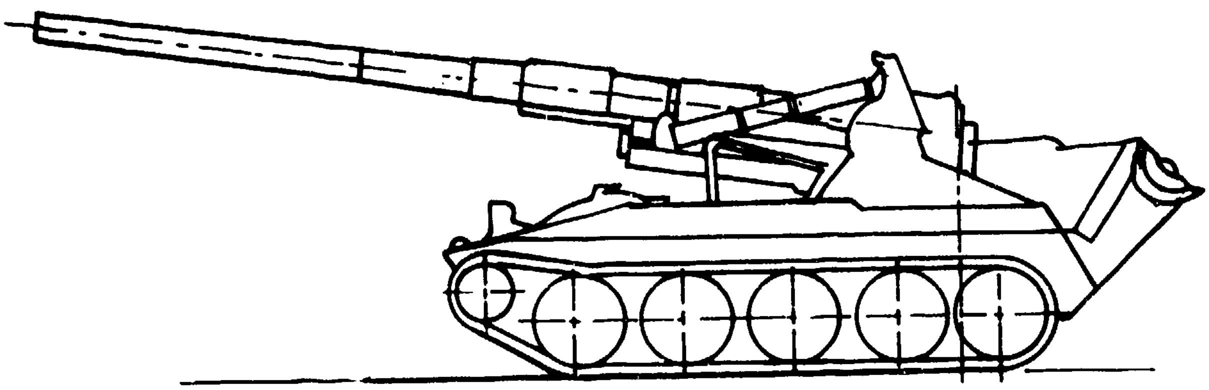
Simpler, more self-contained breech mechanisms are required for towed weapons as compared with self-propelled types; this consideration extends to other subsystems of the weapon as well. The degree of breech mechanism sophistication possible is set by many factors, but in towed weapons the lack of external power imposes one definite limit. (Existence of auxiliary propelled field pieces is recognized—e.g., the 155 mm Howitzer, M123A1—however, such power sources have limited capability even for motive power and are impractical for breech assistance.) Therefore the breech designer must employ internal power sources as practicable (par. 2-15.2.1) and substantial design ingenuity to achieve automation of certain breech functions.

Normally, breech operations are accomplished manually. This is quite acceptable up to the weapon calibers where ammunition type, physical package, and handling requirements are such that competitive weapon performance is achieved. For towed weapons it is an acceptably

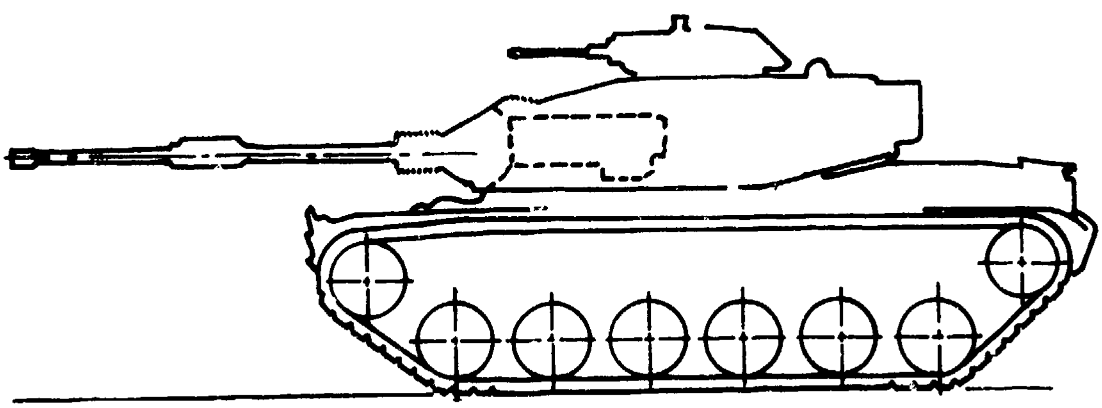
Downloaded from http://www.everyspec.com



(A) 105 mm Howitzer, M101A1 (Towed)



(B) 175 mm Self-Propelled Gun, M113A1 (M107 Tracked Vehicle)



(C) 105 mm Gun, M68 (M60A1 Combat Tank)

Figure 1-1. Large Caliber Weapon Forms

Downloaded from http://www.everyspec.com

TABLE 1-1. TOWED WEAPON CHARACTERISTICS AS RELATED TO BREECH DESIGN (Refs. 9 to 13)

	WEAPON (Caliber, Type and Model)	Breech Mechanism Type	Ammunition Type	Firing Mechanism Type	Recoil Distance min-max, in.	Elevation min-max, deg+	Traverse Angle, ±deg	Firing Rate, rounds/min Burst• (Sustained)	Estimated Breech Mechanism Weight lb	Max Rated Chamber Pressure, psi	Breech Operating Mode
CURRENT MODELS	105 mm Howitzer, M101A1	Horizontal Sliding Wedge	Semifixed	Continuous-Pull Percussion (M13)	39-42	-5 +65	22.5	10 (3)	360	28,000	Manual
	105 mm Howitzer, M102	Vertical Sliding Wedge		Percussion	30-[illegible]		360		*	*	
	155 mm Howitzer, M114A1	Interrupted Screw (Stepped-Thread)	Separate Loading	Percussion Hammer (M1)	41-60	0 +65	23.5	4 (1)	830	*	
	8 in. Howitzer, M115				51-70	-2 +65	30	1.5 (0.5)	*	*	
REPRESENTATIVE OLDER MODELS	37 mm Antitank Gun, M3A1	Vertical Sliding Wedge	Fixed	Percussion**	20-20.5	+10 +15	30	25 —	*	50,000	Manual
	75 mm Pack Howitzer, M116	Horizontal Sliding Wedge	Semifixed	Continuous-Pull Percussion (M13)	27-32	-5 +45	3	8 (2.5)	121	26,000	
	120 mm Antiaircraft Gun, M1	Vertical Sliding Wedge	Separated	Spring Actuated Inertia Percussion **	31-44 (At 0°) 34-36 (At 80°)	5 +80	360	12 --	*	38,000	Semiautomatic++
	155 mm Howitzer, M1A1	Interrupted Screw (Stepped-Thread)	Separate Loading	Percussion Hammer (M1)	41-58	2 +65	26.5	2 (2/3)	840	40,000	Manual
	240 mm Howitzer, M1				**-60	+15 +65	22.5	1 (0.5)	*	36,000	
	280 mm Gun, T131			Electric or Percussion	40-95	0 +55	7.5		*	*	

LEGEND:
- \+ — Negative minimum elevation indicates depression } To obtain mils, multiply by 17.778.
- @ — ± indicates both right and left traverse. } To obtain mils, multiply by 17.778.
- • — Firing rate, first 3 min.
- * — No information.
- ** — Conflicting or insufficient information
- ++ - External power used to great degree. Remote power control, automatic loader, rammer, fuze setter. Bulky overall system. Cannon weight 10,675 lb.

Downloaded from http://www.everyspec.com

large, proficient gun crew, and lesser space constraints that make the performance possible. In the upper caliber range of weapons, e.g., above 155 mm bore, the physical size of ammunition and inherent weapon functions hold down the rate of fire without the presence of power assists. It is in this area where innovative uses of internal power to automate breech functions are most desirable and also the most difficult to achieve.

The preceding is not to say that breech mechanism automation has not been achieved at all in towed weapons. Indeed, several weapons have used recoil system energy to obtain semiautomatic breech operation, wherein several functions are removed from the hand operation mode. Recoil energy is the most commonly used internal power source and the sliding wedge type breech is especially well suited for actuation by the readily available linear motion of a gun in recoil (see pars. 1-5.2 and 2-15.2.1). Probably the best example of recoil energy utilization in a towed weapon is the 75 mm Antiaircraft Gun, T83E1.

Towed weapons, particularly howitzers, impose additional limits on recoil energy utilization, in firing variable charge ammunition (pars. 1-4.3 and 2-2). Inherent to the weapon structure, a long recoil stroke is necessary to contain the largest charge used. Consequently, at a low zone fire mission, the recoil stroke is much shorter thus making it difficult to provide for breech actuation. Also, high elevation fire in the lower zones, provides low counterrecoil force for operating the breech. The magnitude of this force is a special problem in lighter weight weapons. Further consideration of this design problem is given in par. 1-6.2.

Nevertheless, recent attempts to develop a rapid-fire towed artillery weapon have taken place in the 105 mm howitzer category and include interesting concepts of recoil energy usage. Single and multiple, revolving or indexing chamber breeches; loader-rammer mechanisms; rotary magazines; and their combinations are some breech automation techniques for which feasibility has been shown. Although none of these concepts meets all military requirements or rigors of that environment, some are promising and offer noteworthy examples for the designer's awareness (Refs. 5 to 8).

Breech system oriented engineering data and related characteristics of both current and previously used weapons represent design state of the art in one form. Table 1-1, offered for guidance of the designer, is a compilation of pertinent data on representative towed weapons from Refs. 9 to 13.

1-4.2 SELF-PROPELLED WEAPONS

In the context of this handbook, all weapons of an applicable caliber permanently mounted on a mobile platform—including self-propelled guns, howitzers, and tank guns—comprise the self-propelled weapon category. At the same time, the distinctly different missions of the various total weapon systems involved cannot be overlooked. Self-propelled guns and howitzers retain the basic mission of artillery. They provide accurate, indirect supporting fire at medium to long range and offer the advantage of full mobility under their own power. These weapons are not normally used in direct confrontation with the enemy, therefore structural and armor protection incorporated around a cannon varies greatly from model to model, but is much less than found on tanks. In contrast, tanks mainly provide direct fire coupled with the greatest degree of mobility possible. They are essentially assault weapons, able to close with the enemy, yet fully enclosed and heavily armored to withstand counterfire.

Several factors which have bearing on breech design stem from characteristics of the overall weapon system. Presence of a vehicle power plant makes external power more readily available for breech actuation. To be sure, this is far from the only criterion for deciding to use external power. Rather, the interplay between various constraints of a given weapon system set the extent of

Downloaded from http://www.everyspec.com

external power utilization. Type and size of ammunition, fighting compartment space, and whether internal power is available in a particular application are just some of the constraints the designer will encounter.

Breech operation is automated to some degree in all self-propelled weapons. This ranges from power assist given to important interface functions in some artillery pieces (e.g., loading/ramming, Fig. 2-35(B); to semiautomatic operation of more major breech functions by internal means, as in a number of artillery and tank applications; to more specialized situations demanding still further automation of the breech system. (Presently, the latter condition is exemplified in the 152 mm Gun/Launcher discussed at various points in the handbook see Fig. 2-36). However, full automation of all breech mechanism functions has not been reached (see par. 2-15.2). To the extent that powered operations are unavailable or impractical, manual operation is used. Manual actuation for certain breech operations need not be a design detriment; in any event, critical automated functions require manual back-ups in case of malfunction or emergency.

Space is generally at a premium in any fighting vehicle. An increase in available space is equivalent to an increase in weight and size. Both of these factors increase vulnerability. A weight increase reduces maneuverability while an increase in size provides a larger target. Nevertheless, space constraints are more severe for tanks than for self-propelled artillery. In certain models of the latter it is acceptable to eliminate defensive structural protection, thereby greatly easing space constraints (Fig. 1-1(B)). Thus the self-propelled weapons—175 mm Gun, M113A1, and 8 in. Howitzer, M2A2 (Table 1-2)—can use a convenient, hydraulically actuated mechanism for the loading and ramming of projectiles (see Fig. 2-35(B)). A rugged and traditional mechanism of this type could not have been used if the cannon were more fully enclosed.

Depending on application, other self-propelled weapons are armored, turreted, or otherwise enclosed — e.g., 105 mm and 155 mm Howitzers (M103 and M126A1), vehicles M108 and M109 (Table 1-2). In these weapon examples, tradeoffs between the ammunition handling task and space allotments rule in favor of manual loading. Instead, the available recoil motion is utilized for such functions as breech opening and closing, open position lockout during insertion of a round, case or primer extraction as applicable, etc. The breech mechanism becomes "semiautomatic" when the foregoing operations (or others) no longer require manual actuation.

Self-propelled vs towed weapons exhibit shorter recoil strokes because the inherently greater system weight and stiff vehicle structure can better contain the generated recoil forces. In tank guns, recoil distance is further curtailed for the additional reason of very limited space within the turret. Yet in tank weapon systems—firing conventional ammunition—a limited but sufficient recoil motion exists to permit semiautomatic breech operation.

The advent of nonconventional ammunition has caused significant changes in traditional weapon design. Specific ammunition influences are discussed in pars. 1-4.3, 1-7.2, and 2-1; however, the example of the 152 mm Gun/Launcher (M81 and M162 versions) is again cited, in connection with the special power requirements of its breech. These hybrid weapon systems—which fire guided missiles as well as conventional projectiles from the same rifled tube — find current application in one model of the M60 Tank and the full tracked, Airborne Reconnaissance/Armored Assault Vehicle (AR/AAV), M551. The low propellant energy of the guided missile—hence low recoil energy availability — and the requirement for rapid fire make the use of external power mandatory. Breech actuation in the 152 mm Gun/Launcher is semiautomatic. An electric motor driven power train provides the complex breech motion needed in this special design (see par. 1-5.3).

In tank guns, a number of breech interface devices may also be used which require designer attention. Mechanisms of this type include recoil

Downloaded from http://www.everyspec.com

TABLE 1-2. SELF-PROPELLED WEAPON CHARACTERISTICS AS RELATED TO BREECH DESIGN (Refs. 9 to 13)

	WEAPON (Caliber, Type, Model and Associated Vehicle)	Breech Mechanism Type	Ammunition Type	Firing Mechanism Type	Recoil Distance min-max, in.	Elevation min-max, deg†	Traverse, deg	Firing Rate, rounds/min Burst• (Sustained)	Estimated Breech Mechanism Weight, lb	Total System Weight, ton	Max. Rated Chamber Pressure, psi	Breech Operating Mode
CURRENT MODELS	105 mm Gun, M68 (M60A1 Combat Tank)	Vertical Sliding Wedge	Fixed	Electric††	12	-10 +20	360	* (6)	825	53	61,600	Semiautomatic
	105 mm Howitzer, M103 (M108 Self-Propelled, Tracked Vehicle)		Semifixed	Spring Actuated, Inertia Percussion		-6 +75		10 (3)	375	23.1	36,700	
	152 mm Gun/Launcher, M162 (M60A1E1, M60A2 Combat Tank	Separable Chamber▲	Fixed and Guided Missile♯	Electric	7	-10 +20		* (4)	510	57.2	38,400	
	155 mm Howitzer, M126A1 (M109 Self-Propelled Tracked Vehicle)	Interrupted Screw (Single-Cut Thread)	Separate Loading	Continuous-Pull Percussion, In-Line Hammer (M35)	24-36	-3 +75		4 (1)	670	26.2	41,000	
	175 mm Gun, M113A1 (M107 Self-Propelled Tracked Vehicle)	Interrupted Screw (Stepped-Thread)			29-70	+2 +65	30@	1.5 (0.5)	1750	31.1	51,000	Manual
	8 in. Howitzer, M2A2 (M110 Self-Propelled Tracked Vehicle)									29.3	39,600	
REPRESENTATIVE OLDER MODELS	76 mm Gun, M32 (M41A3 Combat Tank)	Vertical Sliding Wedge	Fixed	Spring Actuated, Inertia Percussion	12	-4 +20	360	* (8)	370	25.9	55,200	Manual**
	90 mm Gun, M41 (M48A3 Combat Tank)					-9 +19		* (8)	788	52	57,700	Semiautomatic
	120 mm Gun, M58 (M103A2 Combat Tank)		Separated		13	-8 +15		* (4)	1680	62.5	57,600	
	155 mm Gun, M46 (M53 Self-Propelled, Tracked Vehicle)	Interrupted Screw (Stepped-Thread)	Separate Loading	Electric or Percussion (T95) **	18-20	-5 +65	30@	1.5 (0.5)	1340	48	47,300	Manual

LEGEND:
- † — Negative minimum elevation indicates depression. } To obtain mils, multiply by 17.778.
- @ — ± Indicates both right and left traverse. } To obtain mils, multiply by 17.778.
- • — Firing rate, first 3 min.
- ▲ — Externally powered semiautomatic breech mechanism (electric). Single-cut, interrupted locking threads.
- †† — Special electrically primed ammunition.
- ♯ — Special weapon system employing unconventional ammunition, including consumable case rounds.
- * — No information.
- ** — Conflicting or insufficient information.

Downloaded from http://www.everyspec.com

guards, loading trays, and case ejection chutes or deflectors. These devices facilitate the breech operational cycle, ease ammunition handling tasks, or otherwise assist the gun crew working in tight fighting spaces. A chart of engineering data associated with breech systems of representative self-propelled weapons is presented in Table 1-2.

1-4.3 AMMUNITION DICTATES

Effective delivery of firepower upon designated hostile targets is the sole, ultimate function of a weapon. Thus, the type (or types) of ammunition to be handled and projected by a given weapon is a strong dictate on the type of breech needed. Indeed, reference to ammunition influences is unavoidable even in the most elemental discussion of breech mechanism design, as contents of the foregoing paragraphs reveal.

Ammunition for large caliber weapons has been variously categorized. For the purposes of this handbook, general characteristics and external properties of ammunition type are the important considerations. Size, weight, kind of physical package, and number of component parts comprising a complete round are obvious characteristics to be borne in mind. Classification on the basis of fixed, semifixed, separated, and separate-loading ammunition types is the most widely used approach (Refs. 14 to 16):

1. Fixed ammunition. A complete round with primer and propellant contained in a cartridge case permanently attached to a projectile. It is loaded into the breech as a unit; caliber size is limited by weight, package size, and other handling considerations.

2. Semifixed ammunition. A complete round in which the cartridge case is not permanently fixed to the projectile so that the incremental charge within the case can be adjusted to obtain the desired range (or zone) of fire. However, it is loaded into the breech as a unit and, therefore, subject to similar caliber size limits as the fixed round.

3. Separated ammunition. A complete round composed of two component parts; namely, the projectile and the propelling charge that is contained in a sealed case complete with primer. The two items may be loaded into the breech separately by hand; in an automated mode, the projectile and case are set into a loading tray "separately", but breech loading is normally performed in one operation. This type of round is used when physical size becomes too large or impractical to handle in the fixed ammunition form.

4. Separate-loading ammunition. A complete round made up of three distinct components, wherein no cartridge case is used. Instead, the projectile and cloth bag encased propellant charge(s) are handled separately and loaded into the breech. In addition, a primer cartridge is inserted separately into the firing mechanism.

The order in which the ammunition types are listed corresponds in a general way to increasing caliber; e.g., fixed ammunition is generally associated with the smaller caliber range of weapons considered here, while the separate loading category implies the larger caliber range. (It should be noted that in foreign ordnance, conventional fixed ammunition exists in much larger calibers than in US Army usage.) Further type/size generalization is problematic—especially in the semifixed and separated ammunition classes—since complicating overlaps occur due to particular weapon application, tactical considerations, or design peculiarity.

Even traditional concepts concerning relative size of "cased" and "caseless" ammunition are changing (types 1, 2, 3 vs type 4). For example, development of the consumable case helps make the fixed round practicable at much larger calibers than hitherto possible. Developmental trends are not in one direction only since interest also exists in adapting separate-loading ammunition to smaller calibers. At least one example of an operational weapon system using bagged charges at 120 mm bore size can be cited in a British tank application (Ref. 17; see also pars. 1-5.2 and 1-6.6).

Ammunition type has definite implications on the type of breech mechanism to be used; the

Downloaded from http://www.everyspec.com

newer, unconventional rounds just mentioned are important situations in point. In par. 1-5 relations between ammunition type and breech closure type are established. The various ammunition types also receive more detailed treatment in par. 1-7.2 and Chapter 2, Section II, relative to their individual influences on breech design. Basic categorization of ammunition in terms of weapon size for representative towed and self-propelled weapons is given in Tables 1-1 and 1-2. Physical characteristics of ammunition fired from those weapons are further developed in Table 2-1.

1-4.4 RATE OF FIRE

The weapon rate of fire, rounds per minute, is an important weapon system characteristic. Rates of fire for the class of weapons treated in this handbook are given in Tables 1-1 and 1-2.

The rate of fire to which a given weapon system can be designed depends upon several interrelating factors. Small bore guns up to about 40 mm, using fixed ammunition, may achieve rates on the order of 100 rounds per minute, per barrel. This rate may be increased by increasing the number of chambers associated with each gun tube and/or the number of gun tubes used.

Ammunition clips and magazines may be used with power loaders and rammers to increase the firing rate. These devices generally are used with sizes up to 90 mm. There has been developmental consideration of multiple barrel-chamber-clip-magazine applied up to 120 mm.

As the weapon caliber is increased to about 105 mm, the automatic features needed to achieve high firing rate require more power than can be obtained from the weapon. Medium and large caliber weapons require auxiliary power to achieve high rate fire which increases complexity and weight. Thus, except for self-propelled weapons, these features are usually unacceptable.

The weapons considered in this handbook have a firing rate in the range of 1 to 10 rounds per minute. Mechanization is provided for breech operations and to assist in ammunition loading in order to reduce the effort required of the gun crew. Thus the weapon system firing rate gives rise to interfaces for the breech designer. The design features relative to the gun crew establish human engineering requirements. Internal power used for semiautomatic operation establishes an interface with the recoil subsystem. External powered operation interfaces with the powerplant in self-propelled vehicles. Par. 2-18 provides additional material pertaining to rate of fire, and par. 2-22 deals with human engineering.

1-5 TYPES OF CLOSURE

Structural features and the types of closure are properties that distinguish one kind of breech mechanism from another. The differences, of course, reach well beyond physical appearance; each design offers particular advantages and, unavoidably, some disadvantages. Those designs that maximize advantage while keeping disadvantage to a minimum acquire long lived acceptance.

Two diverse, complex requirements are imposed on every breech structure, regardless of type:

1. The breechblock—or equivalent plug-like part depending on the design—must effectively seal the breech recess during firing to contain the high pressures and loads developed. For separate loading ammunition (bagged charges), a gas-tight condition must be achieved in the breech structure proper. Therefore an obturator must be specifically included in the design of the breechblock to achieve the "effective" sealing requirement. In contrast, cased ammunition (with metallic cartridges) is inherently "self-obturating" since propellant pressure expands the case against the chamber walls forming a seal against rearward escape of gas. Consequently, the breech structure for this situation need not be gastight for "effective" sealing; however, it must provide adequate support for the case and prevent its rearward displacement or rupture.

Downloaded from http://www.everyspec.com

2. The breechblock (or plug) also must be able to expose the chamber efficiently, in quick succession before and after firing—for loading and extraction (or reloading), respectively.

Breech structures that can fulfill these dual requirements are termed "mobile closures"; the designation applies to the breeches of all weapons treated by the handbook. Among the numerous mobile closures tried (past, present, and developmental), acceptable and truly distinct types are limited. This is not surprising since the severity of the preceding requirements on design cannot be overemphasized. A successful breech design must not only meet such basic technical concepts but must also incorporate reliability, simplicity, and production economy into that design. At the same time compatibility with the several breech mechanism interfaces must be maintained.

Elaboration is given in the paragraphs that follow to those relatively few, distinctive closure types that reached operational status in Army artillery. Among these, the interrupted-screw and sliding-wedge closures are the most commonly applied breech designs for large caliber weapons, to date. The designer also is made aware of the role of developmental and experimental closure concepts on such weapons. When possible, the merits/demerits of the various closure types and the background whereby certain ones were rejected or accepted are also treated.

1-5.1 INTERRUPTED SCREW

Two truly distinct breech types with a long record of acceptance remain in use today. In one of them the closure principle centers around the basic mechanical locking device, the thread. Simply, the structure is composed of an outer component or breech ring attached to the gun tube, and an inner component or breechblock which engages the ring through a specialized thread design. The breech ring in conjunction with the rear of the tube assembly forms the breech recess and provides access to the weapon chamber for ammunition loading. (Design aspects of the important tube-breech interface are separately treated in par. 2-7.) The primary threaded closure is between the ring opening and the closely fitting block as shown in Fig. 1-2. This breech type is also known under the equivalent terminology of interrupted thread, slotted screw, or plug closure.

To obtain ease or speed of operation and to optimize the motions needed to seat (or unseat) the block, other than normal, continuous threads are employed. Interrupted or sectored threads are used which require the exterior of the breechblock and the interior of the breech ring to be specially machined—with equal numbers of threaded sectors in each piece, alternating with longitudinal clearance channels (Fig. 1-2(B)). Depending on the number of sectors used in a particular design, the threaded areas are fully engaged (or disengaged) by rotation of the block through only a small part of one turn. Hence, the breech is conveniently locked (or unlocked); an operating mechanism imparts the necessary limited rotary motion of the block. The pitch of the threads is such that, under the force of the propellant pressure, friction will prevent the locked breechblock from rotating and opening due to the component of the force along the screw threads (Ref. 18). Breech locks, however, are commonly employed.

In modern weapon applications, the total breechblock motion consists of two cycles:

1. The rotary motion and a pivotal, hinge motion that exposes the chamber for loading after the closure threads have been unlocked.
2. The motions take place in the reverse order after the weapon is loaded.

Suitable clearance cuts, made in both the breechblock and ring, to permit the hinge motion, can be seen in Figs. 1-2(B) and 2-20(C). (Older, heavy gun designs employed a three-cycle breechblock motion, wherein the block was not swung directly into or out of its seat in the breech recess; breechblock proportions required an intermediate translating motion along the

Downloaded from http://www.everyspec.com

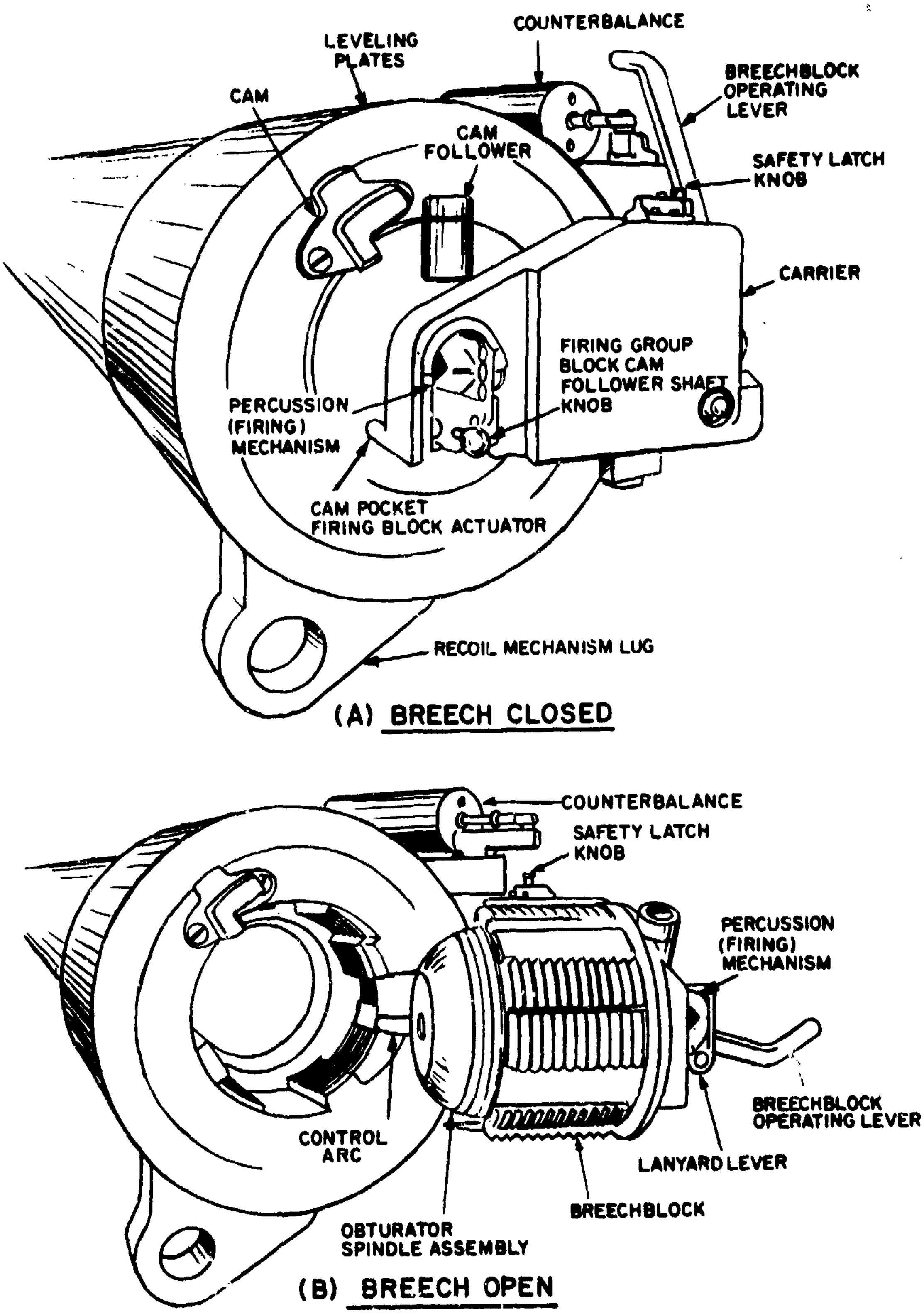


Figure 1-2. Interrupted-Screw Breech, Stepped Thread (175 mm Self-Propelled Gun, M113A1)

Downloaded from http://www.everyspec.com

chamber axis to make the hinge motion possible. Thus, operating mechanisms were necessarily more complex.)

Breechblock motions are produced in one continuous cycle when the operating mechanism is actuated. A support member—the block carrier—facilitates the action by supporting the breechblock and connecting it to the breech outer structure (Fig. 1-2(A)). The carrier allows the block to be rotated with respect to the ring and provides the hinge axis for further motion to expose the chamber. The operating mechanism performs yet another important function. When the breech is open it prevents further rotation of the block; this maintains proper alignment between threaded sectors and clearance channels that must mate as the block is swung into or out of the breech recess. A spring loaded counterbalance device smooths the hinge motion and aids the actuating effort.

Both horizontal and vertical (downward) hinge motions have been designed, but the latter are identified with older, very heavy caliber, immobile weapons. Hinge motion in or close to the horizontal plane represents recent Army design practice—the block opening to the right side with an observer facing the breech. With regard to the thread form itself, various types have been utilized, among them the buttress, modified V, and square forms. These thread varieties are treated in detail in par. 2-28.

Several variations of the interrupted screw exist; these are design alternatives taken either to improve the closure strength or optimize breech opening and closing. Absence of threads in the clearance channels makes for loss of strength that is inherent in the interrupted screw closure principle. However, the loss is compensated by increasing the length or surface area of thread engagement. Par. 1-6.1 and Fig. 1-7 describe structural variations of the interrupted screw closure that have evolved, namely:

1. Single-cut threads
2. Conical taper threads (Bofors)
3. Stepped threads (Welin).

In Army usage, the interrupted-screw breech has generally been applied in weapons of 155 mm size and larger. This breech mechanism is especially well suited to separate-loading ammunition—particularly from the standpoints of ammunition handling and obturation. Since ammunition traditionally has been of the separate-loading type for such calibers, a high degree of ammunition-breech compatibility is realized. However, the closure principle is not absolutely limited to one ammunition type—older, foreign ordnance applications using cased rounds and recent Army developments with unconventional (consumable case) ammunition and substantial breech redesign can be cited (see par. 1-5.3).

A relatively modern example of the interrupted-screw breech as used on the self-propelled weapon system 175 mm Gun, M113A1/8 in. Howitzer, M2A2, is shown in Fig. 1-2. Specifically the closure is a Welin, two stepped-thread type (see also Fig. 1-7(C)). Structural components discussed earlier—such as the breechblock, breech ring, and block carrier—are indicated in Fig. 2-20. This figure also illustrates portions of other mechanisms treated elsewhere and their typical arrangement—e.g., operating, firing, and obturating mechanisms.

According to Ref. 18, principal advantages of the interrupted-screw breech are strength, more uniform distribution of the longitudinal stress produced by the propellant, and relative ease of obturation. The closure does not lend itself to automated functions—especially by power internal to the weapon—and therein lies its chief disadvantage. But no matter what the power source, automation is not readily obtained; the situation is obviously more complex when two distinct motions are involved, in contrast to a single linear motion for the sliding-wedge breech.

1-5.2 SLIDING WEDGE

Another elementary mechanical locking device—namely the wedge—acts as the closure in the sliding-wedge breech. Together with the

Downloaded from http://www.everyspec.com

interrupted-screw closure (par. 1-5.1) the sliding-wedge type is one of two basic designs that is both long lived and yet currently used. A breech ring attached to the rear of the gun tube assembly makes up the outer structure of the mechanism. Two major slots are machined in the "ring". One, oriented axially, forms the breech recess and exposes the chamber for loading and case extraction. A second slot—perpendicular and interconnected to the first—runs completely through the ring to provide "ways" or "tracks" for the breechblock (Fig. 1-3). The breechblock fits into the slot and slides on the ways between the open and closed breech positions when actuated by a suitable operating mechanism. According to recent design practice, the through slot and consequently the breechblock cross section are roughly T-shaped. The slot shape is so oriented that firing loads are resisted along the top or cross of the "tee", as indicated by Fig. 1-3(C). (Older sliding-wedge closures relied on a more complex geometry of block grooves and mating projections in the breech recess.)

Major variations of the sliding-wedge closure arise from the direction of breechblock motion within the ring. Block motion is to the right when the breech is opened in the horizontal sliding wedge, while in the vertical sliding wedge—also known as the dropblock—motion is downward (Figs. 1-3(A) and (B), respectively). In either situation, the block moves with a one-cycle linear motion and therein lies the main advantage of the closure. It is well suited to breech operation in a semiautomatic mode, allowing use of actuating mechanisms that are relatively simple and rapid acting.

Additionally, the block travel distance is minimized by cutting a semicircular clearance notch at the end of the block nearest the chamber. Loading of the weapon or case extraction can, then, take place as soon as the breechblock notch clears the bore diameter—thus, total travel distance is not much greater than one bore diameter. Moreover, the sliding-wedge breech is best suited to cased ammunition. The metallic cartridge case associated with fixed, semifixed, and separated rounds provides the necessary gas seal—since obturation is not inherent in the closure, nor easily adapted to it. Obturation is treated separately in par. 1-6.6.

Consequently, Army applications of this breech type have been limited to those weapon calibers where cased ammunition is available (traditionally not over 120 mm). Despite the difficult techniques involved in effecting a propellant gas seal, there is interest in adapting the sliding-wedge breech to bagged ammunition. The potential of simpler motions and more rapid acting mechanisms at larger calibers are obvious motivating factors. This principle previously has been applied in a few gun designs of foreign armies. A more recent, significant application is the British CHIEFTAIN tank employing a sliding-wedge breech and separate-loading ammunition in its 120 mm gun. The weapon is in service, but a design departure of this kind is not without inherent complexities, aside from the nonstandard obturating mechanism necessary—which is further identified in par. 1-6.6—a separate means of firing the bagged propellant must also be provided. The CHIEFTAIN tank gun incorporates a feature whereby the primer cartridges are fed automatically into the firing mechanism (Ref. 17). Recent Army activities along these lines are developments to adapt the sliding-wedge closure to larger caliber weapons that fire separate-loading ammunition.

The wedge closure principle is utilized by inclining both the breech ring guide tracks and mating contours of the block slightly forward of the breech face plane; a common wedge angle is 1.25 deg. Therefore as the block moves to the closed or firing position it also advances slightly toward the breech face. This action plays a part in the ammunition-breech interface. Full seating of the cartridge is assured when the block is closed—if the round was not completely inserted in loading—by the beveled, upper part of the

Downloaded from http://www.everyspec.com

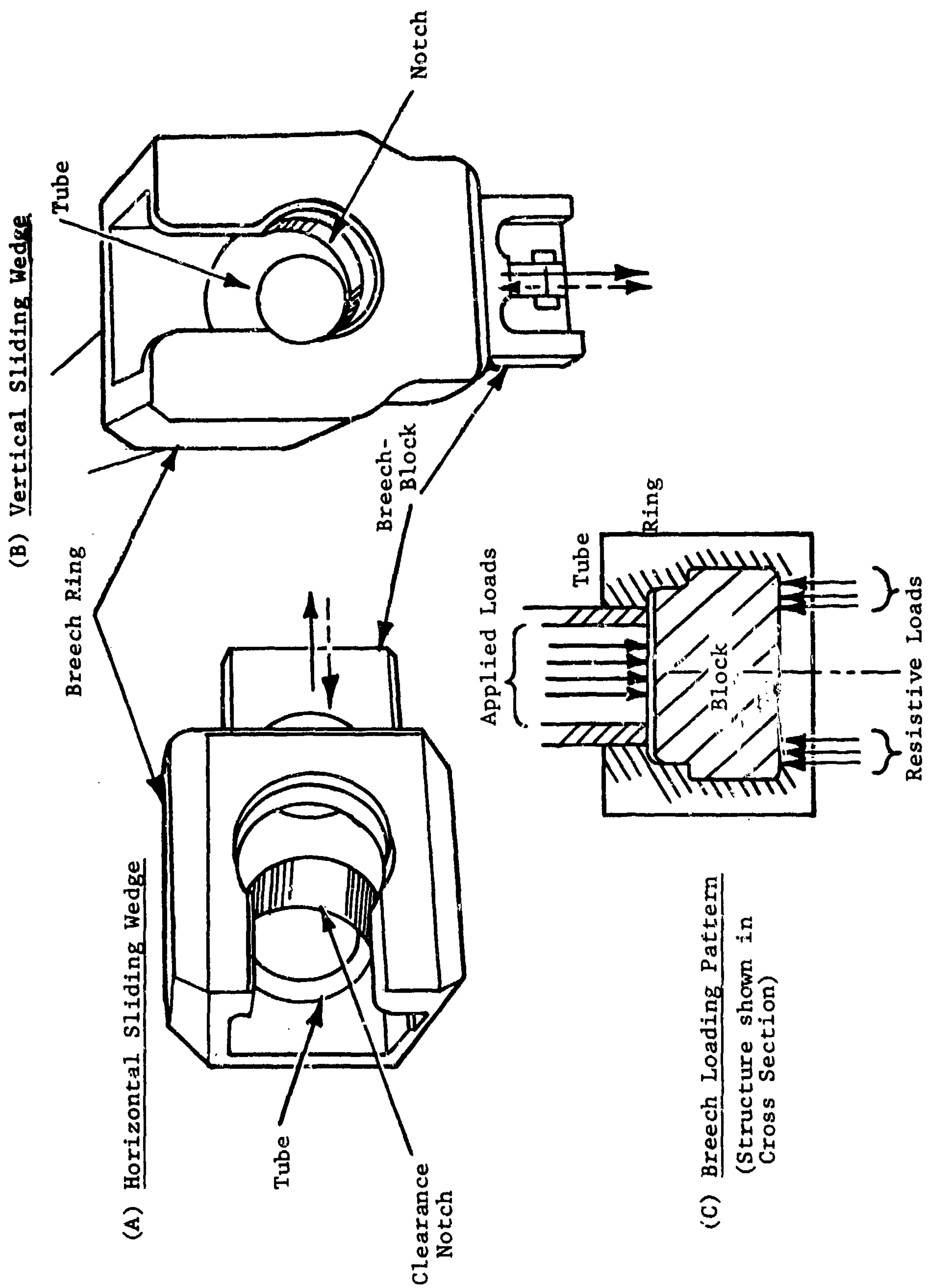


Figure 1-3. Sliding-Wedge Breech Principles

Downloaded from http://www.everyspec.com

block front face. The sequence of events is shown schematically in Fig. 1-4 for a vertical sliding-wedge breech. In the closed position, a small axial space must be left between the cartridge base and the block front face to avoid jamming. This dimension, termed head clearance, generally varies between 0.010 and 0.025 in., indicative of the close tolerances necessary in breech component manufacture.

Both the horizontal and vertical design versions are currently in use. Conclusive advantage cannot be given to either block travel direction. Much depends on the particular weapon application, space constraints, or considerations of gun crew convenience. A very important guidance criterion is that the open side of the breech ring must be located for maximum convenience when loading the gun. Horizontal block motion is generally used on towed weapons, where lateral space is more readily available for the sideways motion of the block and the breech operating handle. A prominent exception is the vertical slide breech of the 105 mm Howitzer, M102 (Table 1-1). Horizontal motion, often used for manual breech operation, offers a relatively constant actuation effort since gravity does not act directly on the block motion. Other factors also favor the hand operating mode—depending on weapon caliber (hence block weight)—efficient manual actuation is nevertheless achieved; a counterbalance device is not necessary; and not least in importance, design simplicity is maintained.

In tank guns, vertical travel of the block is used most often, although a number of dated contradictions can be found. More stringent space limits in a turret often demand that the "drop" rather than sideways motion be used. A counterbalance device (one of several spring forms) is included in the actuating mechanism to smooth gravity effects on the breechblock; the spring is charged during the opening or downward motion and assists upward motion by releasing energy. Vertical block motion is also better oriented to tap off recoil motion for breech automation.

Operating mechanisms that perform the various system functions—open and close the breech, provide lockouts at either extreme of motion, and work in conjunction with other mechanisms—take on different arrangements depending on block travel direction and whether breech actuation is manual or semiautomatic via recoil motion. Operating, firing, safety, and obturating and extracting mechanisms applicable to the sliding-wedge breech receive specific treatment in pars. 1-6.2 to 1-6.5 and Chapter 2, Section IV. Since the sliding-wedge and interrupted-screw breeches currently comprise almost every large caliber weapon application, their salient features are summarized and compared in Table 1-3.

1-5.3 SEPARABLE CHAMBER

The third type of large caliber weapon breech in use today is a combination of previous, well accepted concepts and modern design additions produced with the current state of technology. It is used on the 152 mm Gun/Launcher (M81 and M162) designed for tank and armored reconnaissance vehicle missions. This breech is similar in some ways to the interrupted-screw type (par. 1-5.1)—e.g., the sectored-thread locking method between the mobile and stationary parts of the breech structure is the same—but distinct enough to carry a separate designation. In the context of this handbook, the breech is referred to as the separable chamber type. ("Pivot" or "split" chamber are other less preferred, informal designations.)

The breech is a recent development created to fill the military need for weapon systems that can project both a consumable case round and a guided missile from the same tube. It exemplifies the most refined use of external power for breech actuation in a larger caliber weapon to date. Liberal use of power is in response to requirements of the special ammunition, turret

Downloaded from http://www.everyspec.com

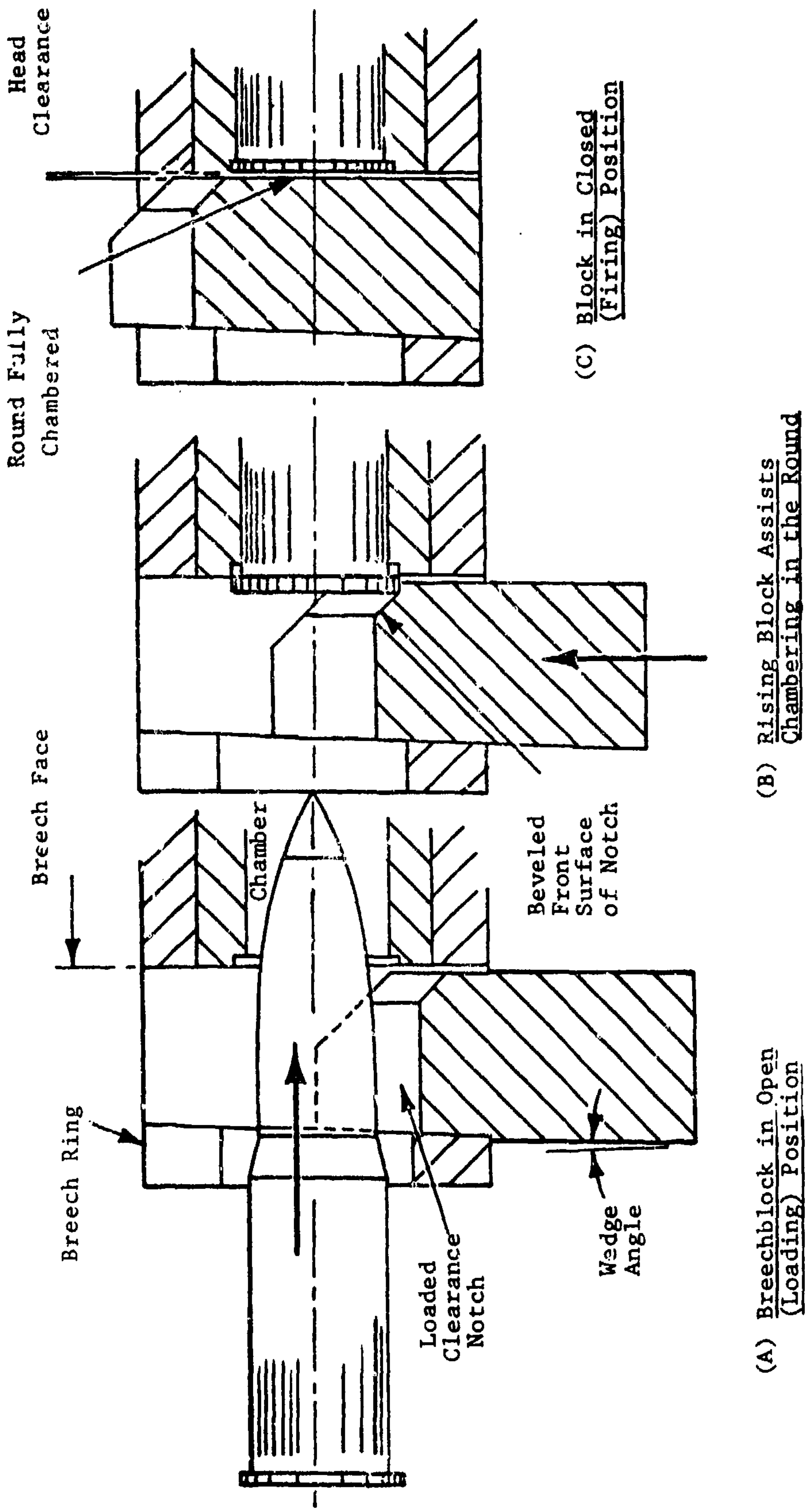


Figure 1-4. Vertical Sliding-Wedge Sequence, Showing Breech-Ammunition Interaction

Downloaded from http://www.everyspec.com

TABLE 1-3. COMPARATIVE CHARACTERISTICS — SLIDING-WEDGE AND INTERRUPTED-SCREW BREECH (Ref. 19)*

Characteristic	Sliding-Wedge Breech	Interrupted-Screw Breech
Readily adaptable to automated features	Yes	No
Breechblock motion(s)	Linear	Rotary and hinge
Operating mechanism requirements	Simpler	More complex
Firing mechanism requirements	Simpler	More complex
Rate of fire	Higher	Lower
Ease and safety of loading	Better	Worse
Longitudinal stress distribution	Less uniform	More uniform
Fabrication/production	More economical	Less economical

*Structured primarily from Ref. 19.

space constraints, and a general sophistication justifiable primarily in a tank weapon.

Structurally, the breech consists of a coupler member—providing the function of a breech ring—and a block-like mobile part, similar to an interrupted-screw type breechblock. An operating mechanism housing, mounted below the coupler, and a block carrier, that supports the separable chamber block relative to that housing, complete the major component groups (Fig. 2-36). Unlike a conventional breech design, the gun tube only forms the forward part of the chamber; this is identified as the fixed chamber. The mobile "block" itself forms the rear of the weapon chamber. Therefore it is more than a normal breechblock, which acts only as a chamber plug, hence the designation separable chamber block is applicable.

This breech type revives the three-cycle "block" motion associated with early interrupted-screw breeches (par. 1-5.1), but the comparison does not go beyond principles. In the first motion, the separable chamber is rotated counterclockwise from locked position through one interrupted thread sector (Figs. 1-5(A) and (B)). The single-cut type threads are disengaged during this movement. Next, the chamber is withdrawn axially—its thread sectors now being in alignment with clearance channels of the coupler—until it fully clears the coupler (Fig. 1-5(C)). Opening is completed as the separable chamber and its carrier pivot counterclockwise about the axis of the operating mechanism housing. A pivot angle on the order of 60 deg is sufficient to expose the fixed chamber for loading (Fig. 1-5(D)).

Downloaded from http://www.everyspec.com

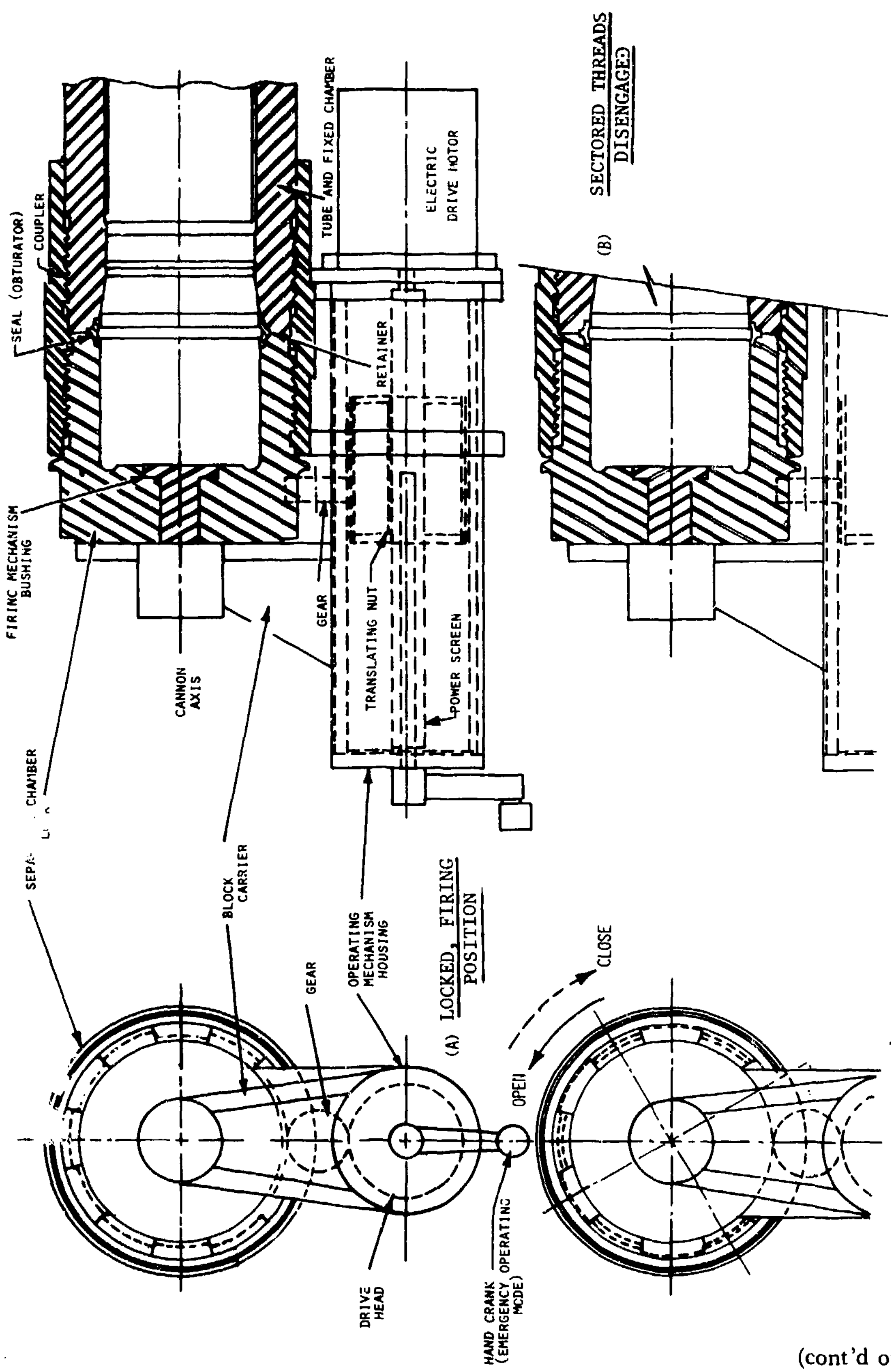


Figure 1-5. Separable Chamber Breech — Schematic Sequence of Motions

(cont'd on next page)

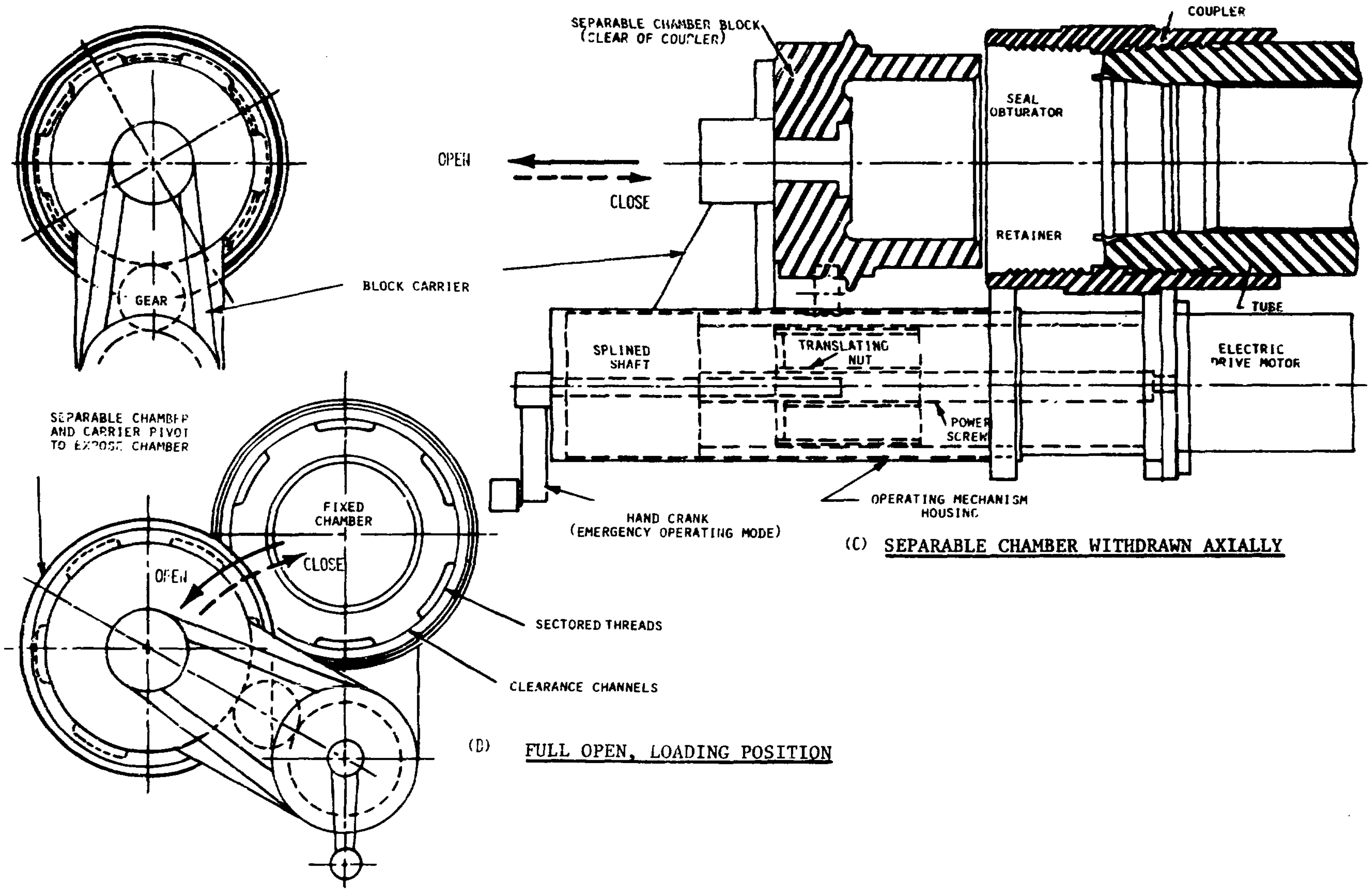


Figure 1-5. Separable Chamber Breech — Schematic Sequence of Motions

Downloaded from http://www.everyspec.com

Downloaded from http://www.everyspec.com

When a round is chambered, another unusual feature of the breech is evident. With the breech in the open position, the case end of the round is left to cantilever after the loading tray is withdrawn; but as the separable chamber is returned to the closed position, it envelops the aft part of the ammunition, not merely backing it up. This is a substantial departure from all other breech types.

Motions of the chamber are produced through an elaborate drive mechanism powered by a dc motor—when the breech operates in its primary, semiautomatic mode. Rotary motion is obtained by gear connection between the separable chamber and a drive head; translatory motion via a power screw and translating nut combination within the drive head; and pivot movement by a cam action. The operating mechanism locks the breech in the closed position and also prevents an open chamber from closing under shock and vibration of the vehicle operating environment (Ref. 20). Manual (or emergency mode) operation is available in case of power failure, by way of a handcrank (see Figs. 1-5 and 2-36).

The separable chamber breech includes a number of other design provisions worthy of mention. It must of co se be compatible with the SHILLELAGH missile. Fin clearance channels in the chamber and an ejection mechanism for empty missile aft-caps are incorporated for this purpose. (These items are not treated further in the handbook.) Scavenger systems for purging propellant residue from the chamber receive coverage in Chapter 2 in connection with bore evacuation; while elements of the firing and obturating mechanisms are discussed in appropriate subparagraphs of this chapter. Refs. 21, 22, and 23 should be consulted for additional details on this breech mechanism type.

1-5.4 ECCENTRIC SCREW

A distinct breech mechanism that utilizes continuous threads as the mobile closure is designated as the eccentric-screw type. It is not in current use but is nevertheless interesting from the design standpoint. The breechblock is cylindrical in shape and threaded on the outside to screw into the breech recess formed by a breech ring or hoop. The block, termed the Nordenfelt type, has a large diameter compared with the gun caliber because its axis is eccentric to—and below—the bore axis (Fig. 1-6). Offsetting the axes is necessary to permit use of continuous threads yet retain a quick acting closure. However a simple, all rotary breechblock motion is made possible, with approximately one-half revolution needed to open or close the breech. Actuation is accomplished by rotating the block about its axis with a manual operating crank. The block remains in the breech recess during both loading and firing, which is a further advantage.

An axial loading recess, cut through the block exterior for insertion of ammunition, and a suitably located through-hole for seating the firing pin are prominent modifications to an otherwise cylindrical block. Rotation of the block to the open breech position (Fig. 1-6(A)) locates the loading recess opposite the chamber for extraction of the spent case (as shown) or insertion of a new round; the firing pin is situated safely out of the way. In the closed breech position (Fig. 1-6(B)) the block is rotated to plug the chamber and to bring the firing pin in coincidence with the bore axis; this being the only position when the pin is in firing alignment. The closure is suited primarily to cased ammunition, consequently, its firing and extracting mechanisms are based on the same principle as in the sliding-wedge breech.

The eccentric-screw breech is considered to be obsolete primarily because of its weight which makes the closure prohibitive for large guns. The last known application of this breech in Army usage is the 75 mm Gun, M1897A4, Carriage M2, and 37 mm Gun, M1916, exterior mount (Refs. 18 and 24). It is evident from Fig. 1-6 that the required breechblock diameter is substantially greater than twice the bore diameter. Even allowing for the loading recess, a Nordenfelt block is much heavier than, for example, an interrupted-screw block of the same caliber. The

Downloaded from http://www.everyspec.com

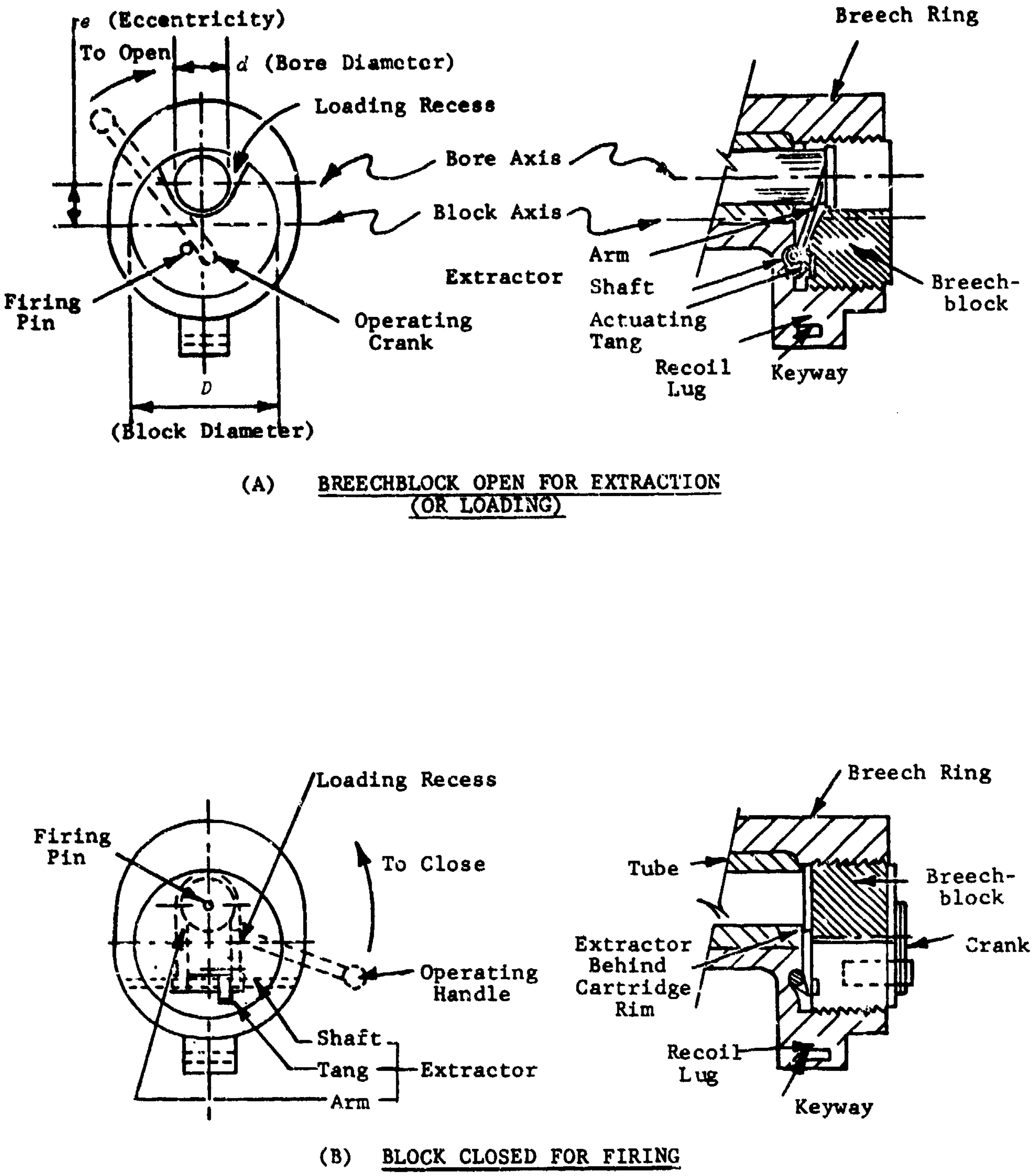


Figure 1-6. Eccentric-Screw Breech

Downloaded from http://www.everyspec.com

ponderously large breech ring must also be considered in a weight assessment. Revival of at least a similar principle is evidenced in experimental weapons of recent vintage that utilize rotary (multiple) chambers.

1-5.5 DEVELOPMENTAL AND EXPERIMENTAL CLOSURE CONCEPTS

The foregoing paragraphs describe those relatively few breech closures which have attained operational acceptance, the designer's ultimate goal. In part, the small number of successful designs testify to the stringent requirements and severe operating environment imposed on breech mechanisms; but more is involved. Substantially new breech designs emerge only in accord with the status of ordnance technology to produce those designs and the ammunition to be projected. For conventional ammunition (pars. 2-11.1 to 2-11.3), the sliding-wedge and interrupted-screw closures fulfill a role that is unlikely to be challenged. Of course, developments are continually underway to upgrade, refine, and otherwise improve functional performance within these basic breech types.

However, progress within the ammunition field and availability of unconventional rounds (pars. 2-4 and 2-5) are most responsible for the demand for newer closures. Development of the previously described separable chamber breech is an explicit illustration of the influence of unconventional ammunition. Probably the one factor that imposes the most serious new design problems is the practical reality of the consumable case round. The design challenges are nevertheless undertaken because their solution offers the potential of improved weapon performance. Depending on the particular experimental breech concept, improvements due solely to the consumable case may be sought—handling, loading, spent case elimination, stowage, etc.—or the design may also strive to increase firing rate, reduce weapon weight, or make better use of restricted fighting compartment space.

A number of experimental breech concepts have been advocated in recent years, but none of them has attained acceptance. Still, such developmental and experimental closure types represent useful information to the designer—recording methods of approach previously tried; offering possibilities to be improved on; or indicating the point of departure for fresh concepts. Refs. 5 to 8, 25, and 26 record examples of experimental breech concepts. Refs. 25 and 26 deal with tank and self-propelled weapon applications, for consumable case rounds, exclusively. Refs. 5 through 8 involve towed weapons using conventional ammunition but contain worthwhile reference material on rapid fire concepts and automation of loading/feeding steps. While the sources cited are representative, they do not exhaustively portray the amount of work done in the area.

1-6 MECHANISM AND COMPONENT BREAKDOWN

The breech system of a large caliber weapon comprises a number of mechanism subassemblies and major components. These constituent elements can be broken down into logical groupings, generally along lines of the functions they perform within the system—i.e., breech structure/closure, operating mechanism, firing mechanism, extractor, or obturator. It is also useful to make a mechanism breakdown for the purpose of discussion.

Important breech mechanism subassemblies and major components are treated in the remaining subparagraphs of this section. The two basic, but distinct breech types—sliding wedge and interrupted screw—are used throughout the discussions, reflecting their importance relative to breech design technology as a whole. For hardware considerations, the 105 mm Howitzer, M101A1, and the 175 mm Self-propelled Gun, M113A1, serve as prime examples—representative of those breech types, respectively. Naturally, other weapon types and calibers receive treatment, consistent with the scope of

Downloaded from http://www.everyspec.com

the handbook, depending on their further contribution to design guidance or state of documentation.

1-6.1 BREECH STRUCTURE/CLOSURE

Major structural elements of the breech consist of a breech ring or stationary part; a breechblock or mobile part; and, depending on the type of breech, other supporting members that guide the block motions. The ring forms the breech recess, provides a receptacle for locking the block into place, and also serves as the interface component between the breech and tube assembly.

The moving part of the structure blocks or plugs the chamber opening, hence the term breechblock is applied equally to wedge, screw, and even separable chamber closures, although parts of drastically different configuration are involved. However, in the separable chamber breech, the block actually forms the rear portion of the chamber as the nomenclature implies. Both the interrupted-screw and separable chamber closures have a block carrier, as part of their structure, to support the block while it is swung out of the breech recess. Although block motions are very different in these breeches, the carrier assembly performs the same support role as a comparison of Figs. 1-5 and 2-21 will indicate.

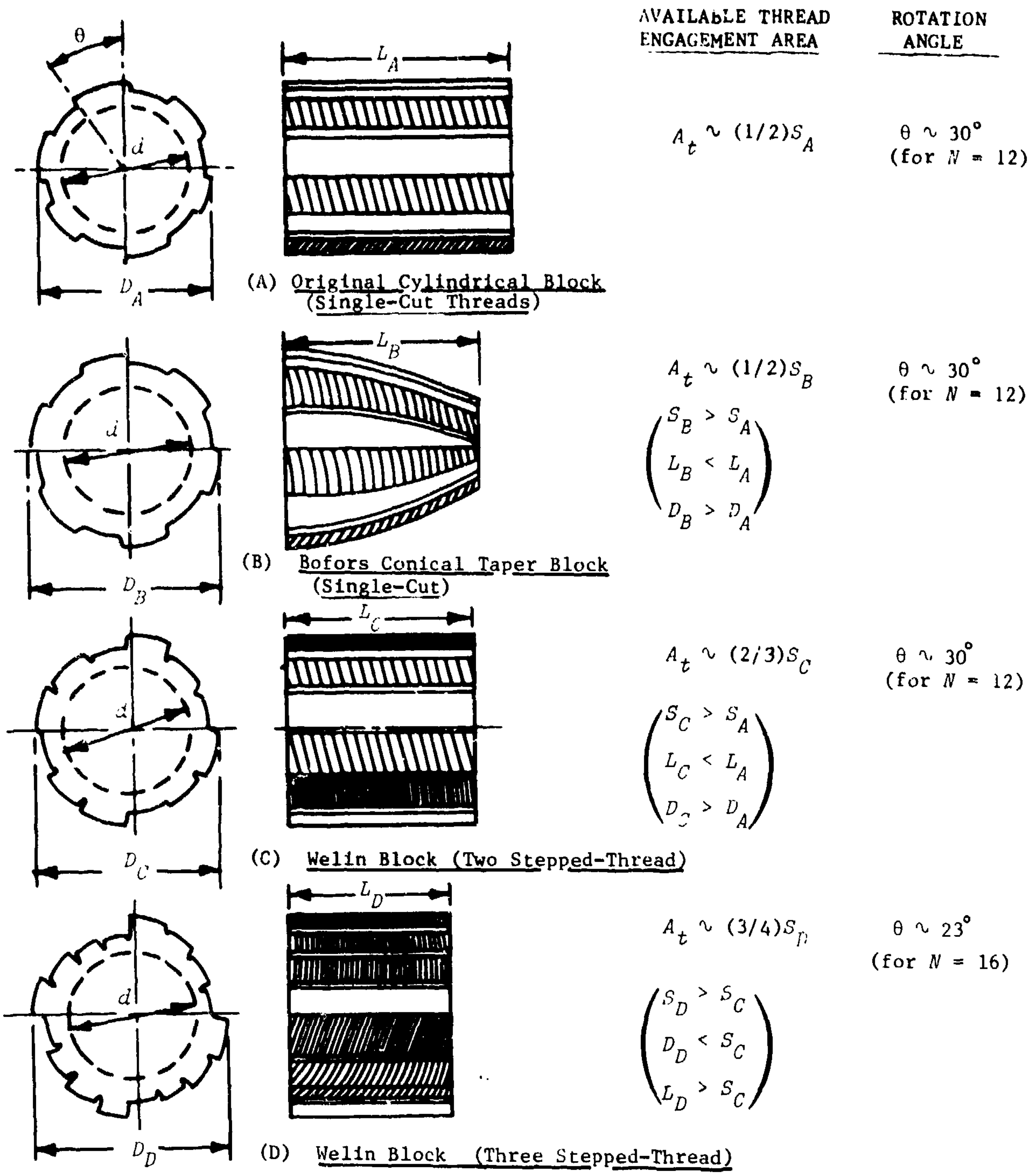
The interrupted-screw breech, in particular, presents additional structural details that are worthwhile to record. These details center around the manner in which the closure threads were interrupted in the evolution of this breech type. Design variations are best described considering the breechblock alone.

The original block had simple, single-cut threads (Fig. 1-7(A)). For an outside diameter D—somewhat greater than a given bore diameter d—thread length L was required for a fixed level of strength. Regardless of the number of sectors, thread engagement area cannot exceed 50% of total surface area in this design. The rotation angle necessary to lock (or unlock) the breech is inversely proportional to the number of sectors; the latter are governed naturally by design practicalities. Six threaded sectors were commonly used for the single-cut block.

By giving the breechblock a conical taper with diameter substantially increased toward the rear, thread area is enlarged allowing the block to be shortened. This form of interrupted screw is commonly referred to as the Bofors closure (Fig. 1-7(B)) but in a strict sense the threads are single-cut. The original shape improves on the right cylindrical form (for the same material strength) but a small linear retraction is still necessary to permit hinge motion (Ref. 27); fabrication difficulties are also obvious. Other functional relations of the Bofors closure are similar to those for case A (Fig. 1-7); this closure type has not been recently applied.

Stepped-thread construction permits more than 50% of the block surface to be used for thread engagement. One clearance channel and two or more threaded sectors of increasing diameter are formed in repeating sequence around the block periphery. The channel and threads are oppositely arranged in the breech ring, hence block rotation through an angle equal to only one sector locks or unlocks the closure. This interrupted-screw variety, also known as the Welin type, enjoyed a favored role in modern weapon design, and only the very latest weapon applications have replaced it (e.g., the 155 mm Self-propelled Howitzer, M126A1, and 152 mm Gun/Launcher, M81 or M162). The Welin type thread is superior to its predecessors since it permits use of a shorter breechblock; consequently, the block can be swung out of the breech recess directly. Block length can be reduced when diameter (or thread area) is increased, depending on other design trade-offs. Both two and three "steps" of threads have been used (Figs. 1-7(C) and (D), respectively); of course, the outside diameter of the block increases while rotation angle decreases with the number of stepped-threads employed. An example of the two-step, Welin interrupted-screw breech is found on the 175 mm Self-propelled Gun, M113A1 (Fig. 1-2(B)).

Downloaded from http://www.everyspec.com



d = bore diameter

D = block diameter

A_t = thread area

S = total surface area

L = thread length

θ = rotation angle to lock (unlock) breech

N = number of sectors

A-D subscripts refer to dim. in Views A-D

Figure 1-7. Evolution of Interrupted-Screw Threads and Breechblock

Downloaded from http://www.everyspec.com

At the same time, the stepped-thread closure makes for a complex breechblock surface. The piece is inherently difficult to produce. Manufacturing efforts and costs previously accepted, lacking a better alternative, are now being reconsidered for the latest weapons. In the current design approach several developments are combined to produce a modern single-cut, sectored-thread breechblock, no larger than a stepped-thread block of equivalent caliber. This is made possible by use of newer, superior block materials; sectored-thread forms optimized for strength; and efficient fabricating processes. Empirical investigations and dynamic simulation tests conducted on thread configuration are significant factors in arriving at a suitable design. These techniques and their important results are treated in pars. 2-27 and 3-17.7. Because of the general trend to fewer numbers of weapons, application of the new breechblock with single-cut sectored-threads is still limited (Table 1-2).

The design of structural elements must also include provisions to house or locate the remaining breech system mechanisms. For example, the firing mechanism and obturator typically are contained in the breechblock; while the operating mechanism is anchored to the breech ring. Still other mechanisms may be located in either the moving or stationary parts of the breech structure—or made to function by both of them. Examples in this category are safety interlocks and extractors, respectively. The principal breech types are treated individually in pars. 1-5.1 to 1-5.4. Since closure designs are covered in detail, structural components receive attention simultaneously in those paragraphs of the handbook. Illustrations found in pars. 1-5 and 2-11 also provide a significant complement to the foregoing discussions; the designer is encouraged to cross-reference with Figs. 2-14, 2-20, 2-23, 2-25, and 2-32, particularly, for the best understanding of mechanism and structural relationships.

1-6.2 OPERATING MECHANISM

One of the most important mechanism subgroups within the total breech system is that which opens and closes the breech—whether by manual or automated means. Operating mechanisms have characteristics associated with the particular type of breech they serve. To date, nearly every application of a semiautomatic breech makes use of power internal to the weapon. This limits the designer's latitude in choosing operating mechanisms to those that are most compatible with recoil energy. However, mechanisms which operate the breech manually or semiautomatically differ largely from the actuation method utilized rather than in underlying principles. Design details relative to the interrupted-screw and sliding-wedge breech types are provided in Chapter 2, Section III.

When external power is available for breech actuation, the operating mechanism can take more varied forms in accordance with other design trade-offs. The primary example of an externally powered semiautomatic breech is found in connection with the separable chamber breech (used on the 152 mm Gun/Launcher, M81 and M162). The operating mechanism for this breech type is treated in par. 1-5.3.

1-6.3 FIRING MECHANISM

All breech system elements that take part in initiating the primer comprise the firing mechanism. However, the makeup of that total mechanism is a substantial variable influenced by:

1. Type(s) of ammunition to be projected
2. Kind of breech system and its operating mode
3. Particular requirements of different weapon applications, which incidentally are not static with time.

Perhaps these are the reasons why terminology and even equipment classification relative to firing mechanism design have been found quite inconsistent or misleading (Refs. 1, 2, 10-13, and

Downloaded from http://www.everyspec.com

24). On one hand, a component group that performs only a part of the firing cycle is too often termed as "the firing mechanism". At the opposite extreme, an assembly which carries out a set function (e.g., the percussion mechanism) may have several different designations from weapon to weapon, although working under the same principle. In short, distinct mechanism types are fewer in number than their descriptive nomenclature.

Mechanism type is best classified according to the manner of primer ignition but, as already indicated, this function does not necessarily fulfill all requirements of a total firing group. This is especially evident in a firing mechanism that must accommodate a separate primer. To date, only three basic firing mechanisms have reached acceptance—percussion, electric, or their combination. They have the following general characteristics:

1. Percussion. The primer is physically struck and indented by a pin. An internal power source (one or more charged springs) supplies the energy. Several design variations and triggering methods exist, as elaborated hereafter.

2. Electric. The primer is initiated by electric resistance generated heat. A special electric primer and an external power source are required.

3. Electric-percussion. The mechanism contains a firing circuit and also a separate percussion device to initiate a special dual-purpose primer. External power requirement is similar to the electric type.

1-6.3.1 ELECTRIC AND ELECTRIC-PERCUSSION FIRING MECHANISMS

Traditionally, nonmechanical firing devices have been associated with separate-loading ammunition, for which special required primers also had been developed. These firing mechanisms were used initially on very large size guns of the day—where convenience derived from an electrical method could be justified on the basis of readily available power, or more cumbersome alternatives. Railway and seacoast artillery fixed guns represent early Army applications of electric firing mechanisms. With the emergence of modern, mobile artillery, advantages diminished for electrical systems available at that time; they were not sufficiently competitive for the trend to smaller weapons. It was Naval ordnance that took up serious development of electric firing mechanisms, having both a more suitable battle environment and weapons of more applicable caliber.

Improvements in reliability brought electric firing back into modern Army ordnance by way of the electric-percussion system. This dual firing mechanism (also referred to as "electric or inertia") was employed on a few self-propelled weapons of large size; e.g., 8 in. Self-propelled Howitzer M47, M55 Vehicle (also see Tables 1-1 and 1-2). In this firing mechanism, electric ignition is the primary mode, with the percussion device serving a backup role. If the special primer fails electrically, it still may be fired by the blow of the firing pin. But the percussion element having failed, the primer will not fire electrically. A relatively simple actuating circuit is used in which an electric potential is developed across the metal primer case.

More recent electric firing device applications for tube launched projectiles are equally scarce. Parallel improvements in the percussion mechanism continue to satisfy needs in most applications. Only new ammunition developments and the most tactically sophisticated weapon system—the tank gun—demand ultimate refinement in all functions. Scarcity of current examples is not an assessment of future trends but an indication of unresolved controversy of the electric vs the percussion method even in tanks. Table 1-2 cites two current examples of weapons with electric firing mechanisms on different models of the M60 Tank. The 105 mm Tank Gun, M68, represents an unconventional situation at this point in time. It fires a special electrically primed round, requiring that type of firing device, but the ammunition is standard in

Downloaded from http://www.everyspec.com

other respects (fixed charge, metal cartridge case).

Consumable case ammunition provides the other area of current demand for electric firing mechanisms. The stringent and often unique requirements imposed on breech design by this ammunition type are cited at numerous points in the handbook—with reference to the 152 mm Gun/Launcher System (M81 and M162). Indeed, demands on firing mechanism design are particularly severe. A contact probe exposed to the chamber must withstand the high pressure, thermal shock, and erosive effects of hot gases developed by the propellant. Adequate sealing of the probe to prevent combustion gas leakage is a further problem area. In a typical firing device, shown schematically in Fig. 1-8, ignition current is carried to the consumable primer by a fixed probe, insulated from the breech. Contact is made through a lead wire spring located in the primer. The circuit is completed to ground with a second wire spring in the cartridge case base (Ref. 25). Probe sealing is accomplished by the combination of close fit with the breech and an elastic ring seal.

Detailed treatment of electric firing mechanisms, particularly for tube weapons that fire unconventional ammunition—or have a dual missile launching capability—are beyond the scope of this handbook. As outlined, the extent of such applications is still limited. However, the present, predominant role of percussion firing mechanisms in large caliber weapons is further elaborated.

1-6.3.2 PERCUSSION FOR CASED AMMUNITION

In Army practice, conventional cased ammunition (par. 1-4.3) is fired from the sliding-wedge type breech, exclusively. The general simplicity of breech operation carries over into the firing function and into the mechanisms that accommodate it. No part of the device feels the full effect of propellant energy release since the setback force is taken by the breechblock through the cartridge base—the firing pin being retracted immediately after primer indentation. Moreover, the percussion mechanism does not require motion independent of the breechblock. (Contrasting requirements apply when designing for bagged ammunition as described later.)

An overall firing mechanism consists primarily of cocking, percussion, triggering, and actuating elements. These may be separately mounted to the breech or—all but the trigger actuator—housed in the breechblock in a common case called the firing lock. Details depend much on the specific weapon application, also on the breech operating mode. The two illustrative examples to follow—(1) the continuous-pull, percussion and (2) the spring actuated, inertia percussion mechanisms—represent firing devices used with hand operated and semiautomatic breeches, respectively. However, use of these devices in a given mode is one of preference or convenience rather than a fixed rule.

While the "continuous-pull" type has automated internal features, it is most conveniently actuated manually by a lanyard pull. Accordingly, it has been used on a number of towed weapons—particularly those with a horizontal sliding-wedge breech, where its trigger actuation technique is especially advantageous. The "spring actuated, inertia" type has several attributes compatible with semiautomatic breech operation, hence it is used largely with the vertical sliding-wedge variety. Therefore weapon applications include antiaircraft and tank guns as well as self-propelled howitzers (see Table 1-2). In this device, the trigger can be actuated by one of several means; actuation by a solenoid is quite convenient (see Fig. 2-26) when prompted by tactical or technical requirements. It should be emphasized that the percussion firing method remains completely unaltered when the spring loaded device, carrying the firing pin, is released and latched electrically.

All percussion firing mechanisms, regardless of type, have a number of common performance requirements. The firing pin must operate within specified limits of travel. Such factors as pin

Downloaded from http://www.everyspec.com

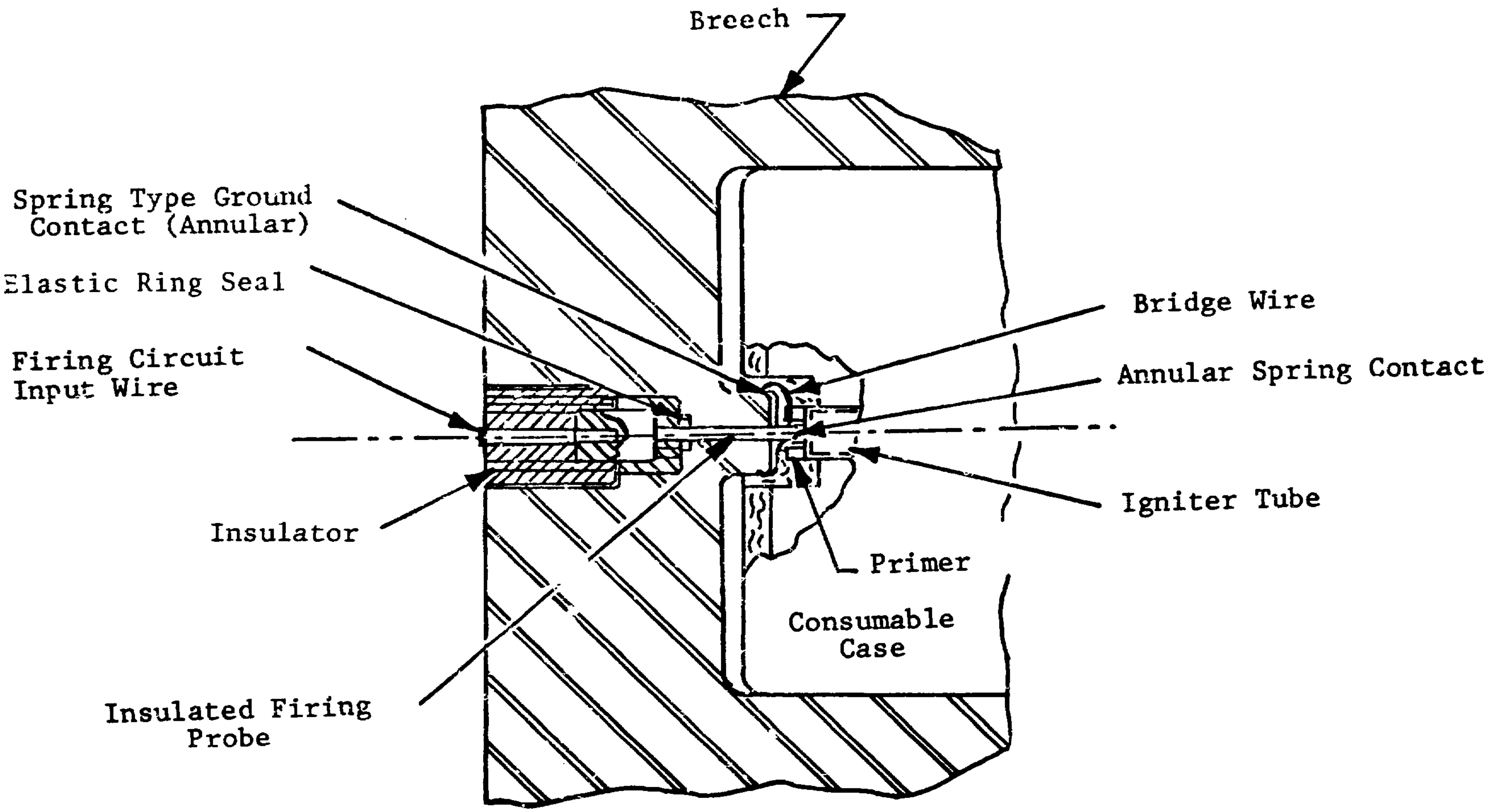


Figure 1-8. Electric Firing Mechanism Schematic for a Consumable Case Round (after Ref. 18)

Downloaded from http://www.everyspec.com

protrusion from the block, retraction therein, and also pin centrality with respect to the primer are set as determined from the breech-tube-ammunition interface dimensions. Firing pin protrusion, for instance, is a function of the head clearance present in a loaded breech.

1-6.3.3 PERCUSSION FOR SEPARATE-LOADING AMMUNITION

A firing mechanism used for separate-loading ammunition is, to all intents and purposes, a complete miniature breechblock. Instead of operating directly on a cartridge containing the complete, full propelling charge, it is built on a smaller scale to operate with a primer cartridge only—the firing of which ignites a black powder charge sewn on the rear of the separately loaded propellant bag. Consequently, the firing device for this ammunition type is complicated and subject to some different and more severe design requirements than its counterpart that initiates cased rounds. Namely, these firing mechanisms must:

1. Move independently with respect to the breechblock for insertion and closure of the separate primer, also for its removal when spent.
2. Incorporate structures sufficient to resist propellant energy effects directly, albeit acting over a small primer chamber area.
3. Interface with the breech operating mechanism for safety considerations (par. 1-6.4) and, depending on the weapon, to acquire a degree of automation.

Firing mechanisms, for separate loaded ammunition therefore, have been designed with considerable variety in elemental arrangement. Contrasts are clearly drawn in two subsequent design examples. It is in this area also that special problems of nomenclature arise. The percussion hammer mechanism is operated strictly by hand. It represents an older design philosophy since the firing lock is completely removed from the breech between successive rounds. However, it is still in use, fulfilling a need for certain large, towed weapons (see Table 1-1).

For equally large but newer self-propelled weapons, a drastically different firing mechanism is necessary. A case in point is the 175 mm Gun, M113A1/8 in. Howitzer, M2A2, self-propelled weapon system (Table 1-2). Here, a small scale vertical sliding breechblock is employed as a sort of firing lock. It contains the firing pin, but the percussion device—a "continuous-pull" type—is a self-contained unit, separately housed in the firing block behind the pin. (Based on previous methods, it is difficult to assign an entirely correct and short designation to this firing group.) The total firing mechanism incorporates several design refinements including automated extraction of the fired primer; the extractor receives further treatment later. At this point it is important to emphasize that automated functions in the firing mechanism are not synonymous with the breech mechanism operating mode as a whole. In the specific example under discussion, the breech itself is operated entirely by hand. Indeed, only one example of a semiautomatic interrupted-screw breech can be cited currently. The 155 mm Self-propelled Howitzer, M126A1, (M109 vehicle) is described in par. 2-11.3.

Examples of the firing mechanisms that follow are representative for design guidance, but do not exhaust the field. Several other firing locks were designed in the past using the vertical sliding block principle (for example the Firing Lock, M17—Ref. 28). These were permanently attached to the breechblock; the primer was inserted manually, but operation of a firing lock handle automatically extracted the spent primer. Electric-percussion firing mechanisms discussed earlier in this subparagraph employed this general type of device for the mechanical feature.

Consideration of pin protrusion, retraction, and centrality—mentioned for cased ammunition firing devices—apply equally well here. Naturally, different dimensional limits apply from one weapon to the next. However, an additional requirement is imposed for mechanisms firing a separate loaded round, i.e., primer

Downloaded from http://www.everyspec.com

headspace—the distance between the firing block front face and the obturator spindle rear face—must be maintained between specified limits. (This is analogous to the dimensional requirement in a full scale sliding-wedge breech.)

1-6.4 SAFETY INTERLOCKS

Those breech system parts and devices which function to prevent dangerous occurrences to the crew or weapon constitute safety interlocks. It is logical to incorporate such important provisions into both the operating and firing mechanisms of a breech. Treatment of safety features is provided in this subparagraph.

Most breech operating mechanisms employ some form of locking device at their closed or firing position. For manually operated breeches, this usually entails a simple spring-loaded latch that is captured by a suitably located slot or notch. The spring loaded male member can be on either the operating lever or breech outer structure as illustrated, respectively, by Figs. 2-14 and 2-16 (horizontal sliding-wedge closure), and Figs. 1-2 and 2-23, items F, G, J, and L (interrupted-screw closure). To release the safety lock, it is only necessary to depress an operating handle or withdraw a latch knob—depending on the particular design.

While the open breech position is not nearly as critical, a positive method of holding the block must be provided. For sliding-wedge breeches (firing metal cartridge case ammunition in conventional practice), the extractor devices take care of this function in their secondary role (par. 2-13). In the interrupted-screw breech, toggle action of the counterbalance assembly is utilized (see Fig. 2-22). This device receives detailed treatment in connection with operating mechanisms.

Design of the interrupted-screw breech type includes other controlling features which make the operating mechanism safe. The breechblock roller and its mating cam (Figs. 1-2 and 2-20) prevent block rotation beyond that needed to clear the closure threads and maintain this attitude during the critical start of hinge motion. (This role is in addition to smoothing the transition of the block between the two kinds of motion.) A guide bracket, mounted in the breech recess swing clearance (Figs. 1-2(B) and 2-23, item KK), provides a datum surface for one of the block interrupted-thread sector flanks as it swings out of the breech recess. Therefore, this component—called the control arc—retains the mesh registry necessary between the block and recess.

Safety interlocks are associated with all firing mechanisms by designing such elements directly into the device or are derived from their operating procedure. Mechanisms for firing conventional cased ammunition have the inherent safety of being in firing alignment only when the breech is fully locked. In applications using separate-loading ammunition, the primer is inserted last, behind a fully loaded chamber and locked breechblock. But that separate primer needs access to the chamber; consequently, the breech system is not completely sealed until the primer is in place and its own small scale "breech" is secured. Comparative design problems associated with firing mechanisms for the distinct ammunition types are discussed in pars. 1-6.3 and 2-12. Specific safety features of the design examples presented are amplified in Table 1-4.

1-6.5 EXTRACTING MECHANISM

After the firing of a projectile, an empty cartridge case remains in the chamber of a gun firing any ammunition except for consumable case and separate-loading types. Obviously, such spent cases must be removed from the weapon before the next round can be loaded. Parts of the breech system which carry out this function fit the term, "extracting mechanism". For fixed, semifixed, and separated ammunition a full size cartridge case in involved; and for separate-loading ammunition, a much smaller cartridge. Accordingly, two broad extractor categories are recognized, i.e.,

1. Those which handle actual full caliber cases and work with the sliding-wedge type breech

2. Those which work with primer cases in certain firing mechanisms of the interrupted-screw

Downloaded from http://www.everyspec.com

TABLE 1-4. SAFETY CHARACTERISTICS OF TYPICAL FIRING MECHANISMS
(These mechanisms are treated in detail in par. 1-6.3)

	Firing Mechanism Type	Safety Feature
CASE AMMUNITION (SLIDING-WEDGE TYPE BREECH APPLICATIONS)	Continuous-Pull, Percussion (with M13 Firing Lock) Ref. 3, pp. 239 and 240 Ref. 35	1. Firing pin is in proper alignment only when breech is fully locked. 2. Firing pin is unseared only upon positive actuation — involving substantial force and motion. 3. The mechanism is not cocked until the instant before firing. 4. It returns to firing position and is seared automatically. 5. In cases of misfire, the action can be repeated at will without exposing the loaded chamber.
	Spring Actuated, Inertia Percussion Ref. 29	1. Same as above. 2. Firing pin is unseared only upon positive actuation of the trigger plunger. 3. In case of misfire, the mechanism may be recocked by hand (normally this function is obtained automatically by virtue of breechblock motion). 4,5. Same as above.
SEPARATE-LOADING AMMUNITION (INTERRUPTED-SCREW BREECH APPLICATIONS)	Percussion Hammer (with M1 Firing Block) Refs. 2 and 30	1. A safety latch interlocks the operating and firing mechanisms: • When the block (M1) is screwed into firing position, it displaces the latch against the breech operating mechanism and the block cannot rotate open. • When the firing block is removed (between successive shots) the latch moves in the opposite direction allowing the breechblock to be opened, and bars access to the firing block housing. The open breech, in turn, locks out the latch. 2. A spring-loaded safety plunger on the firing block engages a notch in the adapter (fixed to the carrier) to hold the block in firing position. 3. When not ready for firing, the block can be rotated to a safe position without removing the primer. A protective rim on the block comes into play and prevents inadvertent contact of the hammer with the firing pin. 4. The hammer itself is provided with a latch pin that locks it in a down position (while the firing block with a new primer is secured into place). The latch pin has to be withdrawn before the hammer can be released.
	Continuous-Pull Percussion, In-Line Hammer (with M35 Percussion Mechanism) Ref. 31, pp. 21 and 75	1. All 5 features of the above M13 device apply, *BUT* only to the M35 percussion mechanism — a part of the overall firing device. The separately housed firing pin is not seared or unseared. 2. Closed position of the slidable firing block is marked by a positive detent falling into place. 3. When the breechblock is opened, the firing pin automatically moves out of alignment with the primer. 4. In case of misfire, the action of extracting the primer (without opening the breech) also starts with the pin moving away from primer alignment.

breech. (Firing mechanisms that permit direct extraction have their own miniature sliding-block breech, see par. 1-6.3.3.)

Design of extracting mechanisms for the full size case is the larger, more involved problem; the discussions in par. 2-14 pertain to this category of extractor.

1-6.6 OBTURATING MECHANISM

The high pressure and high temperature propellant gas, created in a weapon chamber upon firing, must be prevented from leaking past the breechblock to:

1. Retain full propellant efficiency for firing the projectile.

Downloaded from http://www.everyspec.com

. Provide safety to the gun crew.

. Prevent rapid deterioration of gun components not suited to exposure to the gas.

Obturating mechanisms are those parts and devices of the breech system that provide a gastight seal at the breech end of the gun.

Only two general methods exist for sealing a mobile breech; namely, compression and expansion. The method employed depends on the type of ammunition fired and the kind of breech closure. For conventional cased rounds (i.e., metal cartridge cases) in traditional association with the sliding-wedge type breech (see pars. 1-5.2, 2-11.1, and 2-11.2) obturation occurs by expansion of the case.

In separate-loading ammunition, which has similar traditional ties to the interrupted-screw type breech, obturator design is based on compressive loading of a resilient pad. There is no inherent provision for obturation in the ammunition. This must be accomplished by the addition of a separate seal which becomes part of the breech mechanism and must be compatible with its opening and closing motions, yet still create a positive seal during the firing cycle (see Figs. 1-2(B) and 2-20(C). Until quite recently, this ammunition-breech combination represented the sole need for a practical obturator device. Consequently, one standard technique was well developed in Army usage. This is the DeBange obturation system invented almost a century ago and unchanged except for minor variations. Again, it has been the advent of unconventional ammunition and nontraditional ammunition-breech combinations—e.g., bagged charge rounds fired from a sliding-wedge breech—which prompted new design developments and, of course, introduced different problems. Obturation for such new, and still limited applications, is discussed at the end of this subparagraph.

Thus, the Debange obturator is predominant in current applications. It is standard on all Army weapons firing separate-loading ammunition, i.e., 155 mm bore diameter and larger. In such artillery applications—howitzers and guns, including both towed and self-propelled versions—a demanding set of design requirements is imposed on the obturator pad material. Although an elastic part is the heart of the device, it is expected to have a long life which is translatable into hundreds or thousands of rounds fired with a single pad (Refs. 29 and 30).

Two weapons may be cited which do not employ metallic cases or DeBange seals. The 152 mm gun/launcher (M81 and M162) uses a flexible metal ring to seal the mating surfaces between the fixed and separable parts of the breech. Gun pressure expands the metal ring to achieve the requied seal. The other seal is used in the British CH EFTAN tank in a 120 mm gun. An elastic face seal is retained at the entrance of the chamber. Gun pressure forces the seal against the breechblock, effecting obturation. Both of these seal types are described in par. 2-14.

SECTION III. DESIGN RESPONSIBILITIES

1-7 INTERFACES WITH OTHER SUBSYSTEMS

1-7.1 GENERAL

A breech mechanism cannot be designed as an isolated subsystem. The breech functions and their relationships with other interfacing subsystems in the whole weapon system must be considered. The interfaces which provide constraints on design are:

1. Ammunition used
2. Tube and chamber conditions
3. Recoil system
4. Mounts
5. Fire control
6. Bore evacuation
7. Loader-rammer
8. Human factors of the crew.

Some interfaces involve actual physical contact with the breech, while others have only

Downloaded from http://www.everyspec.com

functional relationships. These subjects are treated more extensively in Chapter 2. The interface with ammunition is more pervasive than the others and is summarized in par. 1-7.2.

The breech designer should realize that for each interface constraint imposed there is a like one for the interfacing subsystem, assembly, etc.—imposed by the breech mechanism. It is assumed that the initial definition of system constraints has balanced the various allocations for weight, space, etc., so that a reasonable basis exists for initiating the design of each element. As the design of the subsystem proceeds from the largest assembly to the smallest, the required adjustments (if any) in any interfacing elements should decrease.

The interface between the breech mechanism and the recoil system provides an example of the dual aspects of an interface. The recoil system design requires that the total recoiling mass be defined. The mass of the breech is an important part of this total. In addition, if the recoil is to be used to automate some aspect of the breech operation, the requirement must be established by the breech designer. The interrelationship of the breech mechanism and recoil system is (as a unit) with the gun mount. The elevation mechanism and traversing mechanism provide another interface example. The spatial relationship of the breech and the mount during recoil, and when the breech is open for loading, must be defined in relation to weapon quadrant elevation and azimuth so that adequate clearance may be established.

1-7.2 AMMUNITION

The interface between the breech mechanism and the ammunition changes with ammunition type. Fixed and semifixed (cased) as compared to separately loaded bag charge ammunition evidence greater differences than do metal cased and consumable cased ammunition. These types have more similar characteristics than they have with separate loaded ammunition. The primary difference arises from the presence or absence of a cartridge case. Associated with this difference is an interface with ignition of the gun propellant.

Chapter 2, Section I, describes the various ammunition types and provides more detailed interface requirements. Rocket assisted projectiles are characterized by fixed ammunition but may fall into any of the categories, depending on the caliber and/or weight. Guided projectiles could be characterized by any of the ammunition types; however, there may be a specific interface requirement stemming from an aspect of the guidance design. The interfaces also may vary depending on the weapon tactical application and degree of mechanization and automation incorporated.

1-8 DESIGN PROCEDURE

The designer has the responsibility for defining all of the components which make up the breech mechanism so that, when they are manufactured and assembled in production, the resulting subassembly will function in the required manner and the weapon system can meet operational requirements. The designer may discharge this responsibility by following the procedure outlined in the subparagraphs that follow. This procedure has been divided into four design activities which can result in the desired definition. Final documentation is prepared which contains the applicable drawings and specifications for the breech mechanism.

The design requirements for a breech mechanism make the initial type selection quite clear and there is little need to perform an iteration cycle to obtain the optimized one. The designer's task is to tailor the breech type to the specific weapon system. Unconventional ammunition may be an exception, but the breech mechanism would be expected to use features of existing types. In the normal situation, metal cased ammunition will require a sliding-wedge breech mechanism and separate loaded ammunition will require an interrupted-thread type.

Chapter 3 presents the design procedure in greater detail; the material in this paragraph (par. 1-8) provides an overview. Its purpose is to

Downloaded from http://www.everyspec.com

correlate the background material presented in the previous section and prepare the user for the material presented in Chapters 2 and 3.

1-8.1 DESIGN LAYOUT

The design procedure is started after all of the requirements and interfaces have been documented and the breech mechanism type has been selected. The initial step is the generation of a design layout of the breech mechanism. The layout is prepared to scale and shows the interrelationship of all the components in the mechanism. Sufficient views are produced so that the following can be determined.

1. Breech and component part configuration
2. That the breech can be assembled and disassembled properly
3. Proper motions have been achieved
4. That moving components do not encounter interference conditions
5. That spatial limitations have not been exceeded for the prescribed range of quadrant elevation and azimuth angles. (This includes consideration of recoil and gun crew loading operations.)

The layout drawings should be reviewed after these requirements have been met. The review should assure that the surfaces and geometries delineated are actually producible. This action completes the first stage of the design.

1-8.2 DESIGN ANALYSIS

The design analyses are started only after the breech mechanism configuration has been fixed. Complete design layouts provide the required definition. Analysis is performed before material selection is made so that there is a defined load stress requirement available for this process.

There are five types of analysis which may be used in breech mechanism design. Kinematic analysis (1) is made to delineate mechanism motions, velocities, and accelerations without regard to the forces required. In the process of preparing the design layout, the designer most likely performed a graphical "kinematic analysis" to assure that the required motion was achieved. This form of analysis is applied to moving parts of the breech mechanism. It is described in par. 3-11 and an example problem is provided in par. 3-17.1.

Kinetic analysis (2) is performed to define the motion produced by the unbalanced forces acting on a body. The weapon recoil gives rise to such forces acting on the breech mechanism. Further discussion is presented in par. 3-12, and a sample analysis is provided in par. 3-17.2. Analysis is performed to describe the dynamics of a body including both kinematic and kinetic analyses.

Breech mechanism kinetic analysis considering weapon recoil requires input from the other weapon elements. The stress analysis (3) made next in the design procedure requires input from the ammunition design to define the gun pressure as well as the results from the kinematic and kinetic analyses. The stress analyst must consider residual internal stresses, which may result from manufacturing, in addition to those arising from externally applied loads. Par. 3-13 explains this subject and provides reference for computational procedure. Pars. 3-17.4 through 3-17.8 provide design examples and illustrate the significance of stress concentration factors.

Completion of the first three analyses is required before the material and manufacturing process can be selected. These decisions should be made prior to performing the weight analysis (4). The significance of this activity is presented in par. 3-14. It is sufficient to note that poor initial estimates of weight and center of mass location may impact the previous analysis and require updating.

Reliability analysis (5) is the final analysis performed and assesses the entire breech mechanism in terms of its capabilities to fill the operational/functional requirements. As such, the effectiveness of all the other design activities is evaluated. Reliability analysis is defined in par. 3-15 and an example analysis is presented in par. 3-17.9. As discussed, design for reliability of mechanical systems is quite difficult and depends to a large degree upon experience obtained with

Downloaded from http://www.everyspec.com

previous similar designs. Breech mechanism parts are complex, and analytical methods are not always suitable for predicting failure location and type. These conditions require previous experience and/or examples of mechanism failure for definition. Par. 2-29 and Refs. 31-34 provide information on failures.

1-8.3 MATERIAL SELECTION

The design of a breech mechanism may be viewed as encompassing two parts. The first part is described in pars. 1-8.1 and 1-8.2, production of the design layout and the determination of the stresses. The second part is the material selection for the various components which make up the mechanism. Closely associated with this is the method of manufacture (forging, machining, etc.), and heat treatment and surface conditions (hardening, plating, etc.). The materials selected have an important effect on part weight, cost, service life, etc.

Pars. 2-28 and 3-8 provide background material pertaining to material selection. Refs. 31-34 contain ten reports relating components and material performance in various weapon systems. Material selection is one area in the design which exemplifies the need for a design team. The part design, coating or plating, manufacturing process, and stress imposed are all significant aspects in the final selection of the material and heat treatment which will be used. The material selection process, combined with the other aspects of the breech mechanism design, may be aided by a trade-off study which provides alternate approaches for the part design. Historical data on similar breech components may be extremely useful in this process.

1-8.4 ENGINEERING DRAWINGS

The design procedure starts with a layout and is completed with the production of engineering drawings which define the various breech mechanism components. The results of the various analyses performed and the material selected are detailed on the drawings. Materials are called out in drawing blocks, notes, and by reference to specifications. The results of the analysis are reflected by the part configuration and dimensions placed on the drawing.

Dimensional practice is critical in defining a functional part which must be manufactured in production and be interchangeable. Key elements in dimensioning practices are:

1. Unilateral and bilateral dimensions
2. Tolerance, limits, and variances
3. Concentricity and centrality, perpendicularity, and parallelity
4. Complex surface dimensioning
5. Tolerance buildup and interface checks
6. Reliability and maintainability compliance review.

Pars. 2-28 and 3-7 provide amplifying material. Ref. 35, Dimensioning and Tolerancing, is the applicable military standard covering approved dimensioning practices.

1-8.5 SUMMARY

Design is a multidisciplinary activity with some degree of involvement from initial concept development throughout the in-service life. Design functions performed at the various stages of weapon life may be grouped as follows:

1. Initial design and development—concept formulation, layout, mathematical analysis, materials selection, detailing, economic analysis, reliability/availability/maintainability/dependability analysis, and producibility analysis
2. Testing and design refinement—simulation, laboratory and field tests, evaluation, design refinement
3. Production integration—manufacturing support
4. In-service design maintenance—updating, upgrading, further design refinement, industrial mobilization support.

Effective integration of these varied functions is accomplished by a multidisciplinary design group comprised of specialists in the various skills involved.

Downloaded from http://www.everyspec.com

REFERENCES

1. ST 9-152, *Ordnance Technical Terminology*, US Army Ordnance School, Aberdeen Proving Grounds, MD, June 1962, pp. 54, 142, 151, 189, 190.
2. AMCP 706-250, Engineering Design Handbook, *Guns General* p. 2-1.
3. T. J. Hayes, *Elements of Ordnance*, John Wiley & Sons, Inc., New York, NY, 1949, pp. 285, 335, 624, 639.
4. D.F.H. Chandler, "Some German Weapons of World War II", 956-8, *The Engineer*, June 1, 1962.
5. R. G. Nutting and A. P. Meyers, *Feasibility Studies of a 105 mm Rapid Fire Direct Support Artillery Weapon*, IIT Research Institute, 1968, pp. 3-23, AD-480 615.
6. J. L. Adimon, et al., *Feasibility Study of a 105 mm Rapid Fire Direct Support Artillery Weapon*, General Electric Co., Burlington, VT, April 1966, pp. 23-38, AD-484 467.
7. R. Blaine, et al., *105 mm Rapid Fire Direct Support Artillery Weapon, Feasibility*, American Machine and Foundry Co., York, PA, January 1966, pp. 7-31, AD-480 291.
8. P. E. Stewart, *105 mm Rapid Fire Direct Support Artillery Weapon*, General American Transportation Corporation, January 1966, pp. 5-55, AD-480 175.
9. *Weapons Systems Engineering*, Vol. 1, *Introduction and Engineering Materials*, Dept. of Engineering, US Military Academy, West Point, NY, 1970-71, p. 1-32.
10. AMCP 706-108, Engineering Design Handbook, *Elements of Armament Engineering, Part 3, Weapon Systems and Components*, pp. 8-1,-2.
11. ST 9-159, *Handbook of Ordnance Material*, US Army Ordnance Center and School, Aberdeen Proving Ground, MD, March 1968.
12. G. M. Barnes, *Weapons of World War II*, D. Van Nostrand Co., Inc., New York, NY, 1947, pp. 111-74, 199-256.
13. TM 9-2300 *Artillery Material and Associated Equipment*, May 1949, pp. 9-76,-98,-99.
14. AMCP 706-250, Engineering Design Handbook, *Guns General*, pp. 3-1 — 3-4.
15. AMCP 20-244, Ordnance Engineering Design Handbook, *Section I, Artillery Ammunition General*, pp. 1-1,-2.
16. TM 9-1300-203, *Ammunition for Antiaircraft, Tank, Antitank, and Field Artillery Weapons.*
17. R. M. Ogorkiewicz, "Chieftan Tank", *The Engineer*, 259-62, 16 August 1963.
18. T. J. Hayes, *Elements of Ordnance*, John Wiley & Sons, Inc., New York, NY, 1949, pp. 213-14.
19. A. N. Latukhin, *Modern Artillery*, Army Foreign Science and Technology Center, Charlottesville, VA, November 1971, pp. 74-5, AD-739 350.
20. MIL-C-45574 (WC), *Cannons, 152 mm Gun-Launcher: M81E1 and XM162E1.*
21. TM 9-2350-232-10, *Tank, Combat, Full-Tracked: 152 mm Gun-Launcher, M60A1E2*, Operator's Manual.
22. TM 9-2350-232-35/1, *Tank, Combat, Full-Tracked 152 mm Gun, M60A1E2*, Direct Support, General Support and Depot Maintenance Manual.
23. TM 9-2350-230-12, *Armored Reconnaissance/Airborne Assault Vehicle, M551*, Organization Maintenance Manual.
24. TM 9-2300, *Standard Artillery and Fire Control Materiel*, February 1944, pp. 45, 161.
25. *Breech Mechanisms for Tank Cannon*, Armour Research Foundation (now IIT Research Institute) Final Report Project K-100, WVT Arsenal Contract DA-11-022-ORD-2182, 20 October 1958.
26. A. E. Thrailkill, *Combustible Cartridge Case Ammunition and Its Influence on Gun and Breech Design*, BRL Tech. Note 1133, Aberdeen Proving Ground, MD, July 1957.
27. T. J. Hayes, *Elements of Ordnance*, John Wiley & Sons, Inc., New York, NY, 1949, p. 218.
28. TM 9-350, *155 mm Gun, M2*, May 1949, pp. 134-8.
29. US Army Ordnance Dept., *A Symposium on Breech Mechanisms, Part II*, Ord. Project No.

Downloaded from http://www.everyspec.com

REFERENCES (cont'd)

TR1-1000L, The Franklin Institute, Philadelphia, PA, March 1949, pp. 2-2, 4-23,-24,-25.

30. James T. Hynes, *Silicone-Asbestos Obturator Pads for 175 mm Gun, M113A1, A Product Improvement*, Watervliet Arsenal, Watervliet, NY, February 1971, pp. 7-18, 25-30, AD-720 988.
31. Donald G. Forkas, et al, *Determination of the Fatigue Life for the Breech Mechanism Assembly for the Cannon, 175 mm Gun: M113 and M113A*, Benet R&E Laboratories, Watervliet Arsenal, Watervliet, NY, February 1971, pp. 5-53, AD-721 291.
32. G. S. Groak, Jr., *Engineering Test of 152 mm Gun-Launcher, XM 81E12, and Recoil Mechanism, XM551 (Life Test)*, Aberdeen Proving Ground, MD, February 1966, pp. vi, 1-6, II-1, III-5, AD 480 086.
33. Kenneth H. Abbot, *Investigation of Failure of XM70 Breech Tubes*, WAL TN 732.1/1, Watertown Arsenal, Watertown, MA, September 1962, pp. 3-25.
34. US Army Ordnance Dept., *A Symposium on Breech Mechanism, Part III*, Ord. Project No. TR 1-10001L, The Franklin Institute, Philadelphia, PA, November 1949, pp. 3-1-136, 1-371.
35. ANSI-Y14.5, *Dimensioning and Tolerancing*, The American Society of Mechanical Engineers, New York, NY, 1973.

Downloaded from http://www.everyspec.com

Chapter 2
BREECH DESIGN CONSTRAINTS
SECTION I. OVERVIEW

The basic or mandatory tactical requirements of a weapon system relate to performance at the target. These requirements are met in terms of rate of fire and ammunition design, and imply or bound other weapon system characteristics. The details of the gun envelope dimensions and weight evolve, which lead to establishing the recoil system and mount characteristics. This process establishes sufficient detail to address the total system mobility requirements and determine the mobility characteristics.

It should be noted that "mobility" is used in two senses. The primary meaning to the breech mechanism designer is that the weapon system mobility is characterized by towed, self-propelled, or combat vehicle. The meaning of mobility to the total system design is indicated by transportability, e.g., helicopter, etc., and terrain traversing capabilities, e.g., off-route, etc. These terms are not applied independently of each other. If the weapon system must be helicopter transportable, its gross weight and envelope become restricted by this transportation mode and the type of transporting vehicle. This in turn would place an initial restriction on the ammunition which would be coupled with the rate of fire to achieve a specified level of performance on the target. The breech mechanism designer will ordinarily not be involved in this "transportation" aspect of mobility.

The weapon vehicle characteristics, relating to the terrain which must be traversed, will not directly effect the breech mechanism designer. This aspect of mobility places functional and design requirements on the carriage and/or weapon system vehicle. Thus the mobility characteristics of the weapon system, within the initial constraints provided by transportation and operating terrain, become defined after the weapon system design has reached the stage which establishes a weight budget and characterizes the recoil system and mount.

The mobility and firepower requirements of a new weapon establish the size and weight of the gun and mount, the space available, the type ammunition to be used, and often the type of breech mechanism that must be designed. Within these broad constraints, trade-off studies are undertaken by the design team to allocate individual component and subsystem weight, strength requirements, and general compatibility requirements of the individual subsystem which interact to perform the required tasks. The breech interfaces with the entire gun system. All other subsystems pose a set of constraints and make design trade-off necessary.

The breech designer must thoroughly understand the requirements of all the subsystems. A detailed set of specifications and a description of all forces that will interact with the breech are necessary inputs.

In this chapter, the important subsystems that constrain breech design are considered. To describe adequately the function and design of each of these subsystems would require an entire handbook. Such discussion is, of course, beyond the scope of this handbook. In this chapter we limit consideration to the manner in which these subsystems affect and influence breech mechanism design. The designer, of course, will want to familiarize himself with all aspects of their function and design. The references are cited for this purpose.

The weapon system operational requirements are used to establish functional and design requirements. The design requirements for breech

Downloaded from http://www.everyspec.com

mechanisms arise from the system functional requirements and from interfaces with the subsystem and subassemblies. The interfaces vary with the weapon system type.

The weapon system operational requirements will have been used by the weapon system program manager to establish key characteristics of concern to the breech mechanism designer. These include:

1. Weapon firing rate required for each munition kill-mechanism type and the required terminal ballistics which lead to munition characteristics of type (fixed, semifixed, or separately or separate-loading), weight, length, diameter, gun maximum pressure and pressure time history, and fire control characteristics. In turn, this leads to gun crew and loader/rammer requirements.

2. Weapon mobility requirements lead to a determination of whether it is to be towed, self-propelled, or a combat vehicle and if it is to be helicopter transportable. The gun subsystem weight, resulting from performance on the target requirements, impacts this requirement.

3. The geographical, climatic, and temperature extremes under which the system must perform provide component design operating and maintenance requirements.

4. The system service/shelf life and the mean time between failure (MTBF) also provide design and operating requirements.

SECTION II. AMMUNITION INFLUENCE

An artillery round consists of a projectile (solid or filled with an active agent) and an integral or separate propelling charge, each with a means (fuze or primer) of initiating function. Artillery rounds, consisting of a projectile and an *integral* propelling charge, are described as "fixed" or "semifixed" "cartridges". Where the projectile and propelling charge are separate, the designations "projectile" and "propelling charge" are used. Such rounds are classified as "separated" or "separate-loading" ammunition. Fig. 2-1 shows the component parts of the various types of complete rounds. Table 2-1 presents characteristics of various ammunition types. Cartridge cases are made of drawn brass, aluminum, spiral-wrapped multipiece, or drawn steel. The metal must be specially alloyed and treated so that the case will fulfill the function of obturation (sealing) and permit ease of extraction.

The case contains the propelling charge in fixed, semifixed, and separated artillery ammunition rounds. The case profile and size, and that of the weapon chamber must be compatible. The base of the case (e.g., the end of the case supporting the primer M in Fig. 2-1) is designed to be relatively heavy to ensure firm attachment of a primer and has a rim or groove to permit mechanical extraction. The cartridge case, with its integral primer, contains the propellant charge. Currently there are five types of ammunition, four of which are illustrated in Fig. 2-1 (refer to pars. 1-4.3, 1-7.2, and 2-1 through 2-4):

1. In nonadjustable (fixed) rounds, the case is crimped to the projectile.

2. In adjustable (semifixed) rounds, the case fits freely to the projectile.

3. In separated ammunition, the case is plugged and the case and the projectile are separate.

4. Separate-loading ammunition has no case.

5. Consumable case round, a completely different type round, used in increased number in both new and existing artillery weapons. The problems it poses to the breech designer are serious and have not yet been completely resolved.

The primer that ignites the propelling charge consists essentially of a charge of black powder attached to a small-arms primer. The primer cap and powder charge usually are assembled in a

Downloaded from http://www.everyspec.com

A-Fuze
B-Booster
C-Shell
D-Ogive
E-Bourrelet
F-Bursting Charge
G-Rotating Band
H-Crimp
J-Base Cover
K-Cartridge Case
L-Propelling Charge
M-Primer
N-Lifting Plug
P-Grommet
Q-Igniter
R-{Cased Propelling Charge
S-Closing Plug
T-Distance Wad
U-{Igniter Charge Assembly

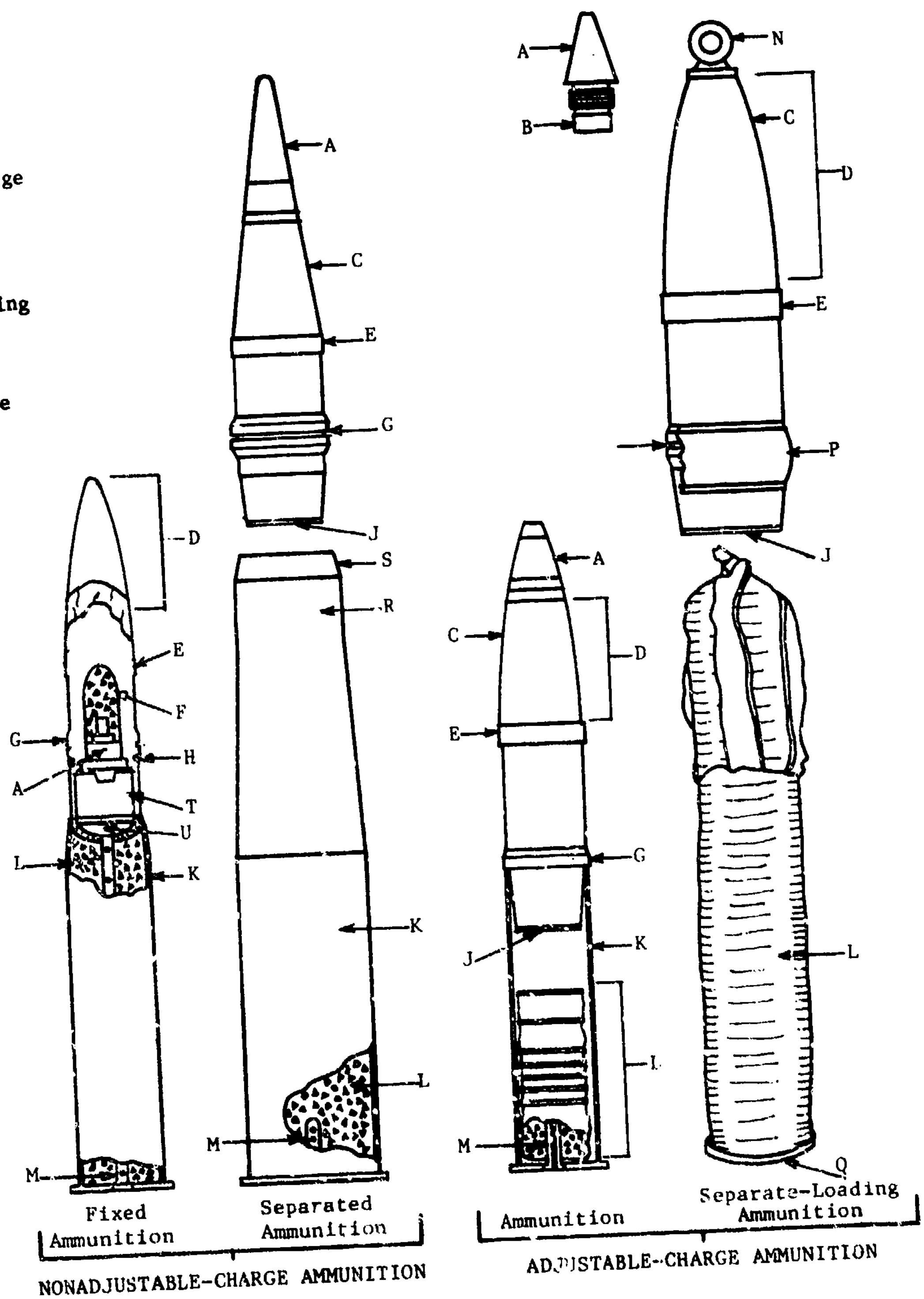


Figure 2-1. Types of Complete Rounds of Artillery Ammunition (Ref. 1)

Downloaded from http://www.everyspec.com

metal tube. When used with a fixed, semifixed, and separated ammunition, this tube is forcefitted into the base of the cartridge case at the time of manufacture. In separated ammunition, an auxiliary igniter charge is placed around the primer or on the wadding to insure proper ignition of the propellant. When separate-loading ammunition is used, the primer is inserted, by hand or mechanically, into the firing block or mechanism as the final step in loading. The igniter charge is in a bag sewn to the base end of the propelling charge. A core through the center of the propelling charge bag is used sometimes for upper zone charges, in addition to the base igniter pad.

Historically, artillery primers have been classified according to the method by which they are fired—i.e., percussion, electric, combination percussion-electric, and friction. The most common primer in use today is the percussion type. The percussion primer, generally used in all artillery ammunition, is fired by a blow of the firing pin. The primers used in cartridge cases contain sufficient black powder to ignite the propellant in the cartridge case. Those used with separate-loading propelling charges contain only enough black powder to ignite a black powder igniter charge attached to the propelling charge. A complete description of artillery ammunition is provided in TM 9-1300-200 (Ref. 3).

2-1 FIXED AMMUNITION

In fixed ammunition, the projectile is permanently fastened to the cartridge case and is loaded into the weapon as a single unit. The propelling charge is not adjustable and the round becomes unserviceable if the projectile and case become loosened or unfastened before firing. The case and projectile usually are crimped rigidly together with the propelling charge loaded loosely or in a plastic bag into the case (Fig. 2-1 (Item L)). When the charge does not completely fill the case, a spacer or distance wadding (usually a cardboard disk and cylinder) is inserted in the neck of the case between the charge and projectile base. Fig. 2-2(A) shows this cartridge chambered.

The breech mechanism designer must consider the following items with regard to this type of ammunition:

1. Cartridge case shape
2. Firing pin actuation
3. Case extraction
4. Case ejection
5. Ramming velocity (debulleting) in an automatic loader/rammer.
6. Safety of the loader's hand when closing the breechblock.

2-2 SEMIFIXED AMMUNITION

In semifixed ammunition, the case fits loosely over the projectile, allowing adjustment of the propelling charge for zone firing. The propelling charge is divided into sections, each containing a bag of propellant powder. The charge is adjusted by lifting the projectile from the case, removing the unnecessary sections or increments, and reassembling the case and projectile.

The breech designer's checklist is nearly the same as that for fixed ammunition. Debulleting is not a problem since the projectile is stopped by the rotating band engaging the forcing cone. Erosion of the forcing cone can cause changes in the chamber volume and affect range accuracy. (In fixed ammunition, it can cause blowby.) Extraction of a round that has failed to fire (misfire or hangfire) must be considered—the projectile will not easily extract with the case and the design must permit rapid clearing of a hot chamber.

2-3 SEPARATE-LOADING AMMUNITION

The components of separate-loading ammunition, see Fig. 2-2(B), are loaded individually. First the projectile is inserted into the breech and rammed. Secondly, the multisectional propelling charge (Fig. 2-3) is placed in the powder chamber immediately behind the projectile. After the breechblock has been closed and locked behind

Downloaded from http://www.everyspec.com

TABLE 2-1
AMMUNITION CHARACTERISTICS (REF. 2)

	Ammunition Designation			Ballistics		Weights		
	Type	Projectile	Propellant Charge	Maximum Pressure, kpsi	Muzzle Velocity, fps	Total, lb	Projectile as Fired, lb	Propel Charg lb
75 mm Pack Howitzer, M116	Semifixed	M48	FNH, M1*	26.0	1500	17.87	14.70	1.1
105 mm Howitzer, M101A1	Semifixed	M1	FNH, M1	28.0	1550	42.07	33.00	3.0
105 mm Howitzer, M102	Semifixed	M1	FNH, M1	36.4	1621	42.07	33.00	3.0
105 mm Howitzer, M103 (M108 vehicle)	Semifixed			36.7				
155 mm Howitzer, M1A1	Separate Loading	M107	M4A1	40.0	1850			
155 mm Howitzer, M114A	Separate Loading	M107	M4A1	40.0	1850	107.00	92.86	13.9
155 mm Howitzer, M126A1 (M109 vehicle)	Separate Loading			41.0				
8 in. Howitzer, M2A2 (M110 vehicle)	Separate Loading	M106	M2	39.6				39.
8 in. Howitzer, M115	Separate Loading	M100	M106			213.375	200.00	13.
240 mm Howitzer, M1	Separate Loading	M114		36.0	2300	439.00	360.00	78.
37 mm Antitank Gun, M3A1	Fixed	M54A1	FNH, M1	50.0	2600	2.67	1.34	0.
76 mm Gun, M32 (M41A3 Tank)	Fixed	M42A1	FNH, M1	55.2	2400	25.52	12.87	1.
90 mm Gun, M41 (M48A3 Tank)	Fixed	M71A1	FNH, M1	57.7	2700	39.54	23.57	7.
155 mm Gun M68 (M60A1 Tank)	Fixed	M393A1		61.8		46.7	24.8	
120 mm Antiaircraft Gun, (M1)	Separated	M73	NH, M1**	38.0	3100	100.00	50.00	23
120 mm Gun, M58 (M103A2 Tank)	Separated			57.6				
152 mm Gun/Launcher, M162 (M60 Tank)	Fixed #			38.4				
155 mm Gun, M46 (M53 vehicle)	Separate Loading	M101	M1	43.5	2800	126.42	94.69	32
175 mm Gun, M113A1 (M107 vehicle)	Separate Loading	M107	M437	51.0		202.3	147.3	55
280 mm Gun, T131	Separate Loading				2500			

* FNH = Flashless nonhygroscopic; ** NH = Nonhygroscopic; # = Combustible cartridge case.

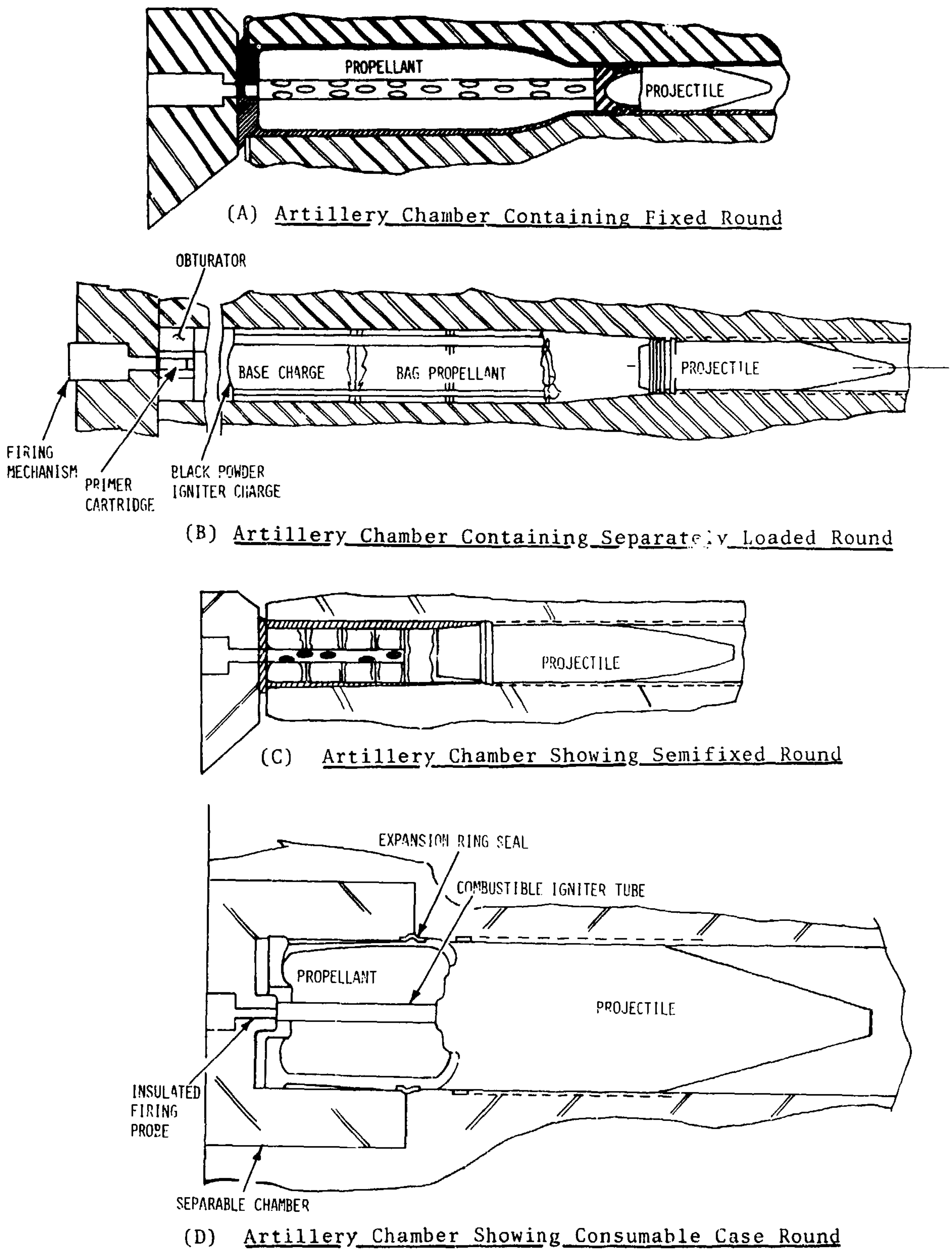
Downloaded from http://www.everyspec.com

Propelling Charge, lb	Lengths			Supplementary References
	Overall, in.	Projectile, in.	Charge, in.	
1.15	23.47	13.76		TM 9-319
3.04	31.07	19.63	Case 14.64	
3.04	31.07	19.63	Case 14.64	APG-MT-3871
	48.00	26.82	21 max	
13.91	48.00	26.81	21 max	TM 9-1025-200-12
39.9		34.35	24 max	TM 9-2350-230-35/1
13.375				
78.75				TM 9-2300
0.375				TM 9-2300
1.14				TM 9-2300
7.31	37.45	16.37	23.70	TM 9-2350-224-10
	37.00			TM 9-2350-215-10
23.62	56.86	24.06	Case 32.80	TM 9-2300KM9-1901
32.23				
55.0	86.73	37.23	49.50	TM 9-2350-230-35/1

Downloaded from http://www.everyspec.com

This page left blank intentionally

Downloaded from http://www.everyspec.com



(A) Artillery Chamber Containing Fixed Round

(B) Artillery Chamber Containing Separately Loaded Round

(C) Artillery Chamber Showing Semifixed Round

(D) Artillery Chamber Showing Consumable Case Round

Figure 2-2 Artillery Chamber and Ammunition Configurations (After Ref. 4)

Downloaded from http://www.everyspec.com

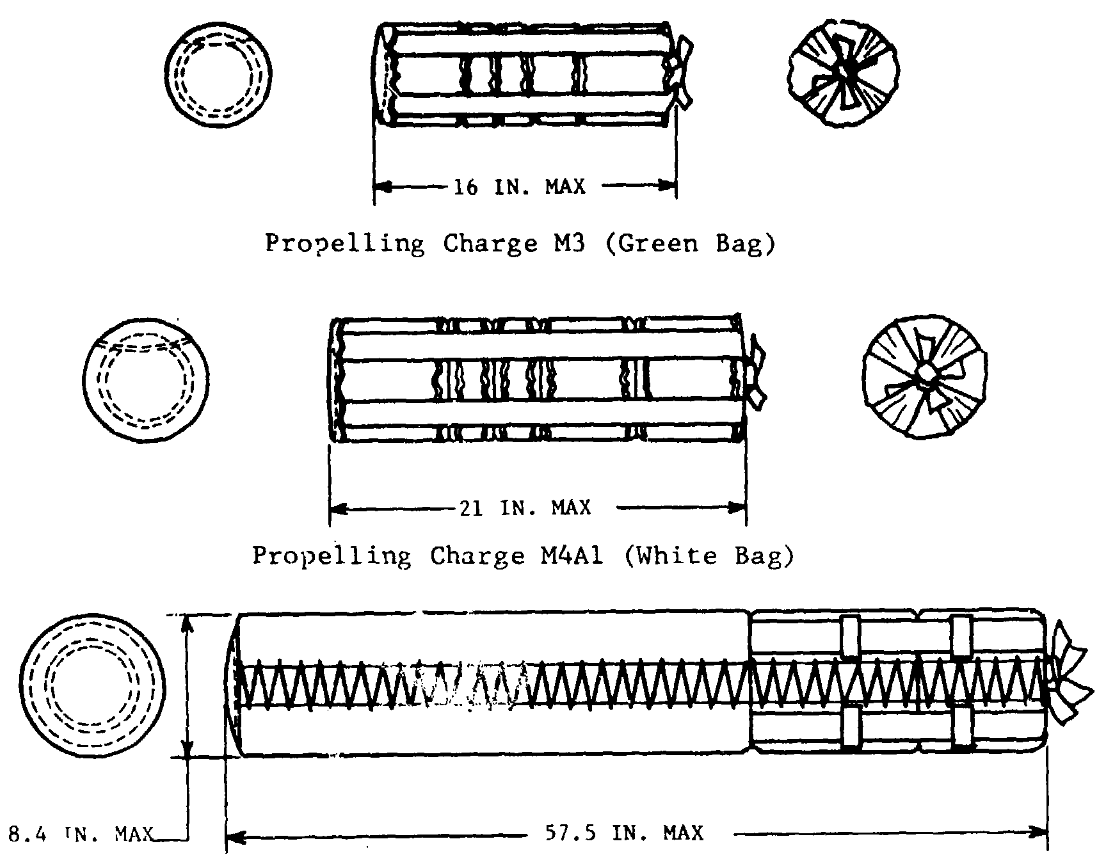


Figure 2-3. Separate-Loading Propelling Charges (Ref. 5)

the charge, the primer is inserted into the firing mechanism.

Cloth cartridge bags are a suitable and convenient means of containing the propellant in separate-loading ammunition. Multisection charges permit varying the size of the propelling charge and facilitate handling large and heavy charges. There are two types of multisection charges: base and increment, and unequal section. Base and increment propelling charges consist of a base section or charge and one or more increments. The increments may be of equal or unequal weight. The base section is always fired; the increments may be removed or fired. One igniter pad is attached to the base end of the base section and, in some types, there are igniters in the increments as well. Unequal section charges are used in howitzers and some guns. The charge may be made up of several equal sections and two or more unequal sections.

Multisectional charges, of equal or unequal sections, are important for weapon zoning in addition to facilitate the handling of heavy charge weights. The tactical employment of howitzer, and some guns, involves "upper" and "lower register" fire and various bands of ranges. Upper register fire means the employment of greater than 45 deg. quadrant elevation, whereas low register refers to angles less than 45 deg Howitzer upper register fire is typically used to achieve desired munition angle of fall, provide troop masking fire, and clear elevated objects such as hills in the line of fire. The charge in these weapons is "zoned" to provide a variety of impact ranges for various register firings. The zoning takes the form of a variable propellant charge weight.

Separated ammunition (Fig. 2-2(C)) is a

Downloaded from http://www.everyspec.com

special type of separate-loading ammunition. The propelling charge is fixed and is contained in a brass or steel cartridge case together with the primer. The case is closed at the forward end by a cork, plastic, or asphalt plug. The projectile does not fit into the case and is loaded separately. The separation of long, heavy rounds into two parts facilitates loading. The 120 mm antiaircraft gun uses ammunition of this type.

The breech designer must consider the following when designing for separate-loading ammunition:

1. Obturation
2. Scavenging after firing (for closed cab weapons)
3. Ramming, supporting, and carrying the projectile
4. That the breech must swing away for clearance to load
5. Firing pin actuation
6. Clearing the chamber after a misfire
7. Breech opening combined with bore evacuation (tank turret).

2-4 CONSUMABLE CASE ROUND

Consumable cases are composed of felted nitrocellulose fiber which serve as the propellant container. Consumable cases offer the following advantages (Ref. 6):

1. The problem of spent case disposal and reclamation is completely avoided. (In Korea, for example, literally mountains of metal cases accumulated.)
2. Case weights are reduced by 50 to 85%.
3. Strategic metals are saved.
4. Production costs are reduced; manufacturing does not require heavy machinery.

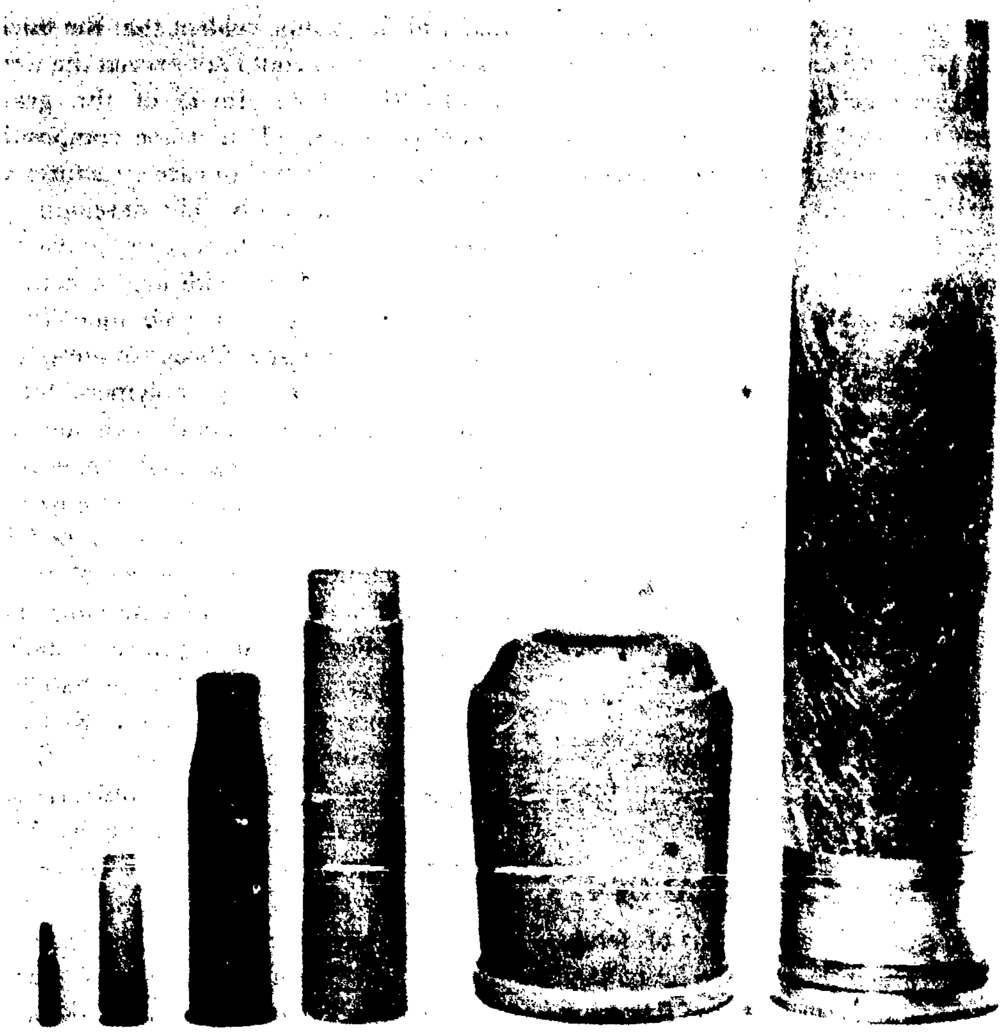
The development of consumable case material, although simple in concept, took more than 10 yr. Briefly, the ballistic problems centered about the fact that the case wall had to burn in the same or less time as the bulk, granulated propellant charge. It was found that nonporous material would burn only on the inside of the case wall and at a linear rate not appreciably greater than that of the conventional propellant material. It became evident that the thickness of a solid case wall could not exceed the web (a few hundredths of an inch) of the granulated propellant grains of the same composition and burning rate. Such thin case structures were inadequate mechanically. The development of the felted nitrocellulose fiber case provided better composition and, in addition, a commercially adaptable manufacturing technique. The process consists of accreting fibrous materials from a water slurry containing a polymeric binder onto a die with the geometry of the cartridge case. It is then pressed to final size and shape in a cavity mold and dried by removal of the solvent. Fig. 2-4 shows the range of sizes that can be fabricated by this technique. The ballistics of all the sizes shown are adequate, and case consumption is complete. Physical strengths are sufficient so that, in general, the round can be handled in the same manner as a metal round (Ref. 6).

The consumable case presents the breech designer with a new set of problems. Since the case material is consumed during the ballistic cycle, a new means of sealing the breech from gas leakage must be devised. The reduced strength of the case presents a major challenge—careful loading and handling procedures must be established. Under some firing conditions not all of the case is consumed. Therefore, it is desirable to purge the chamber before opening the breech, and accommodation for scavenging may have to be provided in the chamber or breech.

The design of the 152 mm Gun/Launcher (M81 and M162 versions) dealt successfully with all these problems. The 152 mm M81 employs a fully consumable cartridge case for the conventional high explosive round but not for the guided missile projectile.

A hybrid cartridge has been developed to adapt consumable case material to existing weapon systems. A metal base, which seals at the breech and provides a receptacle for the primer, and a consumable sidewall body are used. This type "partially consumable case" ammunition has been developed for use in the 105 mm howitzer (Fig. 2-4) and gun, and the 120 mm weapon

Downloaded from http://www.everyspec.com



A. 7.62 mm (Nato)	D. 57 mm Recoilless
B. 20 mm	E. 152 mm
C. 37 mm	F. 105 mm

Figure 2-4. Fiber Felted Consumable Cartridge Cases (Ref. 7)

system. These cases afford many of the advantages of fully consumable cases, i.e., reduced weight and less consumption of critical raw materials.

The breech designer must consider the following factors if a consumable case is selected:

1. Obturation of the breech
2. Scavenging after firing may be necessary
3. Automatic breech operation
4. Extraction of a hangfire or misfire (manual)
5. Breech opening combined (timed) with bore evacuation in a turret installation.

Downloaded from http://www.everyspec.com

2-5 ROCKET-TYPE ROUNDS

Several types of unconventional artillery in various states of design and development use rocket motors in some phase of their functional cycle. The rocket-assisted projectile (RAP) combines the properties of conventional (action-propelled) and reaction-propelled projectiles. On ignition of the conventional (action) powder charge, the delay pellet of the reactive charge is ignited. The powder gases generated from combustion of the conventional charge eject the projectile from the barrel at a certain muzzle velocity. The reactive charge, which burns during part of the trajectory, creates additional velocity, assuring a significant increase in the range of fire. The rocket-assisted projectile permits either an increase in the maximum effective range with a fixed gun weight or a decrease in the gun weight with a fixed range.

SECTION III. WEAPON INTERFACES

Weapon interfaces were introduced in par. 1-7. The ammunition interfaces were presented in the previous section and this section provides similar information for the tube and chamber bore, evacuation, recoil system, mount, and fire control.

2-6 TUBE AND CHAMBER

When the ammunition and interior ballistics data become available, a chamber and tube that are sufficiently strong and durable to meet the ballistic requirements and a breech with dimensions that are compatible with the ammunition must be designed.

The interface between the breech mechanism and chamber (Fig. 2-5) is critical. The chamber is usually considered the rearmost region of the gun tube rather than a component of the breech. One design in which the breech forms part of the chamber is the separable chamber breech used in the 152 mm gun/launcher used for consumable case ammunition. Dimensional and concentricity tolerances of the chamber must be closely coordinated with the ammunition designer to ensure adequate fit with the ammunition.

If the gun is to fire existing ammunition, the chamber must be designed so that there will be no problems when loading the round or extracting the case—manually or mechanically, hand mode or semiautomatic. If the ammunition is newly designed and not finalized, early difficulties in handling extraction or firing should be resolved by the gun designer after discussions with the ballistician and the ammunition designer. The chamber volume is designed so that it is compatible with the propellant density of loading and, in addition, the chamber interior should be shaped to promote the most effective flow of gas from chamber to bore

In US artillery, threads are used to attach the breech ring to the tube. These are usually acme, buttress, or square threads (Fig. 2-45(A)). The angle of the thread should be small enough to preclude any reverse rotation which tends to produce unlocking during firing. A more thorough discussion of thread is provided in par. 2-27 and analysis is presented in par. 3-17.7. The pressure and force acting on the breech are described in par. 2-21.

The chamber shape for fixed and semifixed ammunition is somewhat more critical than that for separate-loading ammunition. Both loading and extracting the cartridge case must be considered. The chamber slope and clearance aid both activities. The clearance between case and chamber should be sufficient for easy loading but not large enough to permit excessive plastic deformation or rupture.

When a round is fired, propellant gas pressure expands the case to the chamber wall. Because the case itself is not strong enough to withstand

Downloaded from http://www.everyspec.com

Figure 2-5. Breech Ring and Tube Interface on an Interrupted-Screw Type Breech (Ref. 3)

Downloaded from http://www.everyspec.com

the pressure, the chamber must be designed to prevent excessive dilation. The mechanics of case recovery is demonstrated by the stress-strain curve of Fig. 2-6. We must assume that the chamber recovers completely from the gas-pressure dilation, otherwise the chamber too would be stressed beyond its yield strength and, therefore, improperly designed. The yield strength of quarter hard 70-30 cartridge case brass is 40,000 lb/in². (Ref. 9). The case, being too thin to contain the gas pressures, will expand beyond the initial clearance to the dilated inner wall of the chamber.

Longitudinal clearance of headspace also is involved in chamber design. If this clearance is too large, cases may pull apart and may delay extraction. Dimensional relationships are established to provide automatic small arms with longitudinal interference between case and chamber and invite crushup. Present practice does not provide crushup in artillery; a nominal clearance of 0.010 in. is currently used (Ref. 11).

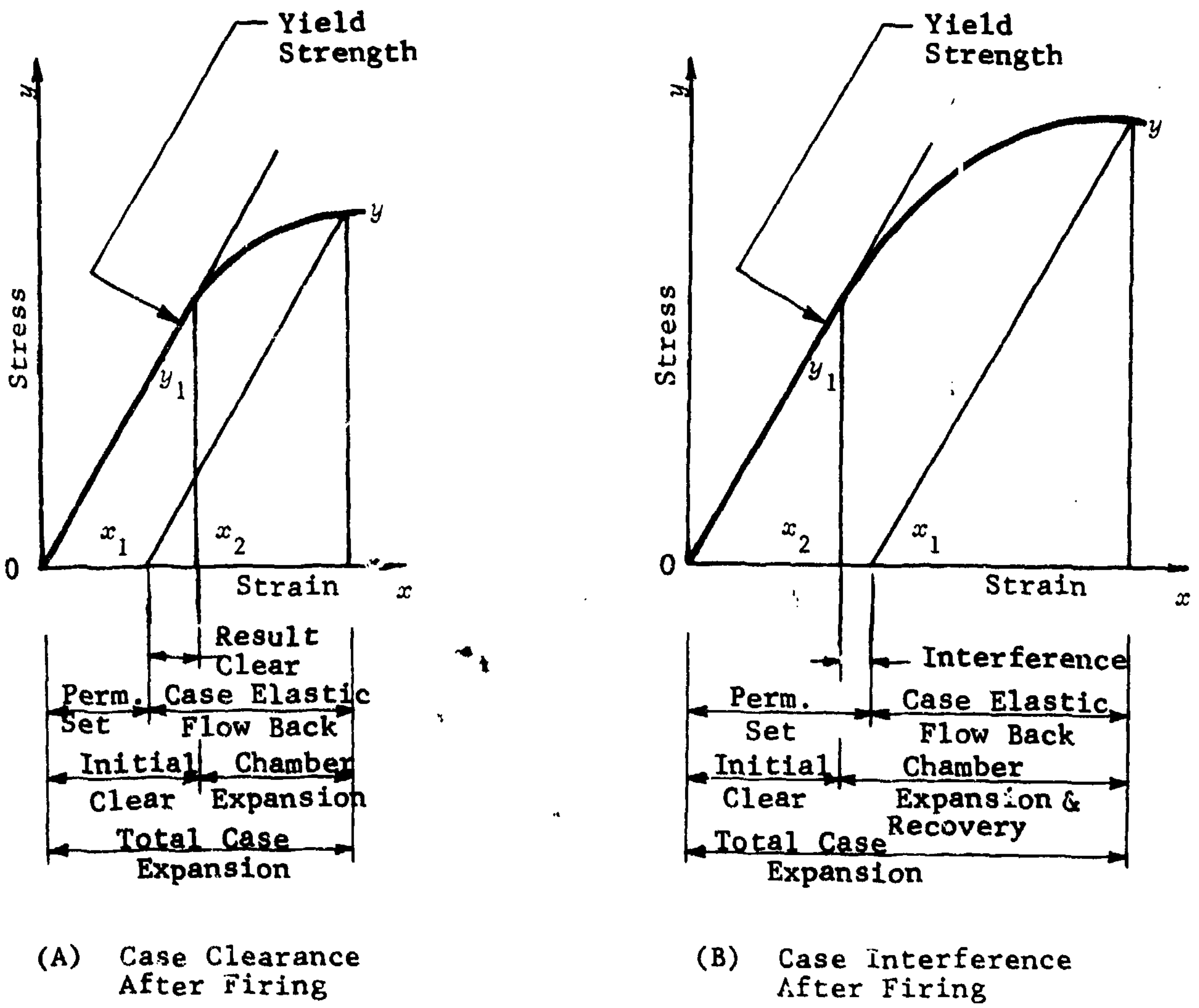


Figure 2-6. Case Chamber Stress-Strain Curves (Ref. 10)

Downloaded from http://www.everyspec.com

Fig 2-7 shows the details of a chamber, including the longitudinal dimensions to the breech face where the base of the cartridge bears against it. All pertinent dimensions are shown; most are dictated by the size and shape of the case.

2-7 BORE EVACUATION AND SCAVENGER SYSTEMS

In some weapons installations, notably tank and other closed cab or turret type vehicular mounts, it is necessary to prevent rapid contamination of the firing compartment by propellant gases that emerge from the bore when the breech is opened. Some large caliber weapons that use separated ammunition have been equipped with a compressed air system that discharges air through the bore to sweep out residual gases before the breech is opened.

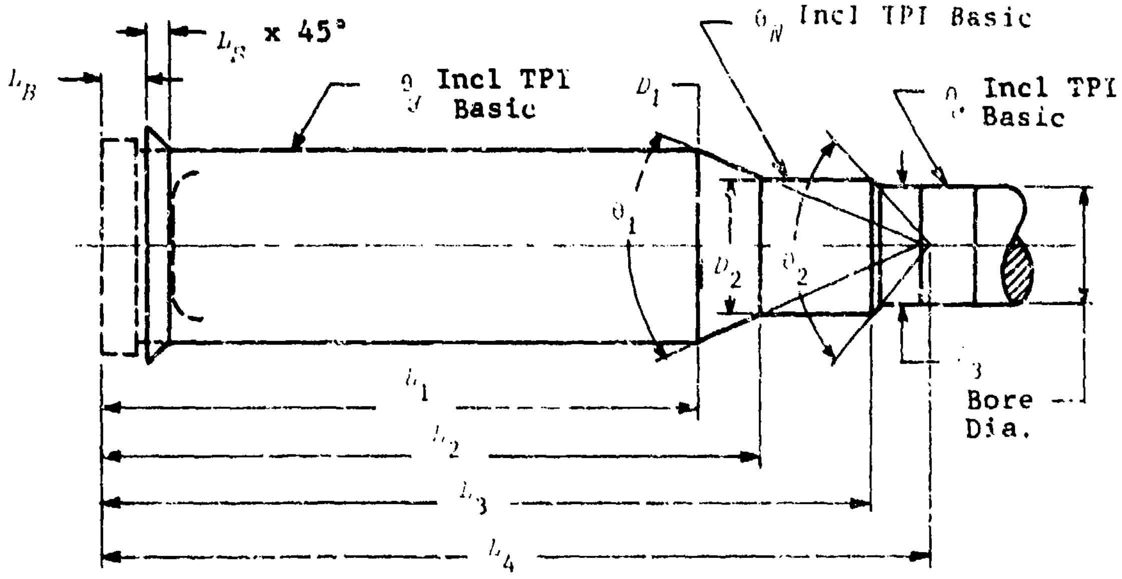
The need for simpler and less space-consuming system for vehicle installations resulted in the development of the currently used evacuator (Fig. 2-8). This system uses a cylindrical jacket fitted around the gun tube near the muzzle to form an annular chamber outside the tube and a series of small drilled holes through the tube wall slanted toward the muzzle to allow a restricted flow of gas between the gun bore and the annular chamber. When the projectile passes the holes, a portion of the propellant gas passes into the evacuator, creating considerable pressure. After the projectile leaves the muzzle, the major portion of the gases follow and the pressure in the bore drops below that in the evacuator chamber. The gas content of the evacuator then discharges through the drilled passages into the bore, then out the muzzle after the breech is open. The high velocity jet discharge creates a low pressure at the muzzle, inducing a flow of air into the breech and forward through the bore. Size and location of the evacuator chamber and passages must be determined carefully to obtain effective flow timed properly with breech opening action. The discharge time must exceed the breech opening time by a margin sufficient to allow time for the induced air flow to purge the tube effectively. The jet duration time is increased 25% above the breech opening time as a precautionary measure (Ref. 14). If conditions are such that the breech opening time exceeds the initial fixed jet duration time, a check valve-type nozzle must be used. A longer discharge time can be had by using a smaller discharge nozzle or by retaining the discharge nozzle and using a larger charging nozzle. Bore evacuator design procedures are described in more detail in AMCP 706-251 (Ref. 15).

A properly designed bore evacuator can remove most of the residual gases from the chamber and bore. The evacuator cannot remove solid residue that may remain after consumable case ammunition has been fired. A scavenger system that introduces a jet of air into the chamber had to be designed and developed for this purpose. The interface between the operation of the scavenger system and the breech mechanism is important. The timing of the jet cycle must be coordinated with the breech-operating cycle, and the air supply tubing and manifold must be introduced through the breech.

2-8 RECOIL SYSTEM

The recoil system modifies the loads generated during firing before transmission to the mount (or turret). Structural strength requirements are reduced, enabling a more lightweight mount design; also, the lay of the gun is better maintained by planned dissipation of energy. Most recoil systems are based upon a single large recoil cylinder attached, through a lug, to the recoiling gun parts. The interface created between the breech and the recoil system must accommodate the recoil piston rod end for transmission of both tensile and compressive loads as experienced in the recoil/counterrecoil cycle. In addition, consideration should be given to stresses that may occur as a result of maloperation or rough handling such as impact during transportation, a galled recoil piston, or excessive buffeting forces. Loss of the recoil lug renders the gun inoperative and requires depot-level service to replace the breech ring. Par. 2-21.2 presents discussion of

Downloaded from http://www.everyspec.com



L_S = length of chamber rear slope

L_B = length from breechblock to beginning of chamber

L_1 = chamber length to start of front slope

L_2 = chamber length to end of front slope

L_3 = chamber length

L_4 = distance to rifling origin

θ_1 = included angle of transition section from main chamber to neck diameter, chamber front slope

θ_2 = included angle of transition section from neck to forcing cone diameter, rifling band rear slope

θ_N = included TPI Basic = neck diameter basic included taper per inch centering slope

θ_c = included TPI Basic = forcing cone basic included taper per inch rifling band front slope

θ_g = included TPI Basic = main chamber diameter basic included taper per inch, extraction slope

D_1 = diameter corresponding to minimum cartridge case side wall diameter

D_2 = diameter corresponding to the maximum cartridge case neck diameter

D_3 = maximum forcing cone diameter

Incl TPI Basic = basic included taper per inch (diameter taper)

Figure 2-7. Chamber With Pertinent Dimensions (Ref. 12)

Downloaded from http://www.everyspec.com

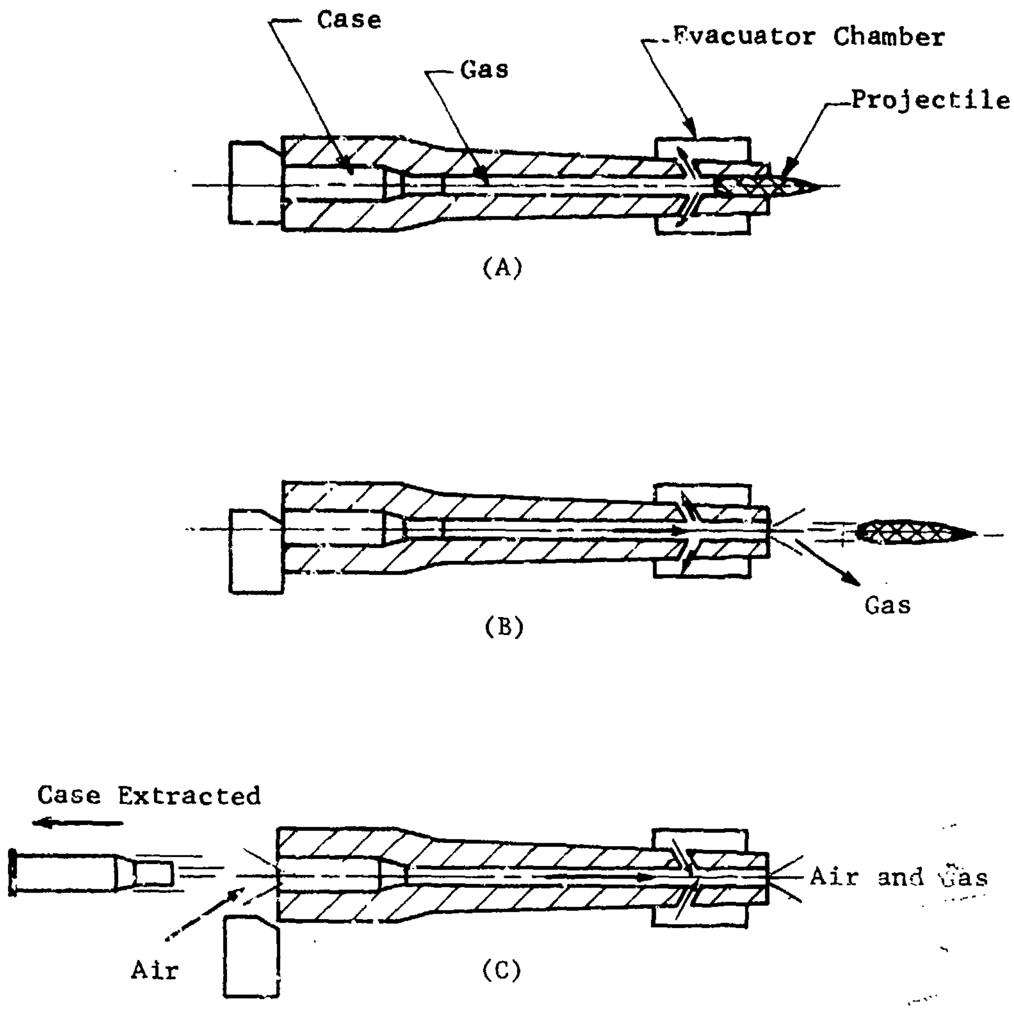


Figure 2-8. Schematic Diagram of Bore Evacuator Operation (Ref. 13)

recoil forces and Fig. 2-39 provides typical recoil parameters.

The guns used in tank weapon systems have hydropneumatic and hydrospring recoil systems that are concentric with the tube to reduce profile and conserve space. The coupling for these is generally a less severe problem. The recoil systems are either based on an annular configuration that surrounds and reacts on the tube or a multipiston configuration that attaches at several points around the breech ring. Additional information on recoil systems may be found in handbook AMCP 706-342, Recoil Systems (Ref. 16).

2-9 MOUNTS

The artillery mount is the carriage that supports the weapon during firing and travel. Simple mounts for manually operated guns are usually pedestals that incorporate a traversing carriage and elevating cradle. Mounts for large-caliber semiautomatic weapons with large recoil forces usually comprise two major components, i.e., the upper carriage and the lower carriage. The upper

Downloaded from http://www.everyspec.com

carriage supports the gun, elevation mechanism, and recoil system. The lower carriage provides a firing base for the weapon, and outriggers for stability. In operation, spades or baseplate protrusions, that dig into the ground, transmit horizontal force. Vertical force is transmitted in compression through the baseplate and vehicle tracks or wheels. Outriggers, trails, and tank spade extenders are used to prevent overturning. Stakes or such additional weights as sandbags can be used to control the reaction of the mount to soil response.

The gun and breech mechanism must clear all mount components in all limits of azimuth, elevation, and maximum recoil. The designer must consider these spatial relationships, and also where the gun operators stand and the motions required for breech operation (loading, ejection). Additional information is contained in the handbooks *Guns-General*, AMCP 706-250 (Ref 17) and *Carriages and Mounts-General*, AMCP 706-340 (Ref. 18).

2-10 FIRE CONTROL

A fire control system is defined as an assemblage of interacting or interdependent equipment that receives data concerning the present position and motion of a target, calculates its future position, correlates this information with exterior ballistic data, and controls the aiming of the weapon to bring effective fire upon the target. Gun fire control is concerned with correcting weapon laying information. Even perfectly corrected firing data are useless if the weapon has not been properly manufactured, adjusted, and aligned with its aiming device. Since tolereances established for external components of the breech may influence weapon alignment, the breech designer must be aware of the breech/fire control interface. Although fire control equipment is frequently classified by its location as either on-carriage or off-carriage equipment, we will consider only on-carriage fire control equipment. On-carriage describes such instruments as sighting telescopes, spotting rifles, and elevation quadrants that are mounted on the weapon or carriage.

2-10.1 FIRE CONTROL EQUIPMENT

This designation includes indicators having graduated dials and pointers that are connected to the elevating and traversing mechanism of a gun. In certain systems, this designation may also include range finders and computers. Three types of quadrants have been developed for aiming weapons in elevation when engaged in indirect fire: the gunner's quadrant, the elevation quadrant, and the range quadrant.

The gunner's quadrant was developed for use in artillery fire control. It is used to adjust a gun to an elevation predetermined by the firing officer from firing tables and range data. The operation of this device is based on the principles of offsetting a spirit level with respect to the gun-bore axis. Fig. 2-9 shows the gunner's quadrant M1, which is a typical design for this type of aiming device.

For coarse elevation, the swing arm with the spirit level is set at the desired angle with respect to the level feet by means of the ratchet; for finer increments, the micrometer is employed. The leveling feet of the quadrant are then set on machined leveling pads on the gun, parallel to its bore, and the gun laid by moving it in elevation until the bubble is centered. For elevations higher than 800 mils (45 deg), a second scale, on the back of that shown, and a second pair of leveling feet are used.

The elevation and range quadrants, improved devices for laying guns in elevation, also use the principle of offsetting a level vial with respect to the gun-bore axis. They differ from the gunner's quadrant in that (1) they are permanently attached to the gun carriage, and (2) they incorporate two sets of elevation scales in order that the two components of the actual quadrant elevation can be set separately into the device. These two devices increase the ease and quickness with which guns can be laid.

Panoramic Telescope M1 (Fig. 2-10) is used with the Telescope Mount M3 to lay the 75 mm

Downloaded from http://www.everyspec.com

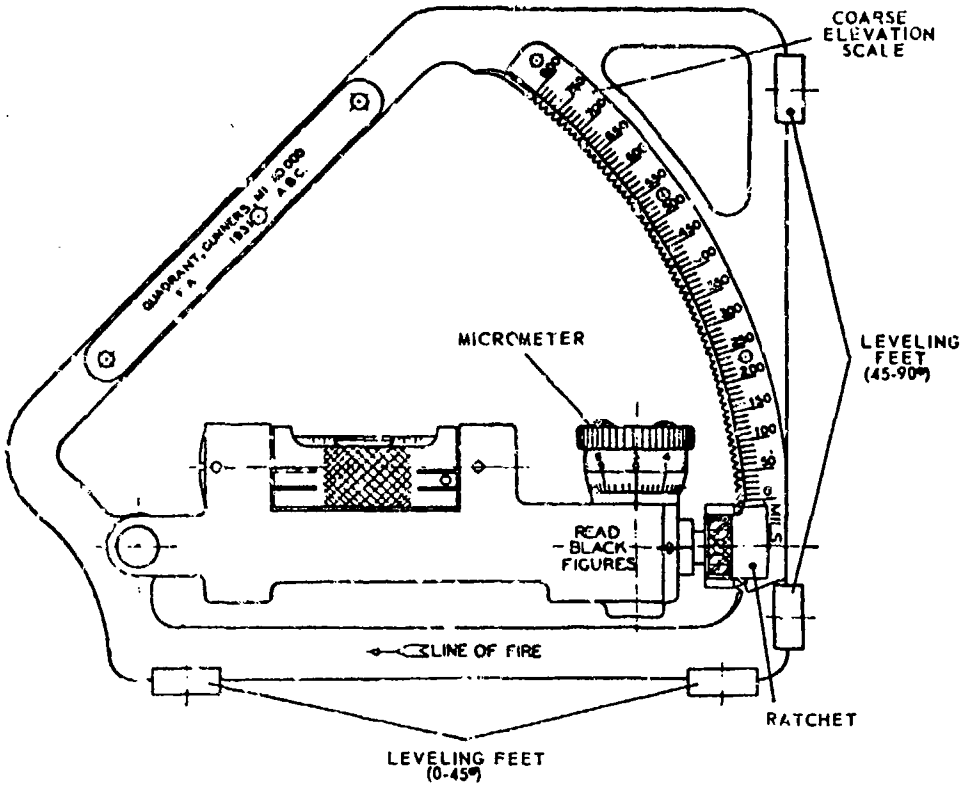


Figure 2-9. Gunner's Quadrant M1 (Ref. 19)

Pack Howitzer Carriage M1. Modern artillery fire control equipment retains a close and sometimes physical interface with the breech. Fig. 2-11 shows the M115 panoramic telescope for the 175 mm Gun M107 and 8 in. Howitzer M110, while Fig. 2-12 shows the Elevation Quadrant M115. The relationship between an advanced fire control system, and gun and breech component in a modern tank is shown in Fig. 2-13. It is obvious from the diagram that breech operating functions must take into consideration the location of fire control equipment as well as provide proper mounting surfaces for equipment that may physically interface with the breech.

2-10.2 DIMENSIONAL RELATIONSHIPS BETWEEN WEAPON COMPONENTS AND FIRE CONTROL COMPENSATION DEVICES

The principal problems of gun fire control are concerned with correcting weapon laying information. Even perfectly corrected firing data cannot be used to position a weapon in the correct direction and at the correct elevation unless the weapon has been properly manufactured, adjusted, and aligned with its aiming device (Ref. 23). Some of the ideal conditions of alignment and adjustment are listed here. The conditions

Downloaded from http://www.everyspec.com

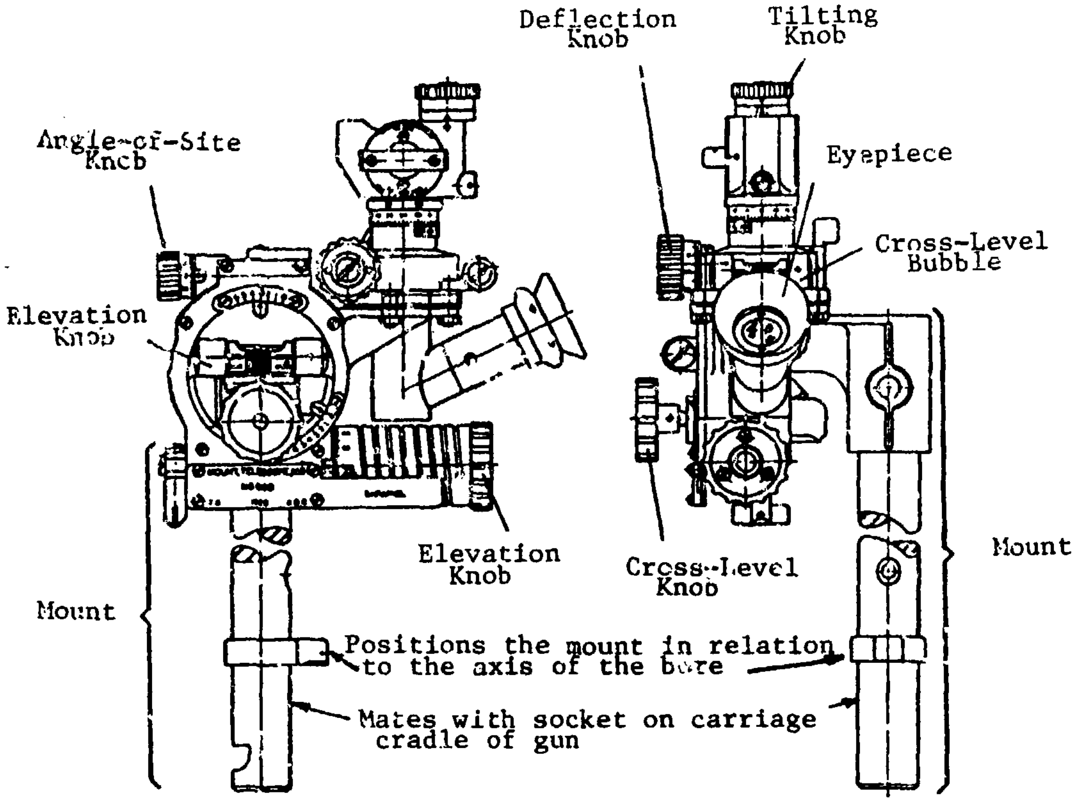


Figure 2-10. Panoramic Telescope M1, and Telescope Mount M3 (Ref. 20)

given are typical for a field artillery weapon using a compensated sight mount, but the approach for other types of weapons is similar. The conditions are:

1. The gun bore axis perpendicular to the trunnion axis
2. The actuating arm (gun bar) axis parallel to the gun bore axis
3. The actuating arm (gun bar) axis of rotation parallel to the trunnion axis
4. Opposite arms of parallelogram linkages connecting the aiming device to the weapon trunnion of equal length.

Engineering Design Handbook, AMCP 760-331 *Compensating Elements* (Ref. 23), describes and estimates the various alignment errors and their relationship to fire control errors. This handbook should be consulted if a tolerance error analysis is conducted on the weapon system and to provide further background.

SECTION IV. BREECH AND SUBASSEMBLIES DESIGN EXAMPLES

The breech mechanism has "internal interfaces" as well as overall weapon system interfaces. The breech mechanism includes a breech ring; a breechblock; and four mechanisms: operating, firing, extracting, and obturating. These six major elements of the breech mechanism have various configurations depending on the type of closure—e.g., sliding wedge, interrupted screw, and separable chamber (see par. 1-5). This handbook section presents design examples of operating, firing, extracting, and obturating mechanisms.

Downloaded from http://www.everyspec.com

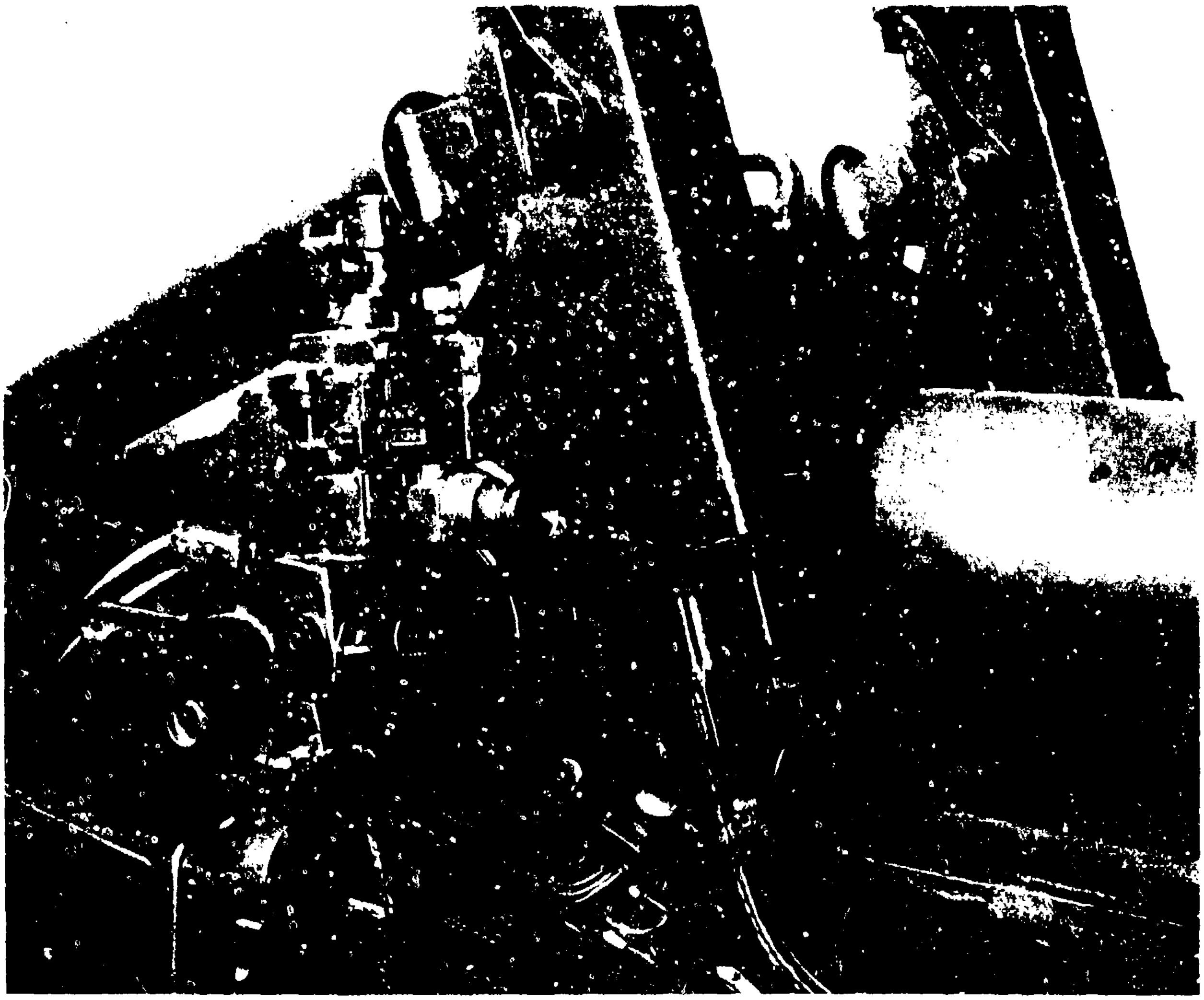


Figure 2-11. Panoramic Telescope M115, and Telescope Mount M137 (Ref. 21)

2-11 OPERATING MECHANISMS

Horizontal and vertical sliding wedges and interrupted thread closures, described in pars. 1-5.1 and 1-5.2, are the major types of breech mechanisms in use. Operating mechanisms for these types are described in the subparagraphs that follow.

2-11.1 HORIZONTAL SLIDING WEDGE

The one-cycle linear motion of the breechblock is produced by the rotation of a single operating lever. The L-shaped lever (Component G, Fig. 2-14) is supported in the breech ring by its pivot stud F. The lever is further connected to the breechblock by a crosshead member which fits into a curved cam path machined in the block H; the crosshead is pinned to the lever crank arm. Operating motions are best described with reference to the schematic sequence of Fig. 2-15. When the operating lever is unlatched and rotated rearward (or clockwise) from the closed and locked position (Fig. 2-15(A)), the crosshead cams the block horizontally to the right. Kinematic relation between the operating mechanism and the block is shown in both intermediate and fully open breech positions by Figs. 2-15 (B) and (C), respectively. For clarity, the

Downloaded from http://www.everyspec.com

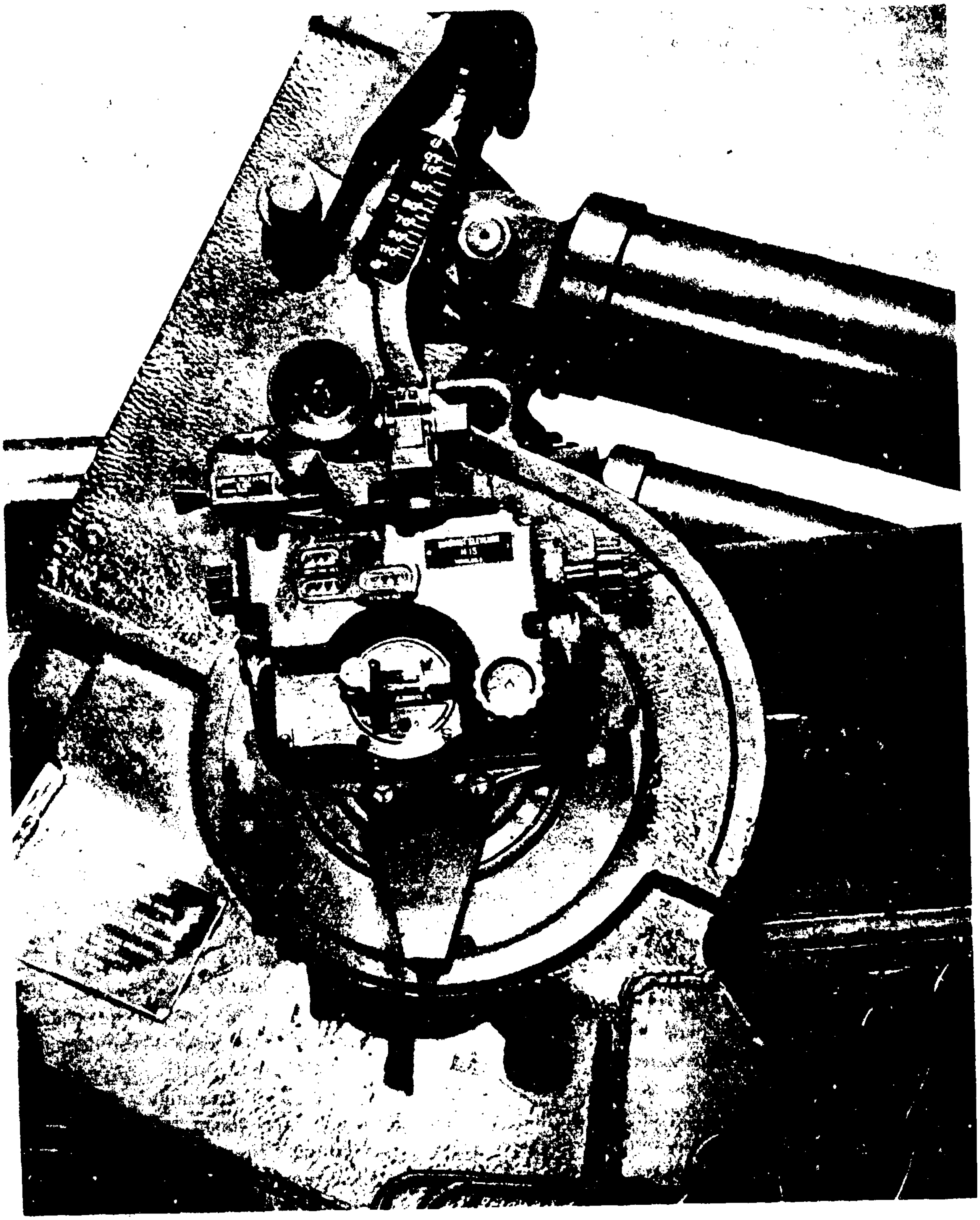


Figure 2-12. Elevation Quadrant M15 (Ref. 22)

Downloaded from http://www.everyspec.com

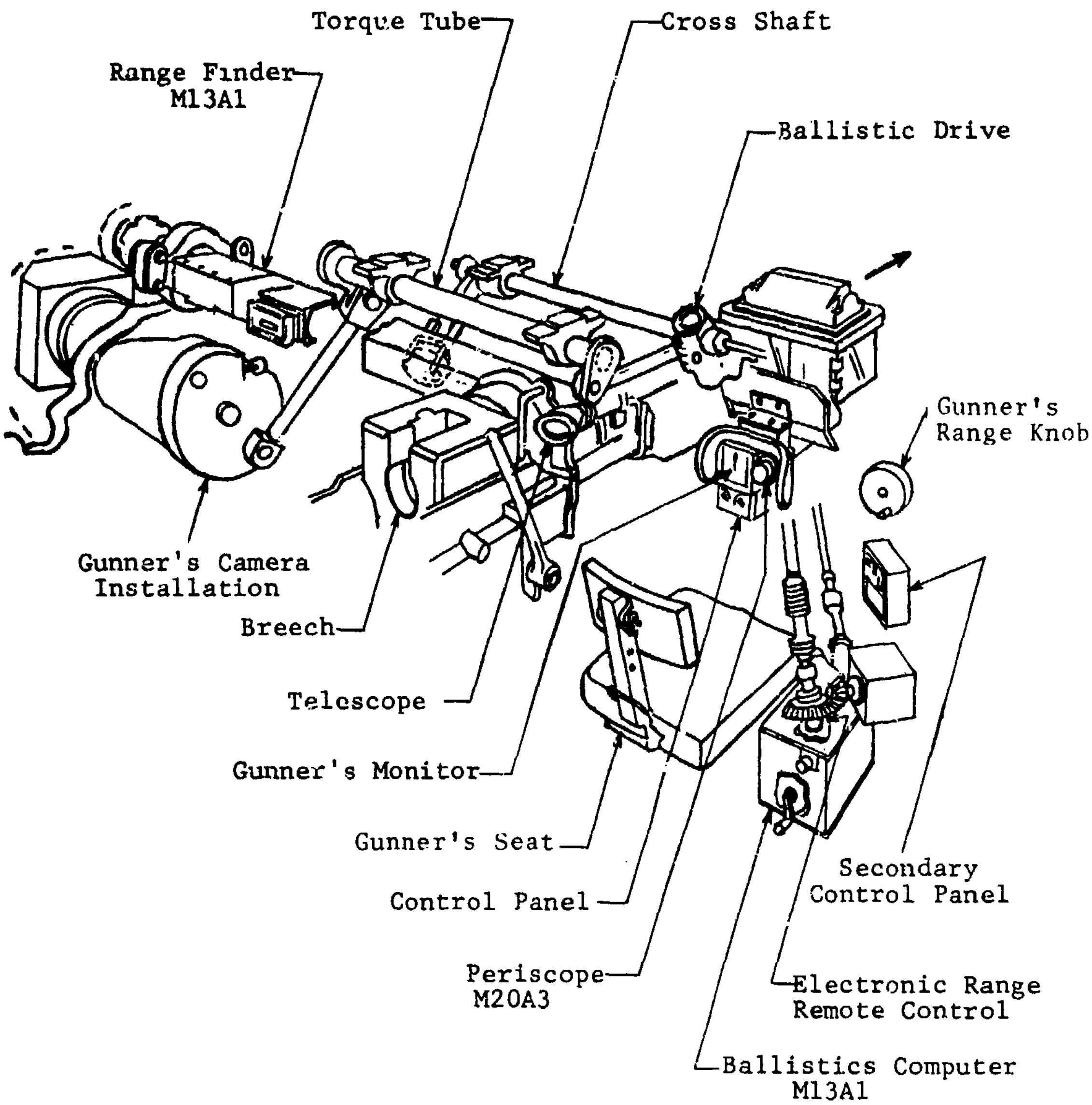


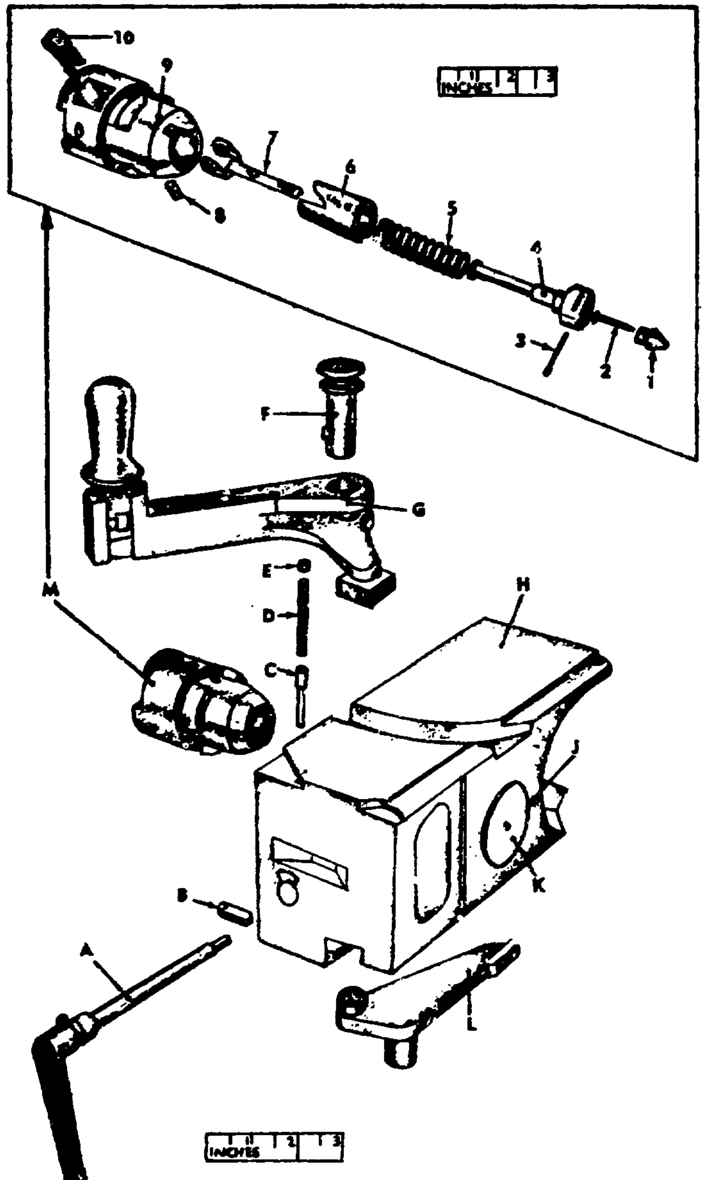
Figure 2-13. Concept of the XM39 Electronic Viewing Equipment Installation (Ref. 24)

breech ring is indicated by dashed lines and the block as a partial section.

The breech ring supports the block and guides its sliding movements; pertinent structural considerations have been previously detailed in par. 1-5.2. An open breech position is stable since weight of the block bears down on the guiding surfaces of the ring. The block is returned to the closed position by rotating the operating lever in a counterclockwise direction. Parts of a typical lever assembly are given in Fig. 2-16, while its relationship to the remaining moving elements of the breech is presented in Fig. 2-14; the weapon application is the 105 mm Howitzer, M101. The relationship of the firing mechanism, trigger shaft, and extractor to the block is also depicted by Fig. 2-14—parts M, A, and L, respectively. These items are treated separately.

The illustrated mechanism satisfies requirements for operating a breech manually. In fact, the horizontal type sliding-wedge breech is operated primarily in that mode (see par. 1-5.2). This is not to say that semiautomatic operation is unfeasible with a block that moves horizontally.

Downloaded from http://www.everyspec.com



A--Shaft, trigger
B--Handle, detent
C--Detent, trigger shaft
D--Spring, compression, 0.0453 diam stock, 0.36 od, 22 coils
E--Screw, retaining detent spring
F--Pivot, operating lever
G--Lever, breechblock operating, assy
H--Breechblock--D8367-6
J--Screw, set, hdls, (0.190)-32NF-3 x 0.40
K--Bushing, breechblock
L--Extractor
M--Lock, firing, M13
M-1--Bushing, firing pin
M-2--Pin, firing--A12755 or pin, firing
M-3--Pin, cotter, split, 1/16 x 1
M-4--Holder, firing pin
M-5--Spring, compression, 0.1144 diam stock, 0.914 od, $11\frac{1}{2}$ coils (firing)
M-6--Sleeve, firing pin holder
M-7--Sear (firing lock)
M-8--Spring, compression, 0.0453 diam stock, 0.40 od, 8 coils (sear)
M-9--Case, firing
M-10--Fork, trigger

Figure 2-14. Parts of the Operating Mechanism and Other Breechblock Mounted Groups in a Horizontal Sliding-Wedge Breech (105 mm Howitzer, M101) (Ref. 25)

Downloaded from http://www.everyspec.com

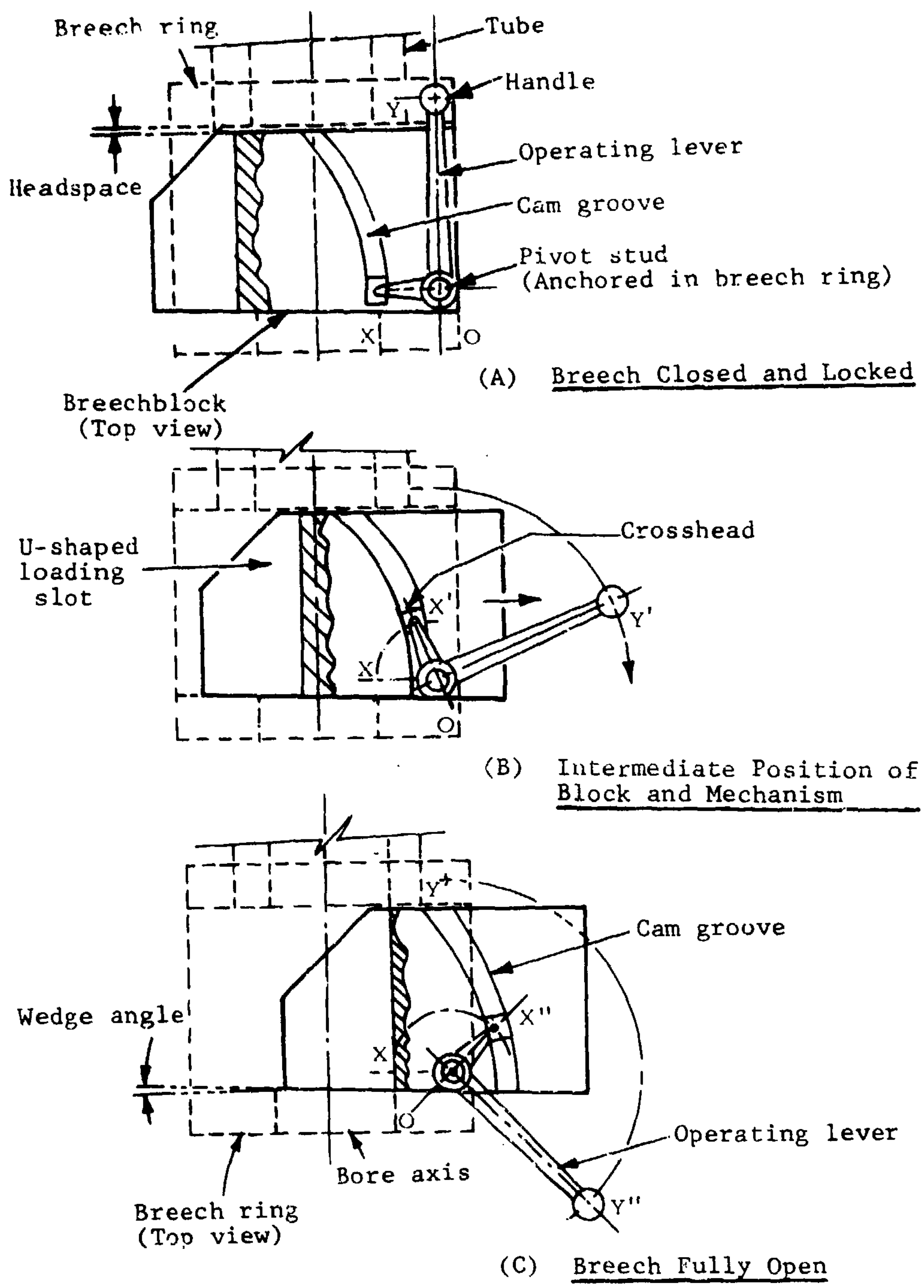


Figure 2-15. Typical Operating Mechanism for a Horizontal Sliding-Wedge Breech (Sequence of Motions) (After Ref. 26)

Automation, however, is more compatible with a vertical block motion as previously discussed. Therefore, the latter breech version offers the best examples of automated functions. At the same time, the handbook user should realize that the semiautomatic mechanism design description that follows is adaptable to the horizontal block motion.

Downloaded from http://www.everyspec.com

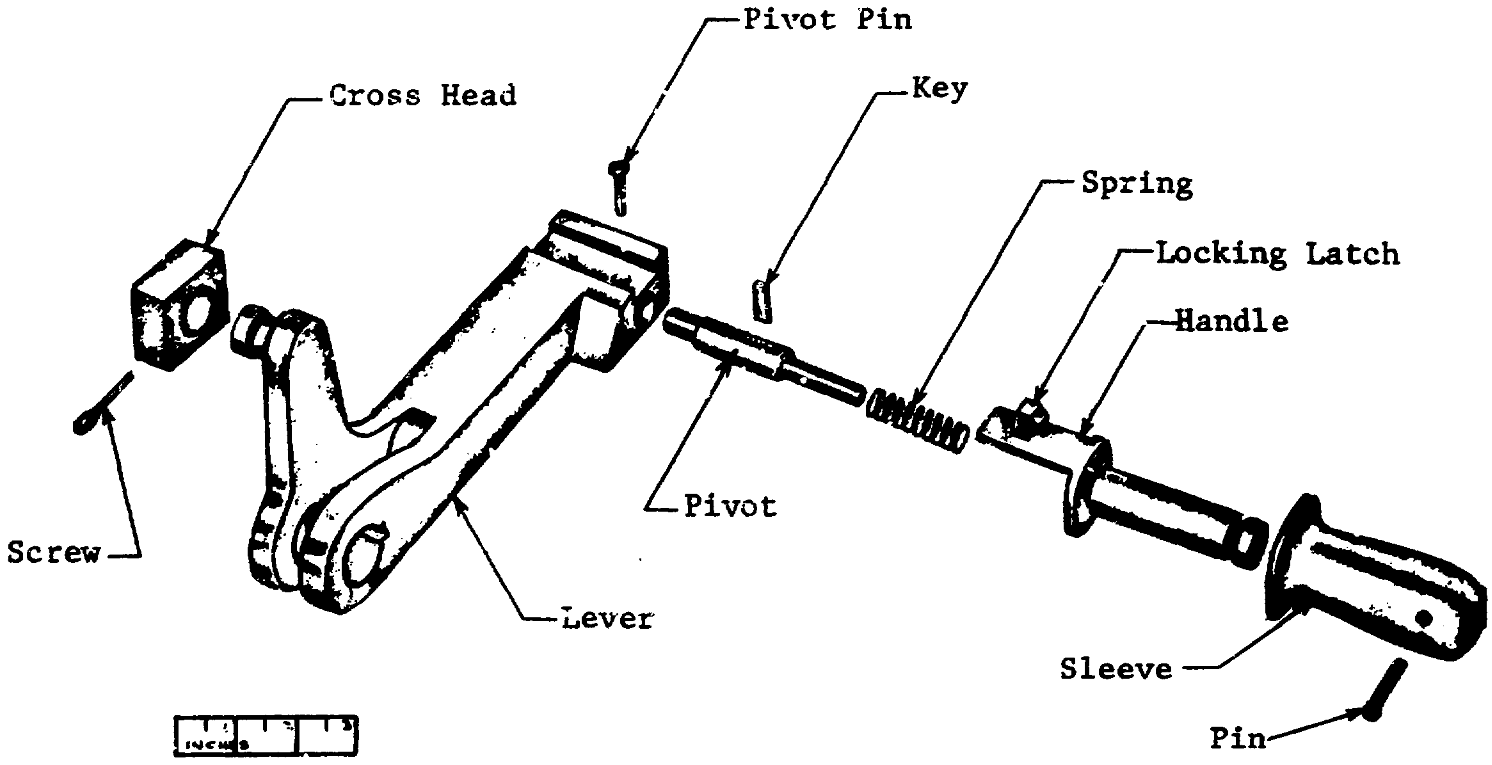


Figure 2-16. Operating Lever Parts (Horizontal Sliding-Wedge Breech, 105 mm Howitzer, M101) (Ref. 27)

Downloaded from http://www.everyspec.com

2-11.2 VERTICAL SLIDING WEDGE

Automation of breech opening, closing, and allied functions by use of recoil energy has been most successfully accomplished with this breech type. Thus concentration is placed on a typical design for semiautomatic operation; however, the remainder of the discussion outlines variations of the automated mode, design differences encountered in manual operation, and miscellaneous considerations related to these mechanisms.

Interaction between a stationary cam and a cam-follower crank recoiling with the breech ring is the basic principle of recoil energy utilization. Actually the counterrecoil phase of motions is preferred for breech actuation because propellant gas pressure acting on the breech must be allowed to decay sufficiently and because motions are more predictable under the control of a buffer or recuperator device.

The technique for synchronizing the interacting elements is important to understand. Fig. 2-17 shows a sequence of events up to the start of cam actuation. With the weapon in-battery, the operating cam fixed to the gun cradle (nonrecoiling part) and the breech crank are positioned as illustrated in Fig. 2-17(A). While longitudinally fixed, the cam is spring loaded in a lateral direction and can pivot outward. As the breech recoils, the crank arm is made to slide past the cam, hinging it outward against the spring (Fig. 2-17(B)). Contacting surfaces of the cam and crank lug are suitably shaped to facilitate the process. During recoil the crank rests against the breech face in an upright or neutral position. The spring returns the cam to its original position as soon as the crank lug passes by. Shortly thereafter, counterrecoil begins and the breech ring, now moving forward, brings the crank into contact with the primary working surface of the cam. Conditions at the start of counterrecoil are given in Figs. 2-17(C) and 2-18(A); the latter diagram continues the sequence of events and also brings other parts of the breech system into the picture.

A second crank is carried inboard of the operating crank on the same shaft. This breechblock crank supports two circular crossheads; these mate with an included T-shaped slot in the bottom of the block. Crosshead diameter is such that a good sliding fit is obtained in the cross of the "tee" (Fig. 2-18(B)). Thus, as the operating crank lug strikes the cradle cam in counterrecoil, it is made to rotate by the cam. The block crank—being splined to the same shaft—is rotated simultaneously, pulling the breechblock downward. Full open position is reached as the operating crank, still moving into battery, passes under the cam (Fig. 2-18(C)); both cranks rotate about 90 deg counterclockwise from initial to terminal position. When the breechblock is open, a flat near the hub of the block crank contacts the underside of the breech ring, preventing possible overtravel of the mechanism. Extractor levers working in conjunction with the operating mechanism lock the breechblock in the open position (see par. 1-6.5).

A summary of parts that comprise the mechanism is given in Fig. 2-19; component functions are sufficiently identified by previous discussions or figures except for the closing spring and spring housing. The spring is a helical torsion type with two straight offset ends. One end is anchored in a hole inside the spring housing; the other is fitted into a slot in the block crank. For applying proper spring torsion, a method of initially rotating the housing with respect to the crank is provided in assembly. Once spring preload is established, the housing is secured to the breech outer structure. Thereafter, automatic opening of the breech winds (or charges) the closing spring simultaneously with the operating shaft rotation.

Tripping the extractors—normally by insertion of the next round or by separate operation of the extractor releases—unlatches the open block and allows the spring to rotate the breechblock crank clockwise. The motion sequence of Fig. 2-18 thereby is reversed and the breechblock is raised to the closed, firing position. At the same time, the operating crank is returned to its upright position for a new cycle.

The semiautomatic breech operating mechanism just described has been applied in several

Downloaded from http://www.everyspec.com

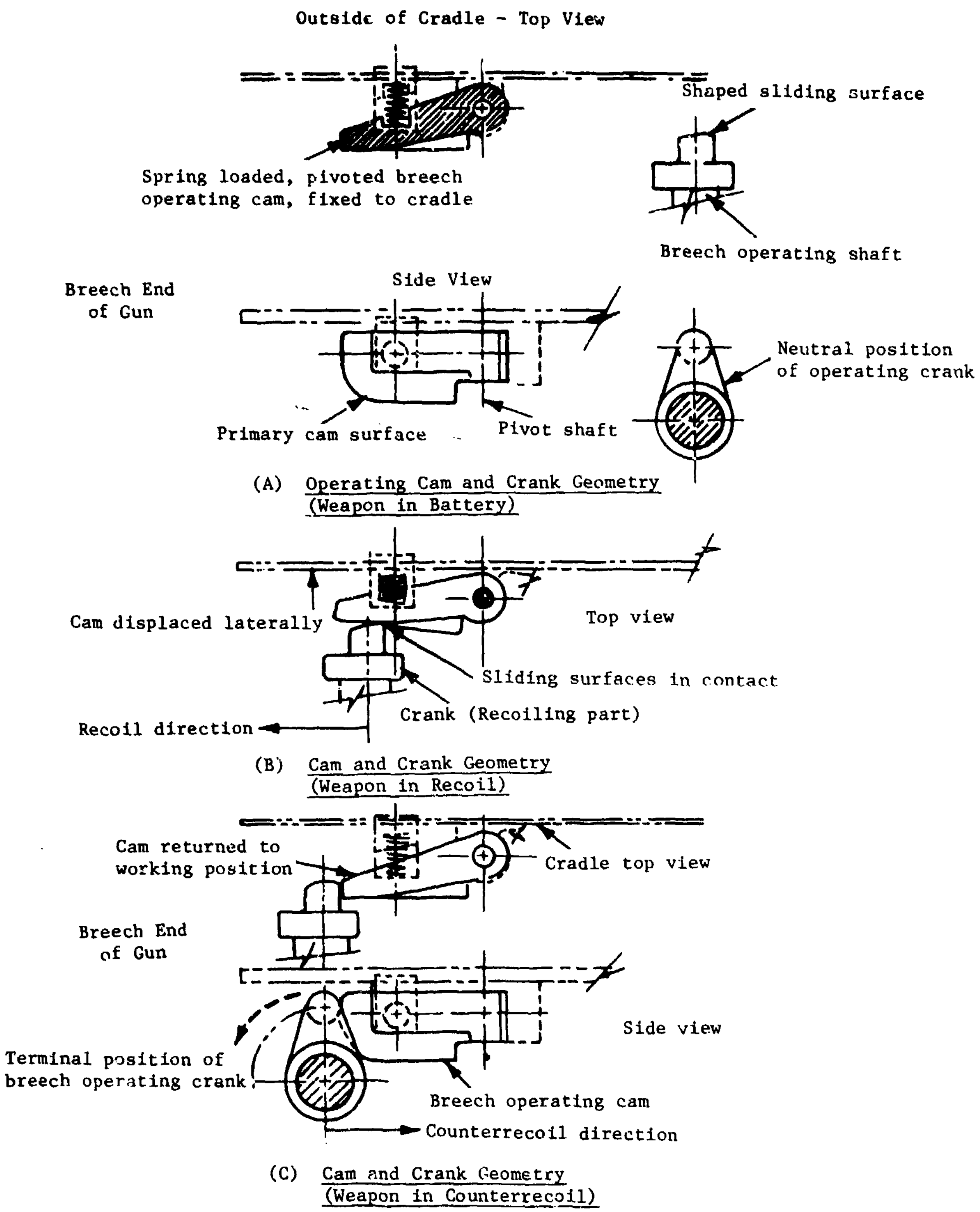


Figure 2-17. Kinematic Sequence Leading to Engagement of the Operating Cam by the Breech Operating Crank-Breech Actuation via Recoil Energy

Downloaded from http://www.everyspec.com

large caliber antiaircraft weapons, notably the towed 75 mm Gun, T83E1, as well as in a number of self-propelled weapons and tank guns. Strictly from the breech designer's viewpoint, the actuating technique is ideal but it has drawbacks. It requires a relatively long recoil motion and substantial recuperator force, which are not always met by weapon characteristics. The problem is especially acute in howitzer applications. Examples are short recoil at minimum charge and small counterrecoil force at all but the higher zones, when firing at the higher quadrant elevations—especially for modern, lightweight towed weapons. Naturally there is corresponding interest in new designs that offer solutions. Ref. 29 details an interesting short recoil breech actuating mechanism. In principle the new system is not radically different from the one discussed previously. However, it is intended to extract all the energy necessary to charge two kinds of springs during the minimum length of recoil available; yet other recoil distances are not detrimental to the mechanism. One spring opens the breech in counterrecoil, the other closes the block behind the next round inserted.

A typical mechanism for operating a vertical sliding-wedge breech in the manual mode does not differ drastically from that shown in Figs. 2-18 and 2-19. To be sure, a number of parts are eliminated or altered; most importantly, the operating crank is replaced by an operating lever and handle that permit rotation of the shaft by hand effort. Lever motion may take place in a vertical plane by direct connection to the horizontal operating shaft; or in a more complex approach a second vertical shaft can carry the actuating lever, much like the situation of Fig. 2-14. In this case, the two shafts are interconnected by a bevel gear mesh. These variations do not exhaust the design approaches possible.

For manual actuation, the operating handle itself is located for maximum convenience of the operator and receives (or ought to receive in all cases) a high degree of human factors consideration. Normally, the handle is positioned at the right side of the breech ring or atop it on that side. It is also necessary to provide manual means of operating a semiautomatic breech to:

1. Open a normally closed breech routinely, for the first shot of a firing mission.
2. Change operating modes temporarily, in case of a malfunction or emergency.

However, the hand actuator of a semiautomatic breech is then considered strictly as an auxiliary mechanism. Placement of the handle becomes secondary and operator convenience can be sacrificed in accordance with the part-time role of the actuator. Handle location can be at either side, atop, and even below or away from the breech ring — depending on weapon type, space constraints, etc. The handle may be connected directly to the primary operating group, in which case a clutch device is added to the design. The clutch readily isolates the hand lever to prevent its rotation when in a semiautomatic mode, yet allows the lever to be "clutched-in" as needed. In certain applications the hand lever is removed completely and stowed on the gun. The auxiliary operating mechanism may also be a simple, yet separate, linkage which engages the breechblock crank independently, but in a manner similar to the automatic breech cam (see Fig. 2-18).

Counterbalance devices are an important part of the operating mechanism. They are required in nearly every vertical sliding-wedge breech; exceptions are small, lightweight breechblocks. For manually operated breeches the term "counterbalance mechanism" is used to denote various spring elements that aid in closing the block; charging of the device takes place during breech opening. For breeches operated in the semiautomatic mode, "closing spring" (and "opening spring" as applicable in a particular design) constitutes the preferred nomenclature for a similar device. While the roles of such devices are comparable in the two breech operating modes, spring requirements (i.e., capacity, energy storage) are obviously more severe under semiautomatic conditions. Several spring types have been

Downloaded from http://www.everyspec.com

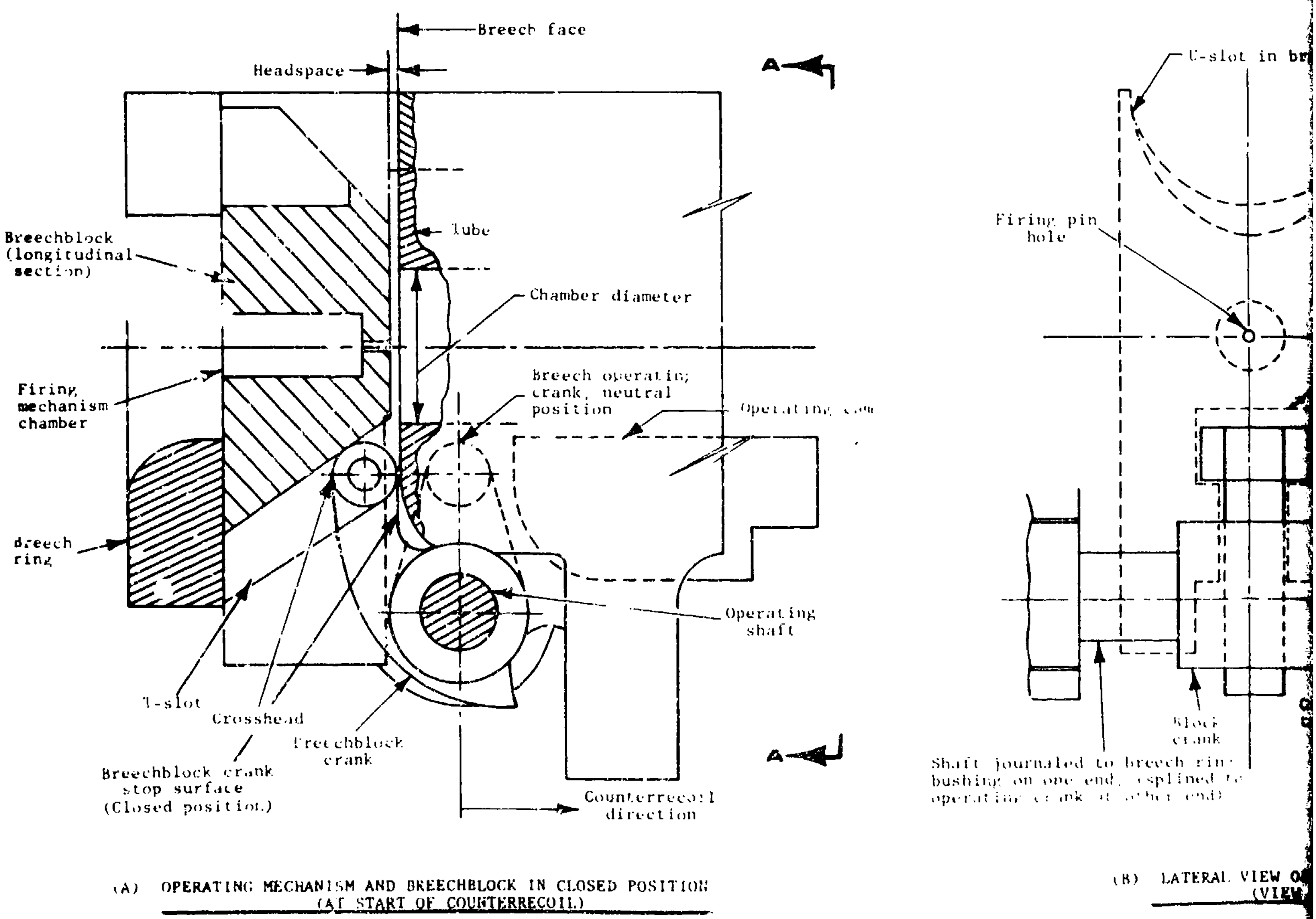
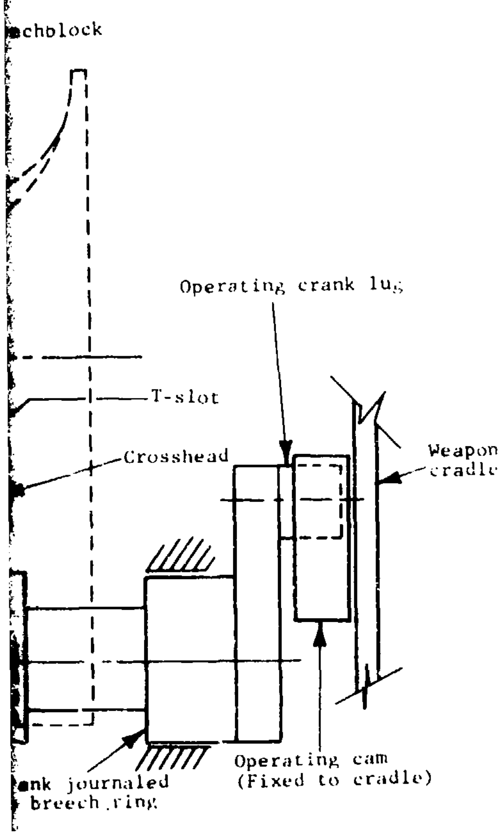
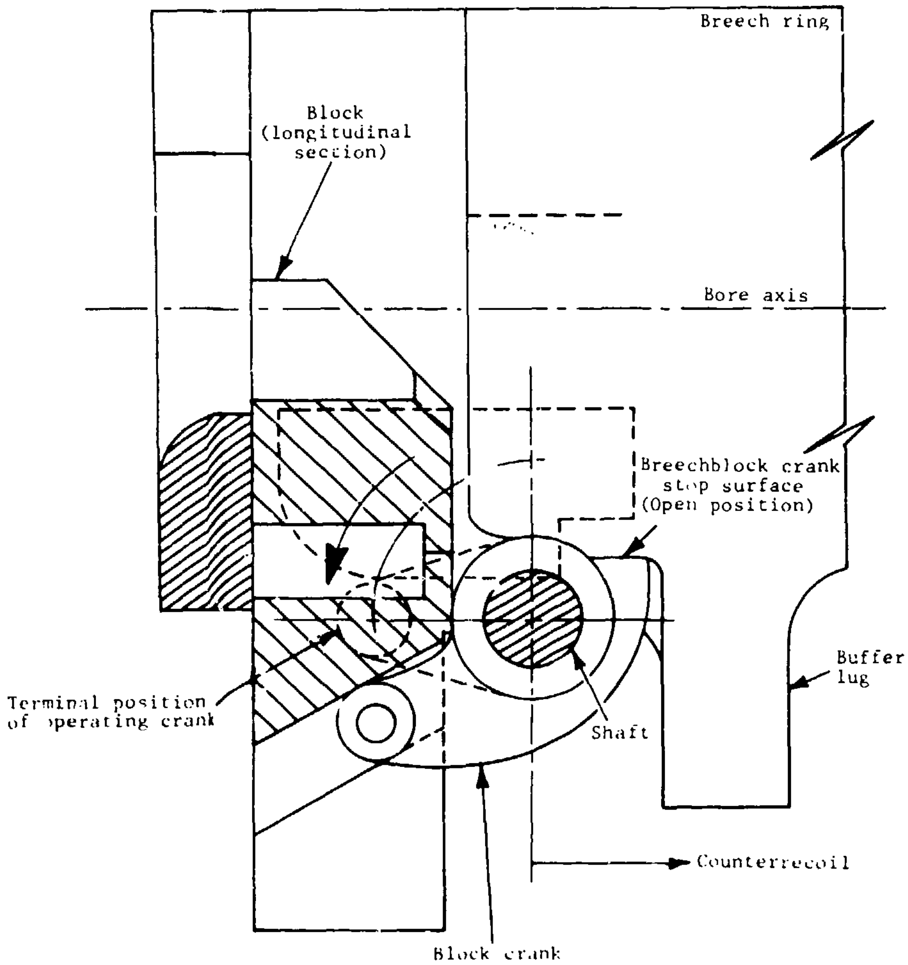


Figure 2-18. Typical Operating Mechanism Schematic for a Vertical

Downloaded from http://www.everyspec.com



OPERATING MECHANISM
(A)



(C) MECHANISM AND BLOCK IN FULL OPEN POSITION (OPERATING CRANK PASSING UNDER CAM)

ding-Wedge Breech (Semiautomatic Actuation via Recoil Energy)

Downloaded from http://www.everyspec.com

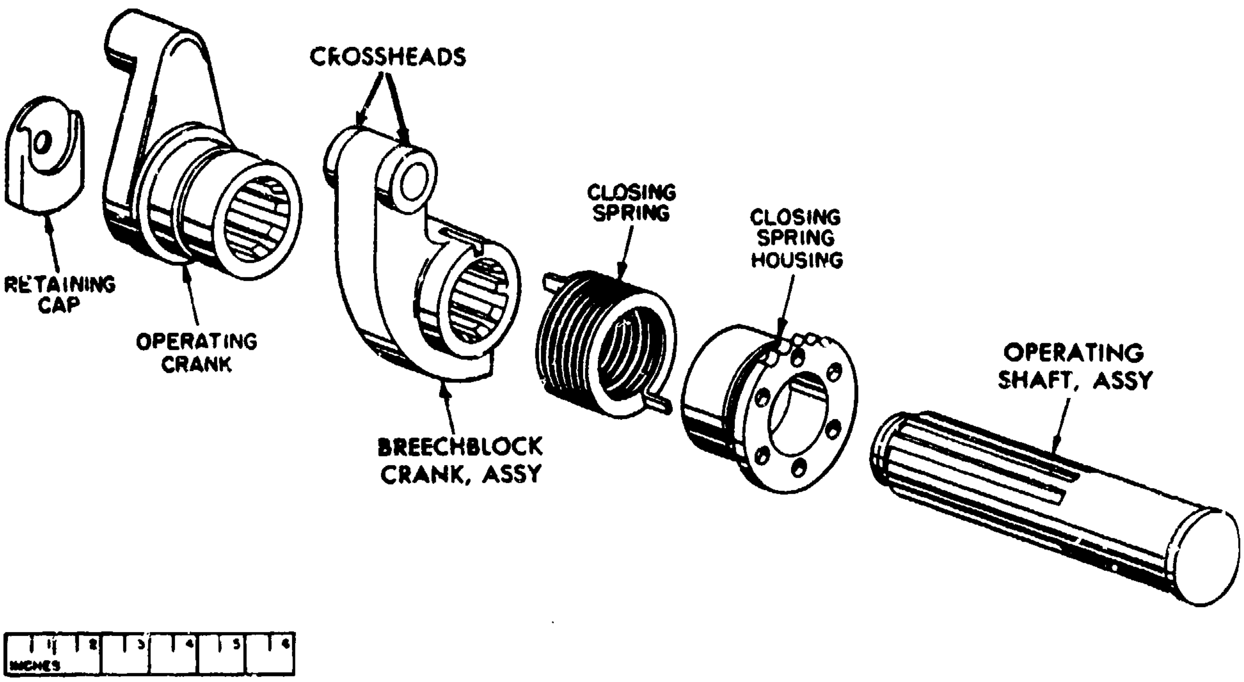


Figure 2-19. Parts of Semiautomatic Breech Operating Mechanism (75 mm Antiaircraft Gun, T83E1, Vertical Sliding-Wedge Breech) (Ref. 28)

designed into counterbalance or closing devices. The helical compression spring was used extensively through the World War II era. This mechanism was quite similar to the one still in use for interrupted-screw breeches (see Fig. 2-22), except for the breechblock connecting method. Springs oriented both parallel to the block motion and parallel to the gun tube were employed. Weight and space requirements have made the compression spring element generally obsolete for this breech type.

Helical torsion springs represent more efficient space usage in extracting elastic energy. Although not at all new, this spring type is seeing renewed emphasis in breech operating mechanism design. In the quest for still greater energy/volume efficiency, other spring element versions are being sought. The torsion leaf spring pack or laminated torsion bar is one such noteworthy candidate. Developments concerning this interesting breech closing spring type can be found in Refs. 30 and 31.

2-11.3 INTERRUPTED SCREW

The two distinct motions of this closure type take place on separate rotary and hinge axes but are accomplished by the actuation of one crankshaft. With the breech in the locked position (Fig. 2-20(A)), a rearward and downward pull on the operating lever (after it has been unlatched) rotates the crankshaft about the x-axis. A crank on the end of the shaft actuates a crosshead that slides in a recess in the breechblock and at the same time causes the block to rotate in a counterclockwise direction. This limited rotation disengages the sectored-threads, of the closure, unlocking the breech as the first half of a two-cycle motion is accomplished (Fig. 2-20(B)).

Component breakdown of a typical crankshaft and operating lever group is provided in Fig. 2-21. This subassembly is supported in the breechblock carrier by the journal bearing component shown in the figure. The carrier, which in turn is anchored to the breech ring, also supports

Downloaded from http://www.everyspec.com

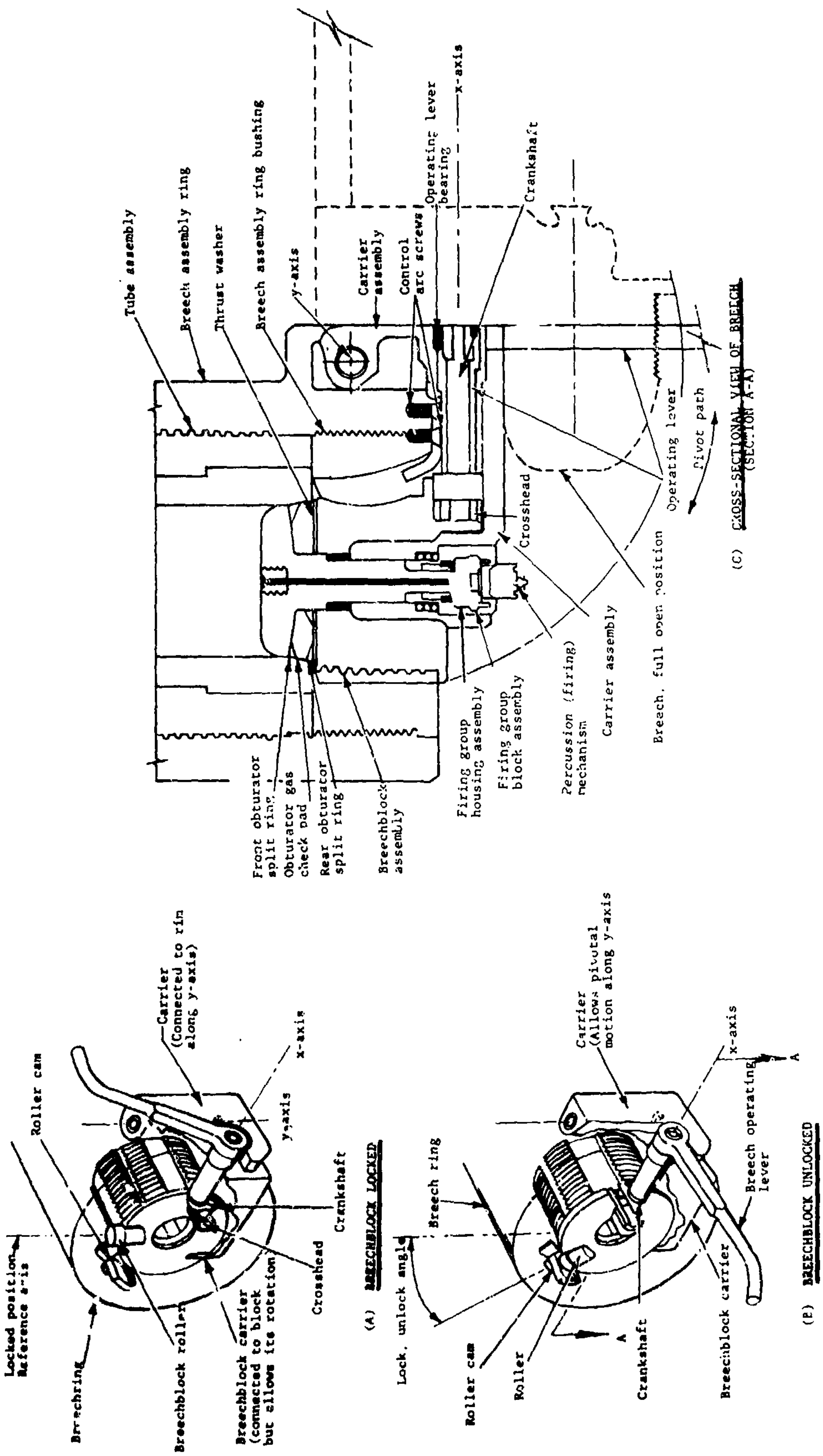


Figure 2-20. Typical Operating Mechanism for an Interrupted-Screw Breech

Downloaded from http://www.everyspec.com

Figure 2-21. Typical Operating Lever and Crankshaft Group (Interrupted-Screw Breech, 175 mm Gun, M113 [T256E3] (Ref. 32)

the block; moreover, it provides the machined bushing surface on which the block rotates. The aforementioned relations between the operating mechanism and the breech structure are better indicated in Fig. 2-20(C), which is a horizontal section through the unlocked breech.

Moving parts of the breech, shown by solid lines in the cross-sectional view. (Fig. 2-20(C)), still represent breech conditions at the end of the first operating step. Further actuation of the operating lever (i.e., a pull to the right), swings the block about the hinge, *y*-axis, and out of the breech recess. Dashed lines of Fig. 2-20(C) illustrate both the pivot path and the final, full open position of the breech. Of course, the two-cycle breech motion takes place as one continuous operation; the sequence having been split into two distinct steps only for the sake of explanation. Actuation takes place in the exact opposite order when returning the breech to closed position.

Other salient features are part of the operating mechanism and impose their individual design requirements. A roller or cam-follower on the rear face of the block and a cam on the breech ring face are used to smooth an otherwise abrupt block motion as it changes from rotary to translatory (and vice versa). As shown in Figs. 2-20(A) and (B), and 1-2(A), the cam-follower engages the rearward curving cam near the end of the unlocking sequence; thus pivot motion about the hinge axis begins gradually as soon as the interrupted threads are disengaged. Transition of the block to a rearward hinge motion is thereby accomplished without undue shock to the mechanism or operator. (Actually, the block continues to rotate a few degrees beyond the disengagement point as it begins to swing away from the recess.) Advantage of the cam-roller is most marked during breech closing (Ref. 33), when energy of the swinging parts is used to impart rotary motion to the block and crankshaft by

Downloaded from http://www.everyspec.com

the suitably oriented cam track. The cam-roller unit also minimizes slamming and rebounding of the swinging parts during closing.

A counterbalance assembly is provided to further facilitate breech actuation. This mechanism serves to:

1. Reduce effort required to swing the block out of the breech.
2. Hold the breech open while loading.
3. Reduce closing effort and make the closing operation more rapid.

The counterbalance assembly consists of a coil spring mounted to a piston head and housed within a cylinder; component arrangement is such that the spring can be compressed between the piston and a cylinder head when actuated by the piston rod (Fig. 2-22). One end of the cylinder is pin-connected to the breech ring, while a

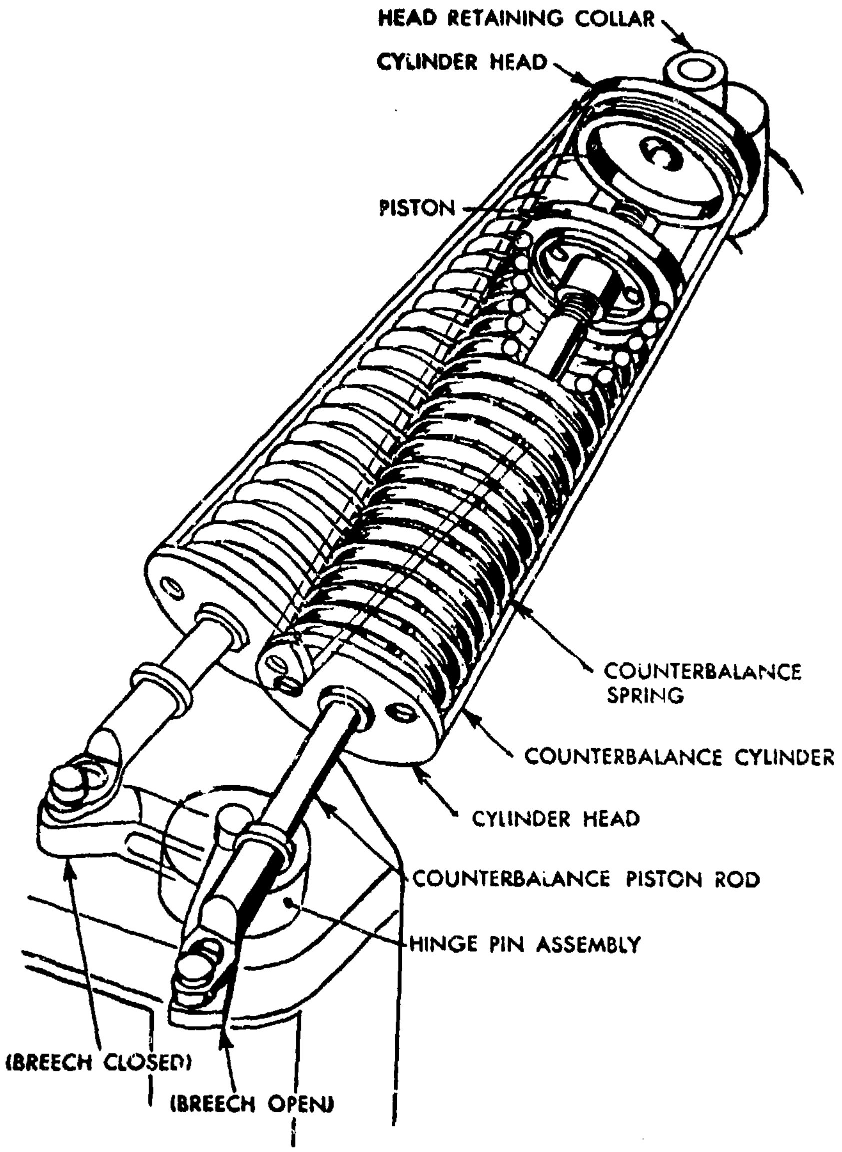


Figure 2-22. Counterbalance Mechanism — Interrupted-Screw Breech (Ref. 34)

Downloaded from http://www.everyspec.com

similar connection is made between the piston rod and hinge pin crank arm at the other end of the mechanism. (To establish proper geometric perspective, the hinge pin axis coincides with the y-axis in Fig. 2-20.

As the breech is opened, rotation of the hinge pin arm takes place, drawing the piston rearward and thus compressing the spring. Maximum spring compression occurs as the pin passes dead center, just before the breech is swung fully open. The toggling effect of the crank allows the spring to decompress slightly, and the spring under compression exerts its force on the hinge pin crank to hold the breech open. In closing, the spring is compressed again until the crank passes over dead center; then the counterbalance spring exerts its force on the crank to close the breech rapidly. Extreme motions of the assist mechanism are indicated in Fig. 2-22. A threaded joint usually connects the piston to the rod, permitting a change in spring preload. This may be required for general adjustment or to increase counterbalance force—e.g., the closing of the breech at a higher quadrant angle.

A more complete breakdown of mobile parts of an interrupted-screw breech is presented in Fig. 2-23. This figure provides an overview of the operating mechanism considerations given and a useful correlation with Fig. 2-20. It also establishes geometric relations with other assemblies or components treated elsewhere in the chapter—namely, the latching mechanism, control arc, firing mechanism, and obturator assembly.

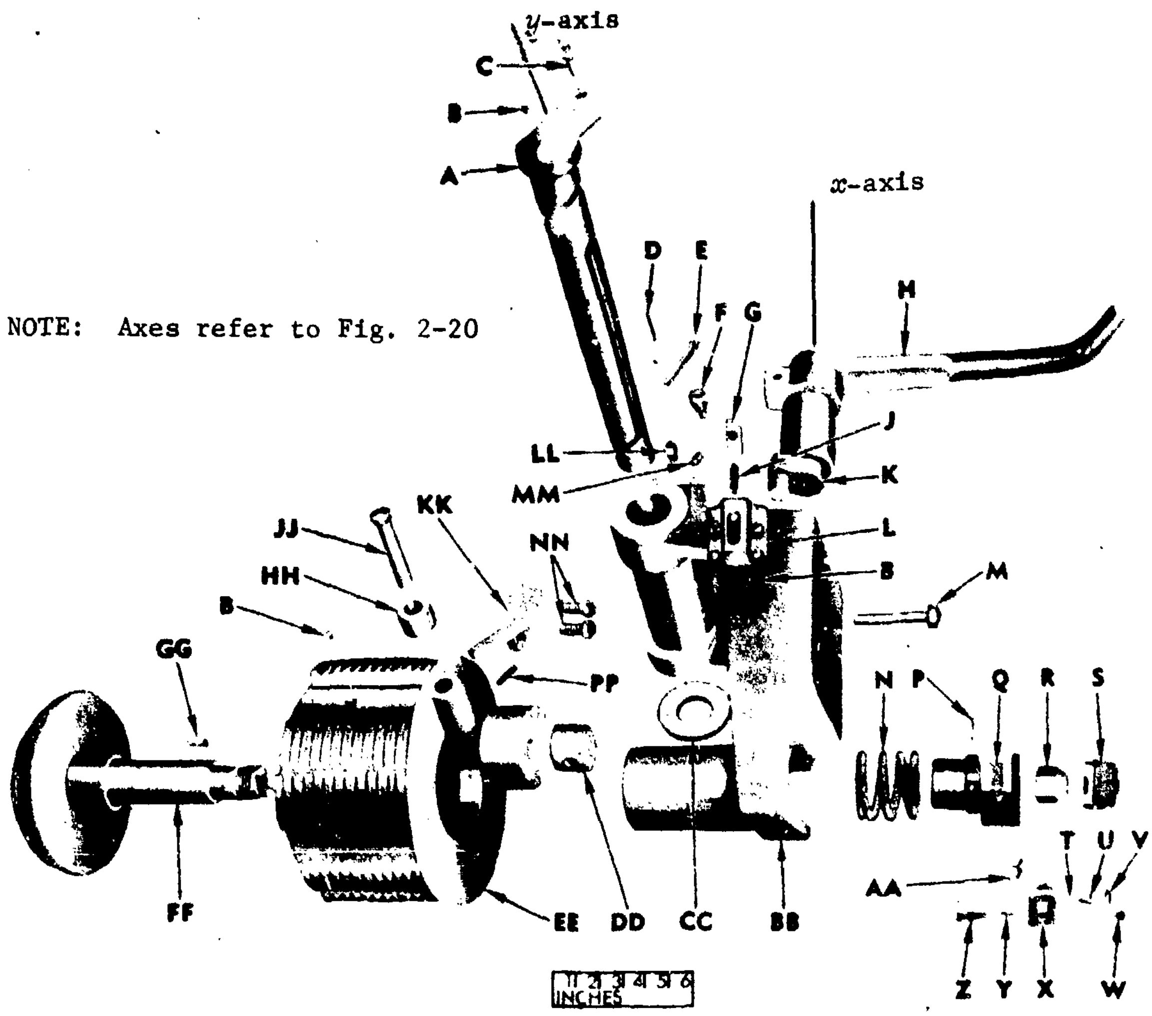
The interrupted-screw breech operating mechanism discussed thus far is designed for manual actuation. As previously outlined, special design problems are encountered in automating breech functions for this closure type. Further coverage of mechanisms is devoted to the semiautomatic mode of breech operation. The citable weapon application is the 155 mm Self-propelled Howitzer, M126A1 (M109 Vehicle). This example is all the more noteworthy since recoil energy of the cannon is used both for rotary and pivot movements of the breechblock.

This 155 mm Howitzer, M126A1, operating mechanism depends on the action of a stationary cam (located on the weapon mount) against a cam-follower crank moving with the breech in counterrecoil. Thus far, the basic actuating arrangement is very similar to the more commonly applied sliding-wedge breech version, previously described. The handbook user should refer to that discussion (par. 2-11.2 and Fig. 2-17) for the manner of synchronizing the cam and cam-follower during recoil motion—preparatory to their working contact. Beyond this point, design of the interrupted-screw breech actuator takes a radical departure:

1. Camming of the operating crank in counterrecoil, rotates a gear sector on the operating shaft. The sector, being in mesh with a vertically oriented breechblock operating rack, forces the rack downward. The rack, which in turn meshes radially with the block, to the left of its axis, causes the block to rotate counterclockwise to disengage the sectored closure threads. Block closing helical springs are charged during the downward movement of the rack. With the block open and threads disengaged, the bottom of the rack contacts the carrier housing and the continued rotation of the crank rotates the housing to the breech-open position. During crank rotation, torsion leaf springs—mounted inside the crank and along the crank axis—are wound up. The breech is retained in the open or loading position by means external to the cannon, i.e., the operating crank roller is engaged in the operating cam located on the mount.

2. Breech closing is accomplished by lifting the cam clear of the crank roller (Ref. 36). When the crank is released, the fully wound return springs pivot the breechblock and carrier back to the breech recess. The carrier latches snap into place as the breech ring and block come into mesh. Then, the rack closing springs lift the breechblock operating rack and thereby rotate the block clockwise into thread engagement. An auxiliary operating handle is also part of the mechanism; it is "clutched-in", when required, to perform the preceding actuations by hand.

Downloaded from http://www.everyspec.com



A - HINGE PIN
B - OIL CUP
C - COUNTERBALANCE PISTON ROD END PIN
D - HINGE PIN KEY
E - COTTER PIN
F - LATCH KNOB
G - LATCH
H - OPERATING LEVER ASSEMBLY
J - LATCH SPRING
K - CRANK
L - LATCH BRACKET
M - RETAINER
N - SPINDLE SPRING
P - EXTRACTOR PIN
Q - FIRING MECHANISM HOUSING
R - SPINDLE NUT
S - FIRING MECHANISM
T - SPRING
U - FIRING PIN
V - FIRING PIN RETAINER
W - KNOB
X - FIRING GROUP BLOCK
Y - SPRING
Z - BLOCK FOLLOWER
AA - EXTRACTOR
BB - BREECHBLOCK CARRIER
CC - THRUST WASHER
DD - CROSSHEAD
EE - BREECHBLOCK
FF - OBTURATOR SPINDLE ASSEMBLY
GG - SPINDLE KEY
HH - ROLLER
JJ - PIVOT PIN
KK - CONTROL ARC
LL - LATCH SCREW
MM - HINGE KEY SETSCREW
NN - SCREWS
PP - PIN

Figure 2-23. Parts of the Operating Mechanism and Other Breechblock Mounted Groups in an Interrupted-Screw Breech (175 mm Gun, M113A1) (Ref. 35)

Downloaded from http://www.everyspec.com

Depending on the particular weapon system, breechblock actuation may have to be synchronized with:

1. Firing mechanism functions
2. Bore evacuation.

These added functions apply specifically to the 155 mm Howitzer, Self-propelled, M126A1. Breechblock-firing mechanism interaction is treated in par. 1-6.3 concerning the same type of firing device employed here (but on a larger size weapon). Synchronization between breech operation and bore evacuation is covered in par. 2-7. This unusual, semiautomatic breech application is further detailed in Refs. 37 and 38

2-12 FIRING MECHANISMS

More complete descriptions of the four major mechanical firing mechanism types introduced in par. 1-6.3 are described in the subparagraphs that follow. Tables 1-1 and 1-2 showed the type of firing mechanism used with various breech mechanisms and ammunition types. Table 1-4 identified the safety features of these devices.

2-12.1 CONTINUOUS-PULL PERCUSSION, M13

The popular name of this device is derived from the "continuous pull" required on a lanyard or trigger shaft to compress and release the firing spring in one operation. (This handbook adds the term "percussion" to its designation because the former nomenclature, while descriptive, neglects the firing pin action.) Distinctive characteristics of the mechanism are:

1. The firing spring is full cocked only at the instant before firing.
2. Separate cocking is not necessary since this action is performed simultaneously with the trigger pull.
3. Trigger pull force has no effect on the percussive force imparted to the primer.
4. In case of misfire, the firing pin blow can be repeated at will without opening the mechanism or breech.

The firing mechanism is self-contained to a large degree. Most of the components are enclosed in a heavy case (Firing Lock, M13) Lugs on the exterior of the firing lock engage with mating lugs in the breechblock firing mechanism chamber to retain the case in firing position. The rear of the lock coincides with the block rear surface, while a threaded bushing fits flush with the breechblock front face and provides the firing pin hole (Fig. 2-24). A trigger shaft, also housed in the block, and parts for actuating that shaft—usually mounted on a nonrecoiling part of the weapon—complete the overall firing mechanism. Arrangement of the trigger shaft, firing lock, and its parts relative to the breechblock of a 105 mm Howitzer, M101 appears in Fig. 2-14.

The trigger shaft actuator, or trigger proper, is kept as simple as possible. In a typical towed howitzer application it consists of a cradle mounted, spring loaded firing shaft having a lanyard connection. A pawl on the firing shaft cams the trigger shaft arm, upon pull of the lanyard. A typical firing cycle and component functions are best described with reference to the sequence illustrated in Fig. 2-24. The trigger shaft (1) enters the firing lock body (2) laterally and its squared end engages the firing mechanism trigger fork (3) as indicated by Fig. 2-24(A). As the trigger arm is rotated by a lanyard pull (or other actuator device) simultaneous rotation and forward movement of the trigger fork take place. This action compresses the firing spring (5) between a shoulder on the firing pin holder (6) and the forward moving firing pin holder sleeve (4). A spring supported sear member (7) keeps the firing pin (8) and its holder in place via a simple sear notch engagement (9).

The trigger fork continues to force the pin holder sleeve forward until the sleeve trips the sear (Fig. 2-24(B)) by riding the sloping sear shoulder (10). This releases the pin holder and allows the compressed firing spring to expand and snap the firing pin forward (Fig. 2-24 (C)). The firing pin strikes and detonates the primer in the cartridge case, which in turn ignites the propelling charge.

Downloaded from http://www.everyspec.com

On release of the lanyard, the firing pin is automatically retracted behind the breechblock face. This cocking action is obtained by using energy still remaining in the firing spring—as the firing spring expands to its original position, it applies equal and opposite forces on its confining members (4 and 6) which in turn act on the trigger fork at their respective contact points (Fig. 2-24 (D)). Equal and opposite forces acting about a common fulcrum point but having lever arms of different length (L_1, L_2) produce a net moment about the fulcrum—in this situation the moment is counterclockwise. Thus, the backward movement of the firing pin holder sleeve permits the sear to rise, engage its sear on the firing pin holder, and the mechanism is ready to operate again (Refs. 40 and 41.)

2-12.2 SPRING ACTUATED, INERTIA PERCUSSION

In this device, the method of using spring energy to drive a firing pin into the primer is distinct from that of the previous example. Actually, the overall mechanism is a system of several assemblies or component groups working in unison. The various elements—namely the percussion, sear, trigger, and cocking assemblies—are housed in the breechblock. A mechanism description that follows is based on Ref. 42, but applicable with some variation to different types of weapons employing a semiautomatic vertical sliding breech. Illustrations pertain to a 105 mm self-propelled howitzer.

The percussion mechanism assembly is housed in the firing mechanism chamber in the center of the breechblock. It consists of a guide into which a stop and a spring are loosely inserted. These components are held captive within the guide by the firing pin which is screwed into the guide and is pinned to it (Fig. 2-25(D) and (E)). The firing pin guide is a cup with a beveled flange on one end and a longitudinally flattened tip on the other. When the assembly is housed in the firing mechanism chamber, the flange mates with the retractor arm and the sear (Fig. 2-25(B)—these components providing the means for setting, locking, and releasing the percussion mechanism.

The stop is a cylinder with a wide, deep slot across one end forming two prongs. The circular opening at the other end of the stop is counterbored to form a shoulder for the retracting spring. This member is a helical compression spring which is placed around the firing pin shaft inside the percussion mechanism guide. (It is the smaller of two springs shown.) One end bears against the stop which is inside the guide while the other end rests against the inside of the head of the firing pin. The firing pin is a shaft with a slotted head, machined to terminate in a blunt point. This point strikes the primer to fire the gun.

The larger, firing spring is also a helical compression type. It extends into the firing pin guide from the rear, and occupies the annular space between the retracting spring and the inner surface of the guide. The forward end bears on the stop in the guide while the rear end seats in the firing spring retainer. The retainer is a plug which closes the rearend of the firing mechanism chamber in the breechblock.

The sear holds the firing spring in the compressed condition and releases it when actuated by the trigger plunger upon firing the gun. The sear is a cylindrical bar which intersects the firing mechanism chamber in the breechblock through a lateral bore in the right side of the block (Fig. 2-25(B)). Within the chamber, its tip lies in the path of the flange on the firing pin guide. This tip is notched so that the guide flange is engaged during the cocking phase, but released when the sear is rotated by the trigger. The right end of the sear is formed into an upward projecting tab which lies in a recess in the breechblock and provides a contact groove for the trigger (Fig. 2-25(C)). A helical torsion spring—suitably anchored to the block, and at the other end to a notch in the sear tab—is wound during trigger actuation and returns the sear to normal position after the guide flange has passed through the sear notch.

Downloaded from http://www.everyspec.com

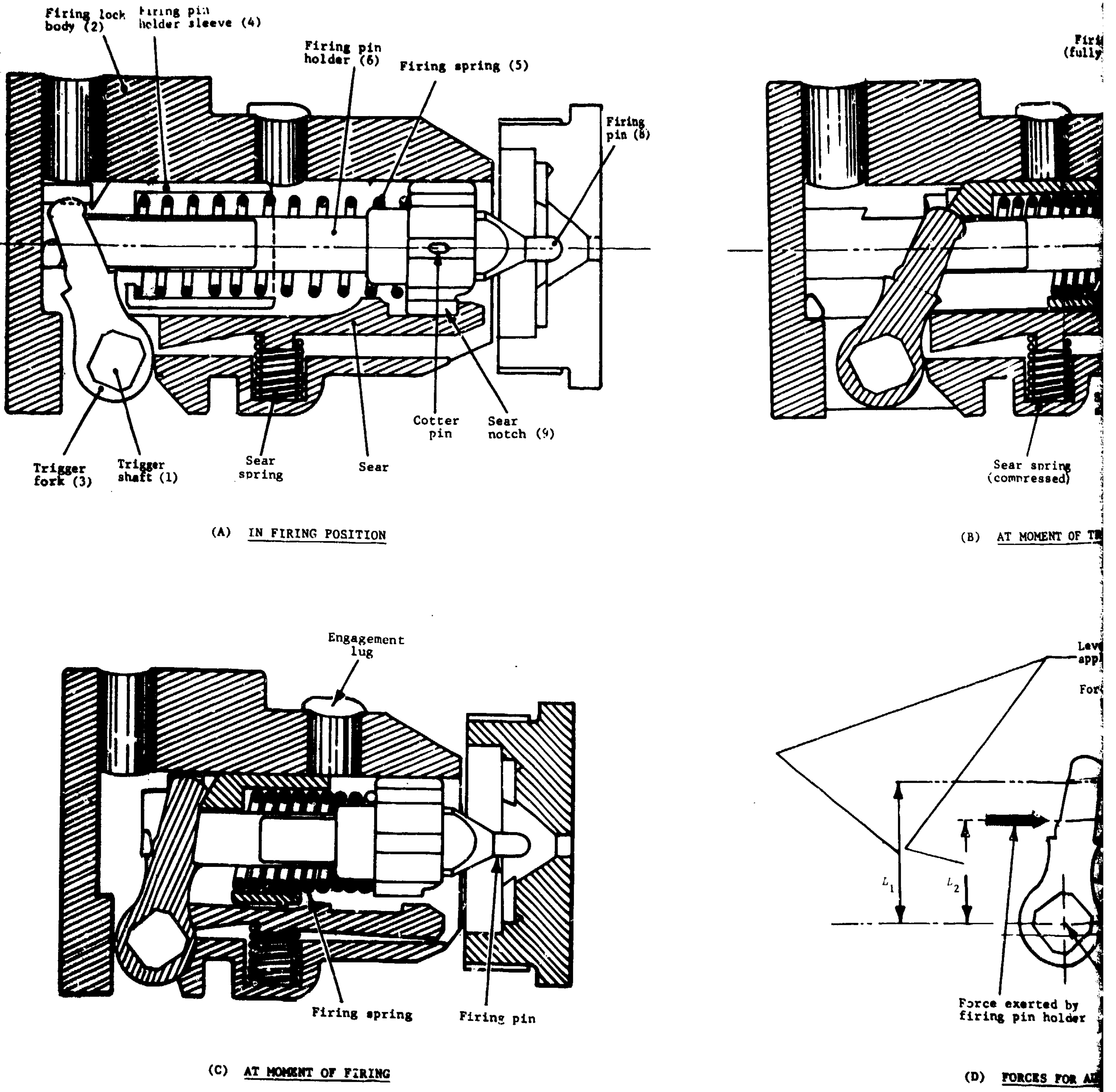
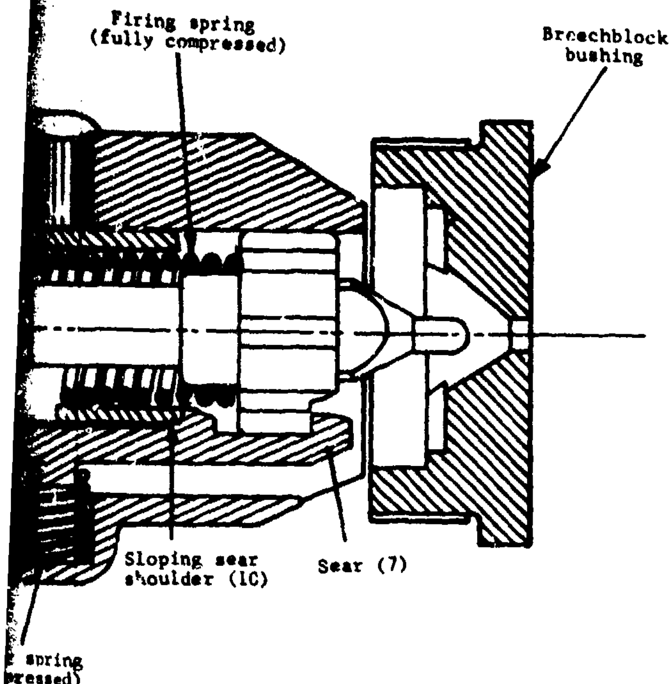
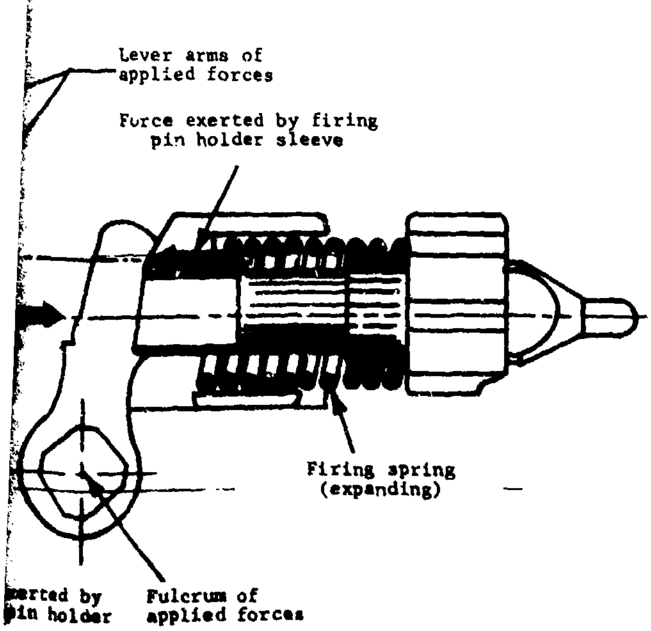


Figure 2-24. Firing Lock M13. Operating Sequence (Ref. 39)

Downloaded from http://www.everyspec.com



MOMENT OF TRIPPING THE SEAR



RCES FOR AUTOMATIC COCKING

Downloaded from http://www.everyspec.com

This page left blank intentionally

Downloaded from http://www.everyspec.com

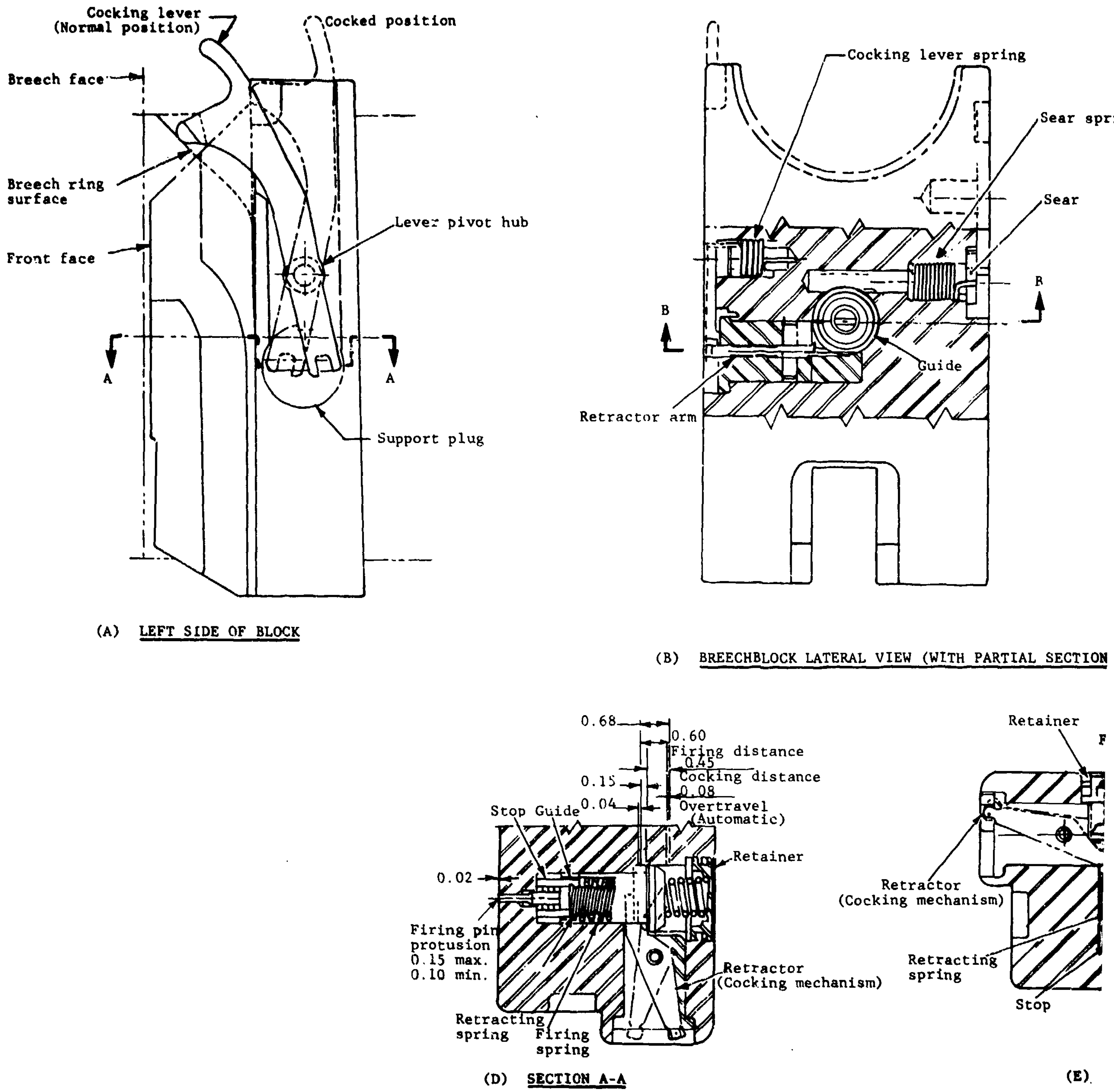
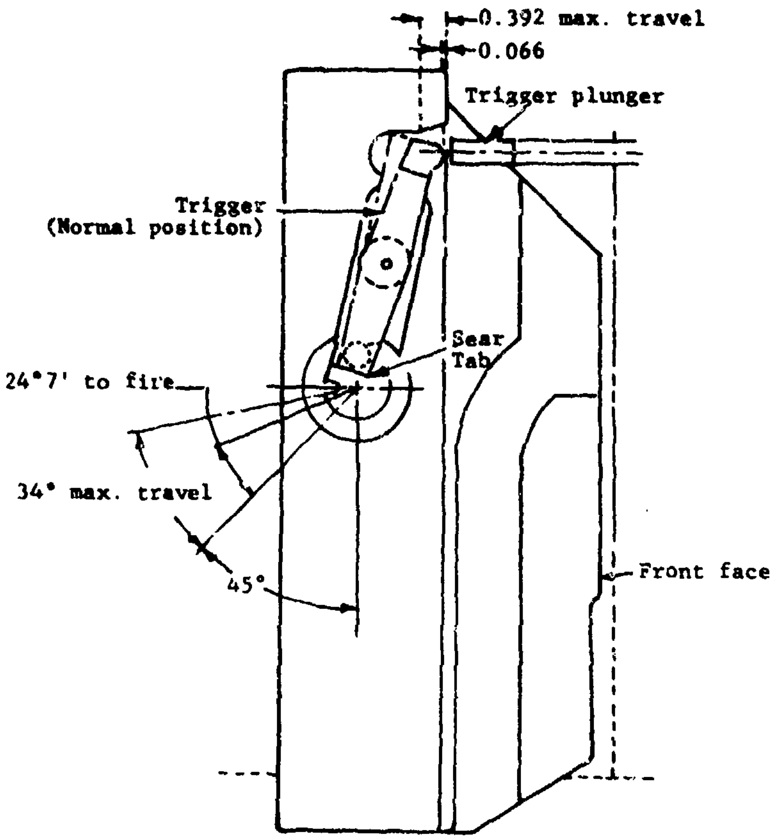


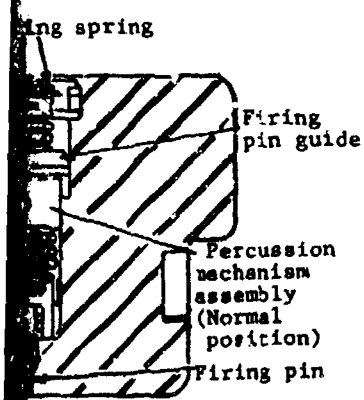
Figure 2-25. Spring Actuated, Inertia Percussion Firing Mechanism With Vertical Sl

Downloaded from http://www.everyspec.com

(Units are in inches)



(C) RIGHT SIDE OF BLOCK



CTION B-B

ing Wedge (After Ref. 45)

Downloaded from http://www.everyspec.com

This page left blank intentionally

Downloaded from http://www.everyspec.com

The trigger is a lever with a central hub, a circular contact surface on one lever end and a smaller, shorter hub on the other end. The trigger is pivot-mounted to the breechblock upper right side via the central hub; it also engages the sear tab groove through the small, lower hub. Free movement of the trigger is restricted by the sear spring. At the same time, the trigger upper contact is aligned in close proximity of the actuating plunger (Fig. 2-25(C).

A cocking assembly completes the overall mechanism complement. It consists of a long, flat lever, pivot-mounted to the left side of the block; a cocking-lever spring; a smaller, pivoted retractor arm, laterally positioned in the block; and a slotted support plug for the latter member. The pivot hub is located near the cocking lever lower end; this end is notched to provide a simple orthogonal connection for the tang end of the retractor (Figs. 2-25(A) and (E)). The cocking lever upper end has complex contours, among them a finger-like extension for manual operation and, for automated actuation, a round cam-follower area that is held against the breech ring camming surface (Fig. 2-25(A)) by torsion spring load at the pivot hub. The retractor inboard end lies in the path of the percussion mechanism and does the actual cocking.

A firing mechanism cycle begins as the breechblock is drawn downward (see par. 2-11.2), camming the cocking lever clockwise. Corresponding motions in the linkage system cause the retractor to push backward against the percussion mechanism flange (Figs. 2-25(A) and (D)). The firing spring thereby is compressed against the spring retainer and is locked in that condition by the sear. The sear is held in a fixed position by action of its torsion spring. When the breechblock is raised to firing position, the cocking lever is returned to normal position by its separate torsion spring.

In firing, the trigger plunger makes contact with the trigger. This action rotates the trigger and sear, the latter moving out of the path of the firing pin guide flange. Upon release by the sear, the percussion mechanism is propelled by the compressed firing spring toward the forward wall of the breechblock. Here the prongs of the stop strike the firing chamber wall and the stop is halted. Meanwhile, the firing pin and its guide continue forward by inertia. By this relative motion, the retracting spring, located between the arrested stop and the firing pin head, is compressed. After the firing pin strikes the case primer, the retracting spring expands and withdraws the firing pin from the gun chamber into the breechblock. Several methods of actuating the trigger plunger are possible. Fig. 2-26 is a schematic of one version of electric solenoid actuation. The push-button convenience for firing a cannon is preferred for combat tanks and other sophisticated self-propelled weapon systems.

The designer's attention is further directed to Fig. 2-25 for important engineering requirements of this firing mechanism. Firing pin protrusion and retraction dimensions, and the several travel or clearance distances of components indicated, are typical specifications encountered in the design of firing mechanisms.

2-13.3 PERCUSSION HAMMER

This overall firing mechanism group consists of a firing block that houses the firing pin and primer holder (sometimes erroneously designated as Firing Mechanism, M1—Refs. 44 and 45) and also the other major components. These include the adapter and mechanism housing—which retain the firing block in the breech—and the percussion mechanism or hammer that actuates the firing pin. The adapter (Fig. 2-27) is an externally and internally shouldered sleeve which fits into the rear end of the breechblock bore through the carrier bracket. It is keyed in the carrier bore to prevent rotation with respect to that member and is retained therein by the mechanism housing. The adapter has a flat, cam-shaped upper arm, notched to retain a safety plunger of the M1 mechanism when the cannon is ready to fire (Fig. 2-27(B)), and a rectangular lower arm that support the percussion hammer. In Fig. 2-27(A), the firing block is shown latched in firing position. The firing block housing is a

Downloaded from http://www.everyspec.com

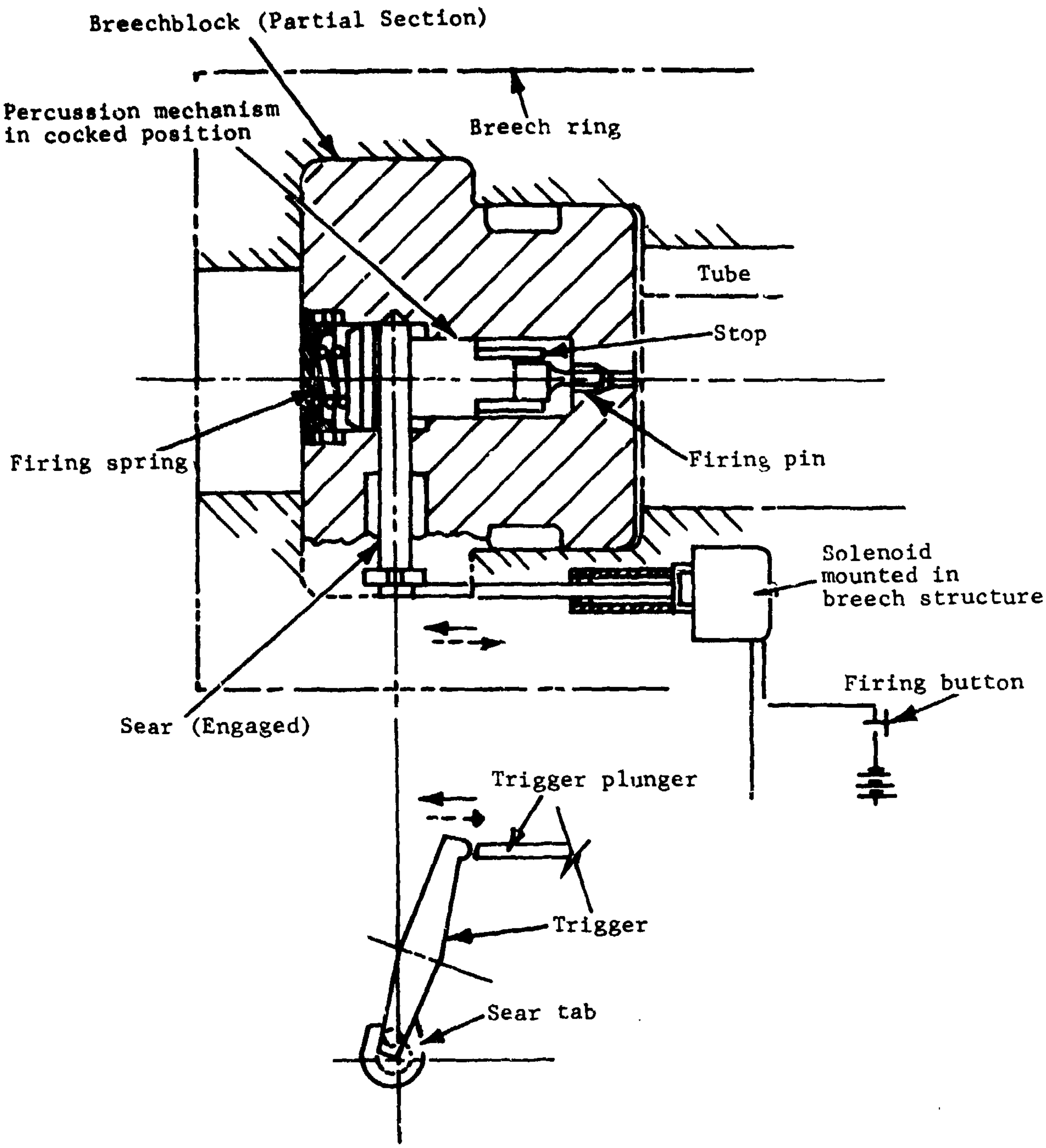
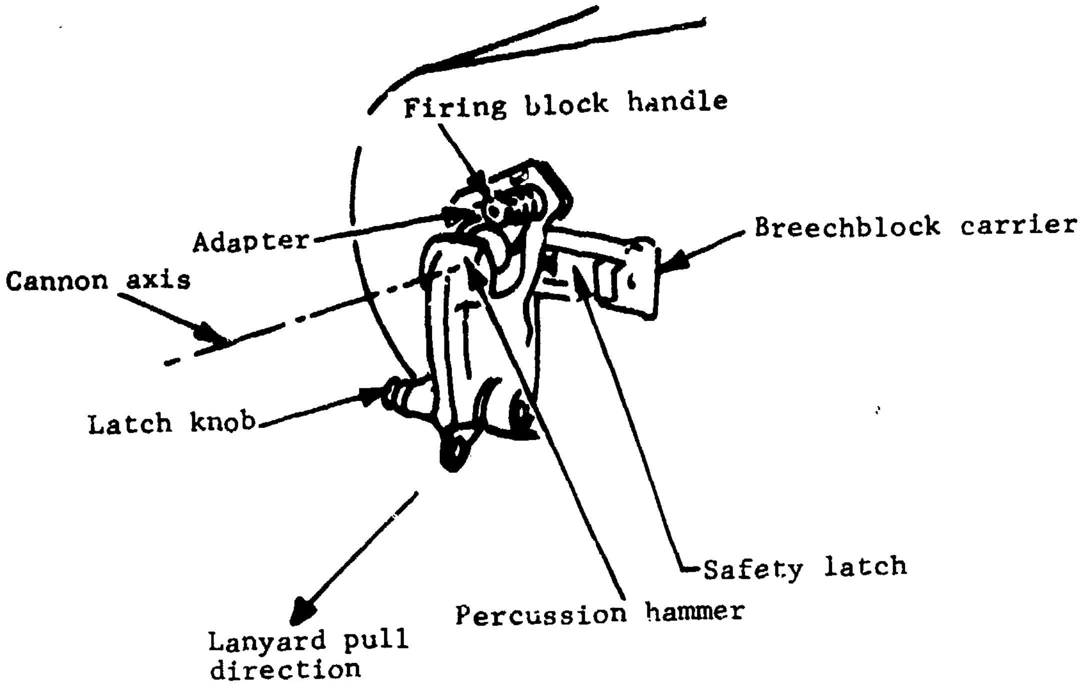
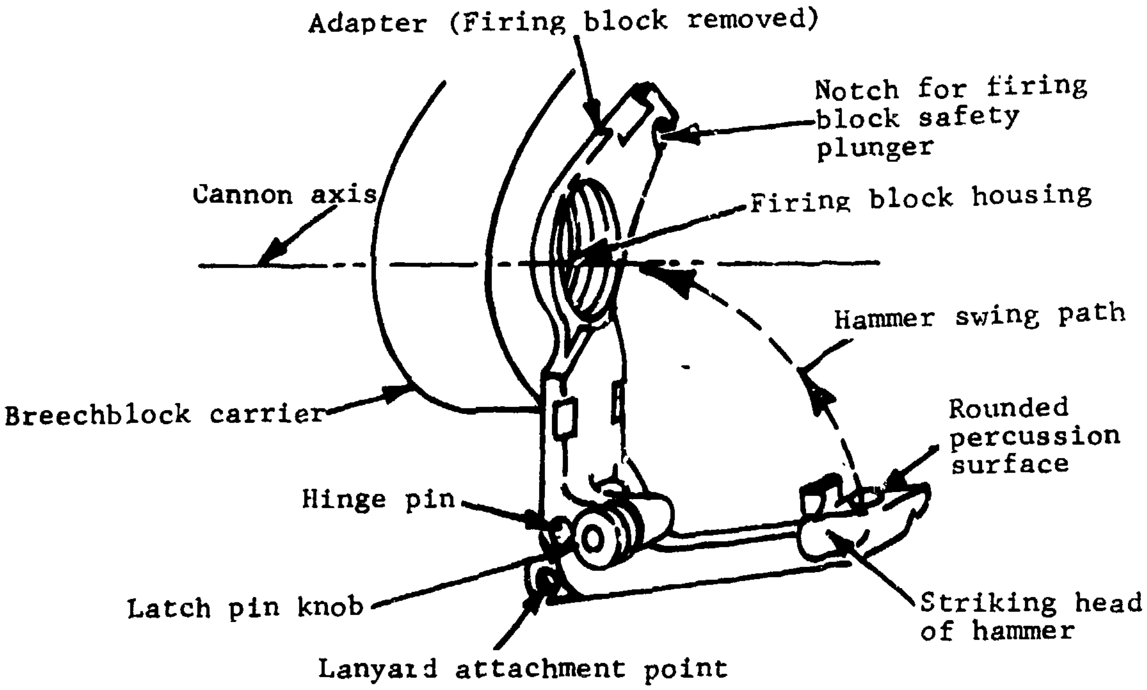


Figure 2-26. Schematic of a Solenoid Actuated Percussion Firing Mechanism

Downloaded from http://www.everyspec.com



(A) Hammer in Firing Position



(B) Hammer Secured in Primer Loading Position
(Mechanism partially dismantled)

Figure 2-27. Percussion Hammer Firing Mechanism (Ref. 46)

Downloaded from http://www.everyspec.com

shouldered cylinder that fits inside the adapter. It has a stepped central bore threaded at both ends; threads in front secure the housing to the obturator spindle while those in the rear receive the firing block. (Although a different firing mechanism type is involved, Fig. 2-20(C) is a valid reference for component arrangement within the breechblock and carrier.) A safety latch (Fig. 2-27(A)) protrudes into the adapter and firing block housing, interlocking the breech operating group. Thus when the Firing Block Assembly M1 (Fig. 2-28(A)) is in place, the breech cannot be opened (see par. 1-6.4).

A hammer and hinge pin, and the hammer latch make up the percussion mechanism. The percussion hammer is a lever which fits into a fork of the adapter lower arm where it is pivoted on a hinge pin. Below the pin is a short arm, drilled for attachment of a lanyard. The upper arm of the hammer terminates in a rectangular striking head with a raised, rounded striking surface on its front face (Fig. 2-27 (B)). This surface impacts the firing pin upon hammer actuation. A rectangular projection is positioned below the striking surface to strike a protective rim of the firing block if the hammer is inadvertently tripped when the M1 mechanism is not in firing position. (This safety feature appears in Fig. 2-28(A)). The hammer latch pin is a detent device. When released as indicated in Fig. 2-27(B), it protrudes into the path of the hammer and prevents the hammer from being raised. This is a preferred position for inserting the firing block and primer cartridge. When the latch knob is retracted, the pin is held from the path of the hammer. The hammer is now permitted to swing in its arc to strike the firing pin, firing the weapon (Refs. 47 and 48). Hammer actuation is produced by a vigorous pull on the lanyard. The latch pin also allows the hammer to be raised and held in an upright, inoperative position convenient when the weapon is traveling.

The M1 mechanism components consist of the firing pin, primer holder and related parts, housed in the firing block as illustrated by Fig. 2-28. The assembly screws into the firing block housing in the rear of the breechblock. It is removed and replaced as a unit between the firing of successive rounds.

The firing block is a short, flanged cylinder with a rim extending around more than half of its rear periphery. This rim prevents the percussion hammer from striking the firing pin unless the mechanism is screwed into firing position. An arm integral with the flange carries a spring loaded plunger and handle by which the mechanism is latched in firing position (Fig. 2-28(A)) and which is also used in removal and replacement of the block between rounds. A large single-thread facilitates the procedure.

As shown by Fig. 2-28(B), the firing pin has a shouldered cylindrical body with a rounded rear contact surface and a flat-ended pin-like nose. It is held in the bore of the block by the firing pin housing at the rear; and by the firing spring, guide, and primer holder at the front. The firing pin guide is a cup which fits, closed end forward, in the forward end of the bore of the block; a hole in the closed end supports the point of the firing pin (Fig. 2-28(A)). This spring is compressed during firing between the closed end of the guide and the shoulder of the firing pin, and afterwards retracts the pin inside the block.

The primer holder is ringshaped and has a left-hand thread to prevent it from becoming loose when the firing block is screwed into its housing. The holder screws into the front of the block, holding the guide and spring in place. Its flanged front has a U-shaped slot to receive the primer case head and support it directly in front of the firing pin (Ref. 47). (When the firing block is removed from the breech, the spent primer cartridge is "extracted" by hand and a new primer inserted.) The primer is retained in position by the pressure of the firing spring bearing against the firing pin guide. The primer holder is locked in the block by a set screw that engages one of a number of notches machined in the rear edge of the holder. The firing pin housing is also locked by a set screw, with a copper shoe inserted ahead of the screw to prevent damage to the housing threads (see both parts of Fig. 2-28).

Downloaded from http://www.everyspec.com

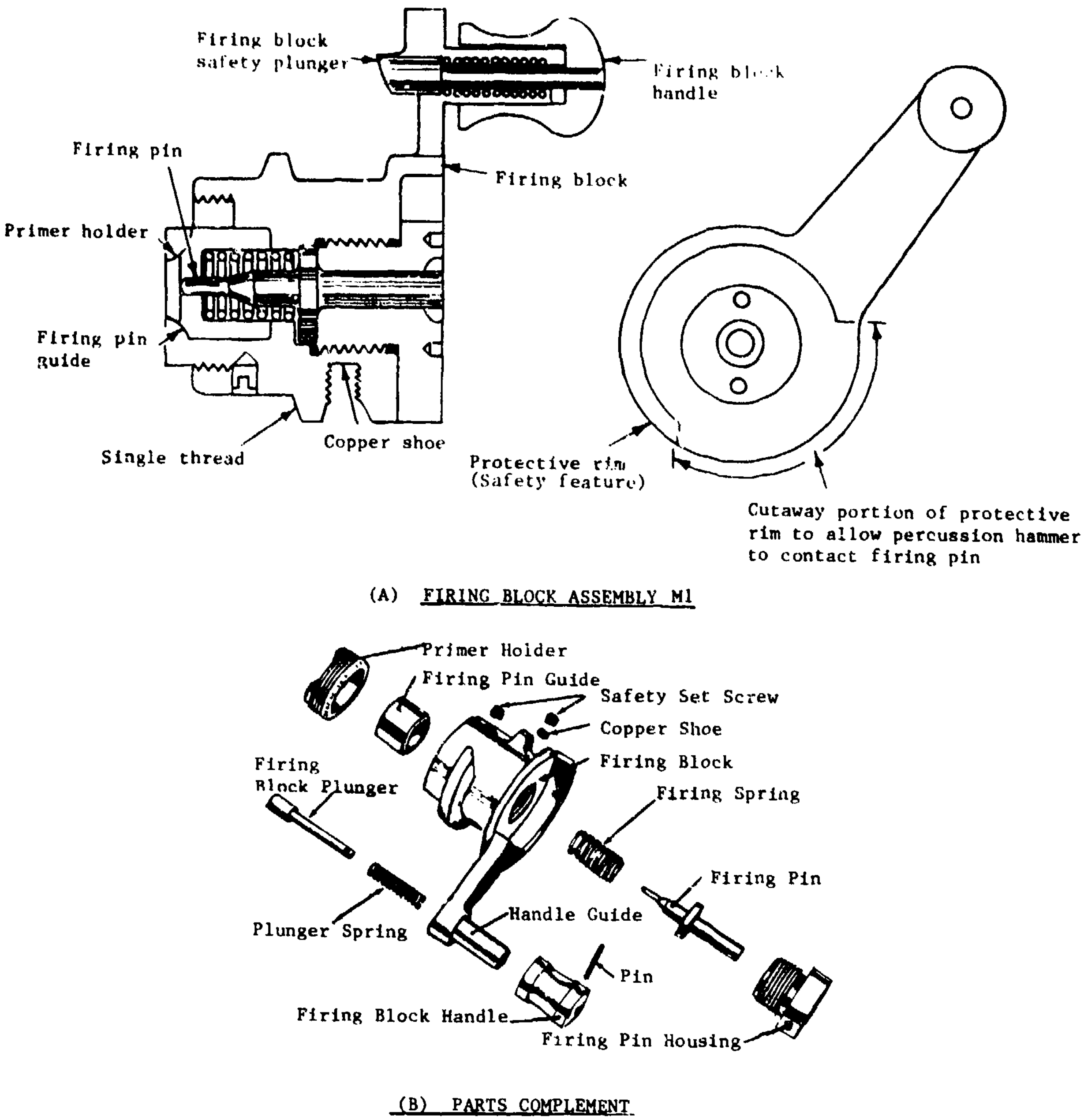


Figure 2-28. Firing Block, M1 (155 mm Howitzer, M1A1) (Refs. 46 and 49)

Downloaded from http://www.everyspec.com

2-12.4 CONTINUOUS-PULL PERCUSSION, IN-LINE HAMMER

The firing mechanism used on the 175 mm Gun, M113A1/8 in. Howitzer, M2A2, self-propelled weapon system, is not adequately classified. Lacking better terminology, the "continuous-pull percussion, in-line hammer" designation is used in the handbook. The common classification, "Continuous-Pull Firing Mechanism M35", refers only to a portion of the total firing group; furthermore it does not even contain the firing pin (Figs. 2-29 and 2-30). Rather, this separately housed, self-contained unit is, here, referred to as the percussion mechanism.

Several other major elements complete the firing group—a mechanism housing assembly and a firing group block combine to form a small scale vertical sliding breech sized to handle the separate primer. The housing is spring loaded against the rear end of the obturator spindle and supported in the breechblock carrier bore. Arrangement with respect to the rest of the breech system can be seen in Figs. 2-14 and 1-2. The firing block contains a firing pin, return spring, and a spring loaded cam-follower shaft which rides in a triangular cam pocket machined into the breechblock rear face (Ref. 50). A primer extractor (pars. 1-6.5, 1-6.3.3, and 2-23) is pivot-mounted in the firing mechanism housing. An exterior view of the firing mechanism and part of the actuating cam pocket is given in Fig. 1-2(A).

The percussion mechanism M35 (Fig. 2-29(A)) mounts directly behind the firing pin in the miniature slide block. It is indeed of the "continuous-pull" type, although substantially different in configuration from the M13 device (Fig. 2-24). Hence, the important design characteristics given earlier in the subparagraph apply. Continuous-pull action is obtained upon actuation of the lanyard lever (1) (Fig. 2-29 (A)) in the manner that follows. Both springs (2) are compressed, allowing the inner hub of the mechanism case (3) to approach the hammer operating sear (4). At full compression, the hub trips the sear, releasing the hammer (5) which impacts on the head (rear) end of the firing pin. Spring expansion returns the lug on the hammer stem behind the sear. At the same time pressure on the hammer guide yoke (6) is relieved, allowing the sear to drop into latch position, aided by sear spring (7) action. All the percussion mechanism components are shown in Fig. 2-30(B).

Simultaneously with the hammer action, the firing pin impacts the primer seated in the obturator spindle vent (Fig. 2-30). The firing sequence is terminated when the retracting spring, which is compressed during forward travel of the firing pin, returns the pin to its normal position.

Between firings of successive rounds, the firing mechanism undergoes the complete motion cycle shown in Fig. 2-30. The follower shaft connects the firing block to the breechblock by means of a cam pocket in the latter. A suitably shaped cam path (triangular) automates the firing block as the breech operating lever is actuated by hand.

When the breechblock is turned to the open position after a shot, the firing block slides down into a slot in its housing assembly to the extract position. As this position is reached, the extractor ejects the primer forcibly from the spindle chamber (Fig. 2-30(B)). As the breechblock is turned to close the breech, the lowered firing block is automatically cammed from the extract position to the load position and the extractor is cammed forward against the rear of the spindle (Fig. 2-30(C)). A new primer is inserted in the chamber by hand like a cartridge into a rifle. Procedures require the firing block to be moved up to the closed position by hand. Accordingly, the follower shaft is manipulated via the follower knob, which snaps into a detent when the top, closed position is reached (Fig. 2-30(A)). The firing block can move to the closed position only when the breechblock is closed. In this position the block must also be capable of being moved manually into the load and extract position—for example, to change primers in case of misfire.

Downloaded from http://www.everyspec.com

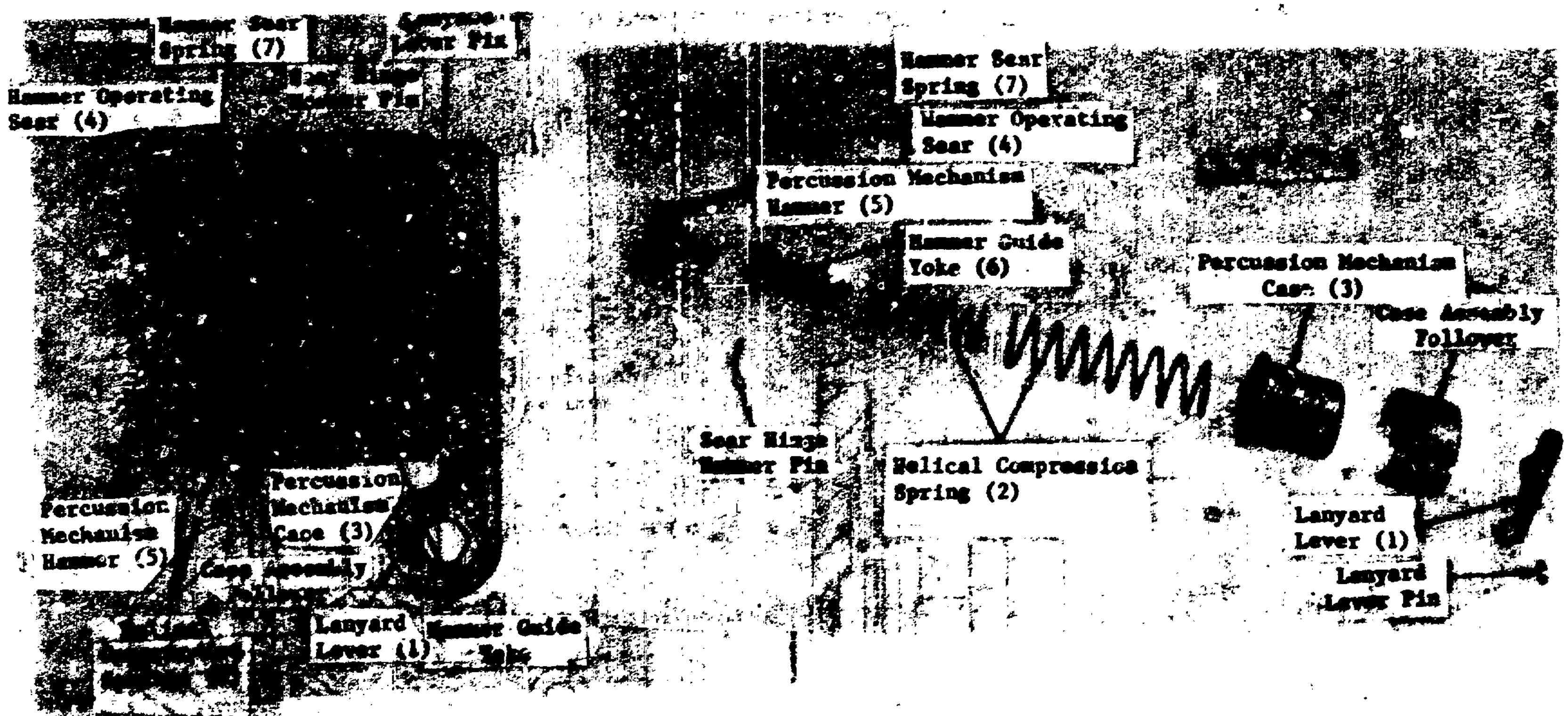


Figure 2-29. Percussion Mechanism M35 (175 mm Gun, M113A1) (Ref. 50)

Downloaded from http://www.everyspec.com

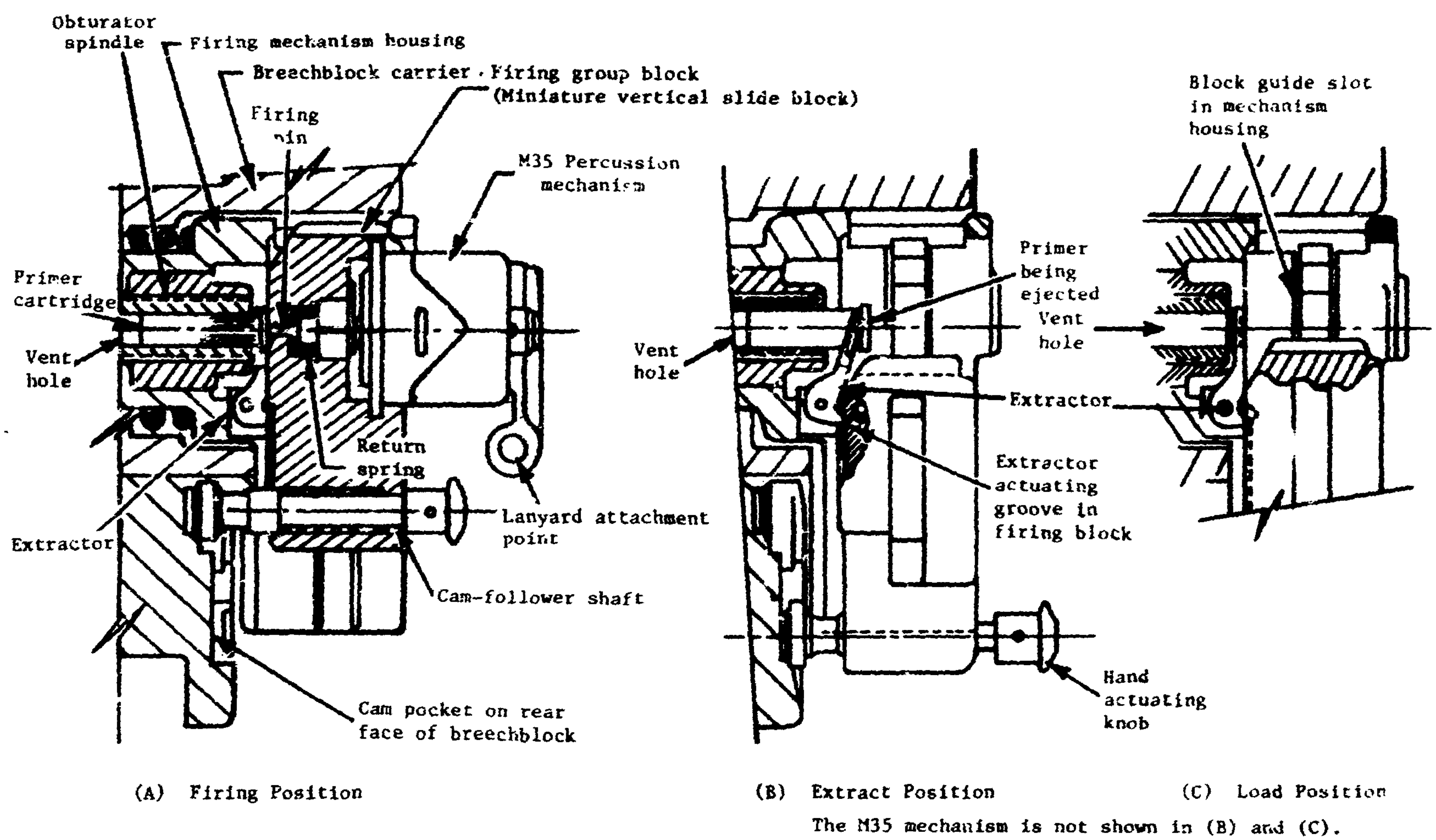


Figure 2-30. Continuous-Pull Percussion, In-Line Hammer Firing Mechanism (Ref. 50)

Downloaded from http://www.everyspec.com

2-13 EXTRACTING MECHANISM

This subassembly of the breech mechanism has the primary function of extracting a "spent" cartridge case. These cases are used to house the propellant charge for fixed, semifixed, and separated ammunition and for the primer case used for ignition of separate loaded ammunition. Par. 1-6.5 provided a general functional description of this device and par. 2-11 illuminated the interrelationship of the extracting and operating mechanisms. Cartridge cases, whether housing the propellant or primer charge, are associated with sliding-wedge breech mechanisms since the case provides the sealing function. This paragraph provides additional description and mechanism examples.

An extracting mechanism for a sliding-wedge breech fulfills more than one function and these are worthwhile to summarize. The device:

1. Extracts the spent cartridge case from the weapon chamber (primary function).
2. Latches the breechblock in the open position for loading the next round.
3. Triggers the closing or counterbalance spring to close the breech, when tripped by the new round.

One or a pair of extractors is used in every breech. The device operates in the same manner whether manual or semiautomatic actuation of the breechblock takes place. In vertical sliding-block applications the extractors are symmetrically placed; however, space constraints and the operating mechanism arrangement usually permit only one extractor when the horizontal sliding-block motion is involved.

Fig. 2-31(A) shows a set of extractors as used in a vertical sliding-wedge breech. These extractors are representative of an older design in vogue through World War II and the era shortly thereafter. Nevertheless, this verison is still typical enough to convey underlying design concepts and illustrate operation of the mechanism. An extractor design typical of current applications is covered later.

When a pair of extractors is used, these members are machined, one right hand and one left hand (Fig. 2-31(A)), and are supported vertically in the front part of the breech—between the sides of the breechblock and the inside walls of the breech ring recess. The upper ends of the extractors have inwardly projecting lips which lie in recesses in the rear face of the tube when the gun is loaded and the breech is closed. In the closed breech position the lips lie under the rim of the cartridge case as indicated in Fig. 2-32(A). The lower ends of the extractors have a trunnion on each side. The inside trunnions ride in curved cam grooves in the breechblock, while the outside trunnions are loosely held in "kidney-shaped" recesses inside the breech ring (Fig. 2-32). (One design variation offsets the outside trunnion above, or ahead of, the inner one; an example is the horizontal sliding-wedge breech for the 105 mm Howitzer, M101A1, shown in Fig. 2-14. In this case, the outer trunnion is simply journaled in the bottom of the breech ring, with the inner trunnion engaged by a suitable actuating cam groove in the block.)

As the breechblock is opened or pulled downward, the grooves in the block first guide the extractors into a gradual but powerful leverage action in order to pry the case from the gun chamber. Then, when the extractor trunnions reach the curves in the breechblock grooves, the forward radii of the extractors rock against the breech face (Fig. 2-32(B)). This motion imparts a rearward, rapidly accelerating thrust to the extractors. The cartridge case rim, still engaged by the lips, is cammed to the rear—thereby extracting the case from the chamber and ejecting it from the weapon (Refs. 53 and 54).

When the breechblock is full open, the inner trunnions of the extractor ride over the top, flat land in each extractor groove. A flat surface on the trunnion assures that the extractors are held in place (Fig. 3-32(C)). Thus, the extractors lock the breechblock in the open position. In certain breech designs the extractors are also latched in place by spring loaded plungers applied against

Downloaded from http://www.everyspec.com

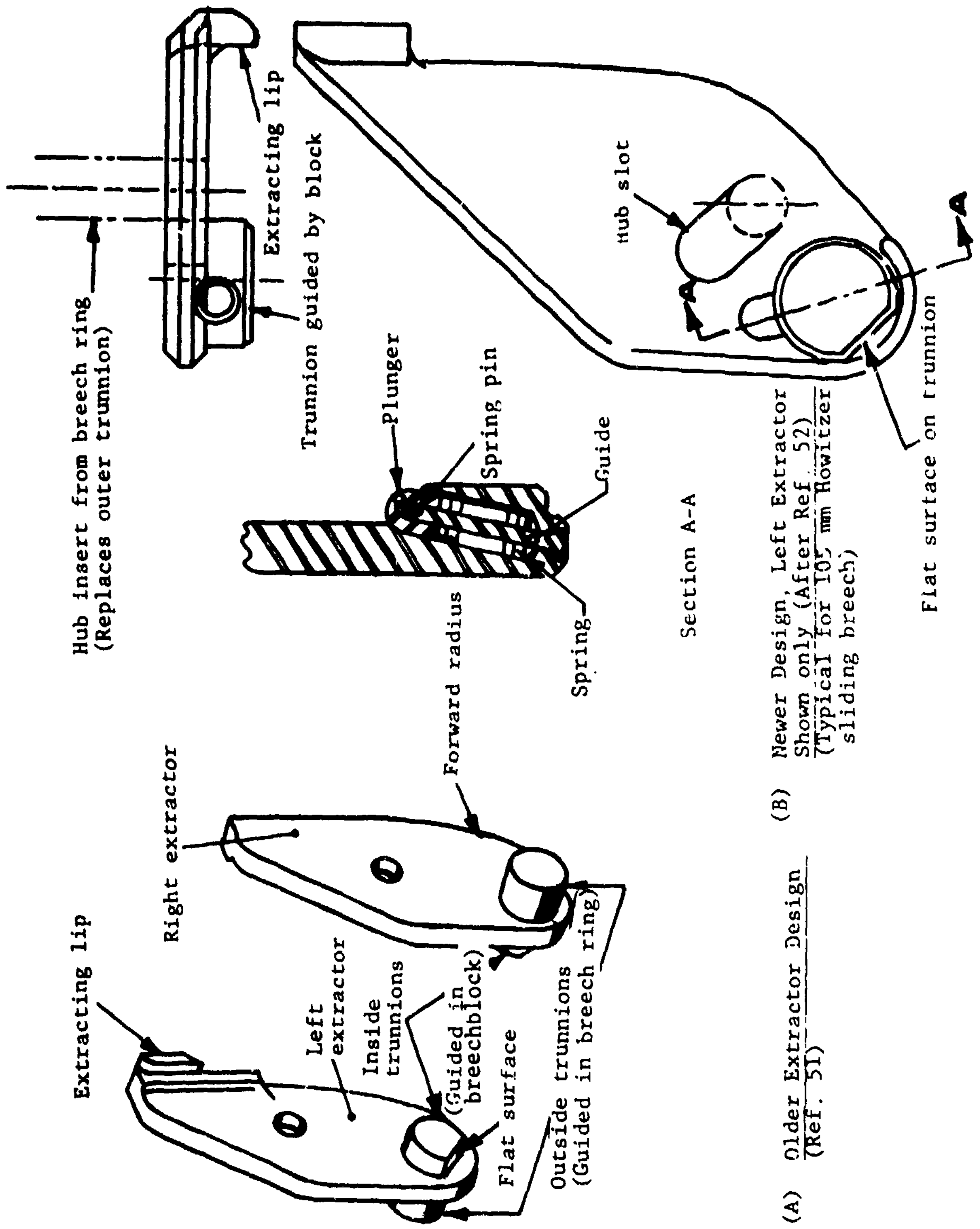
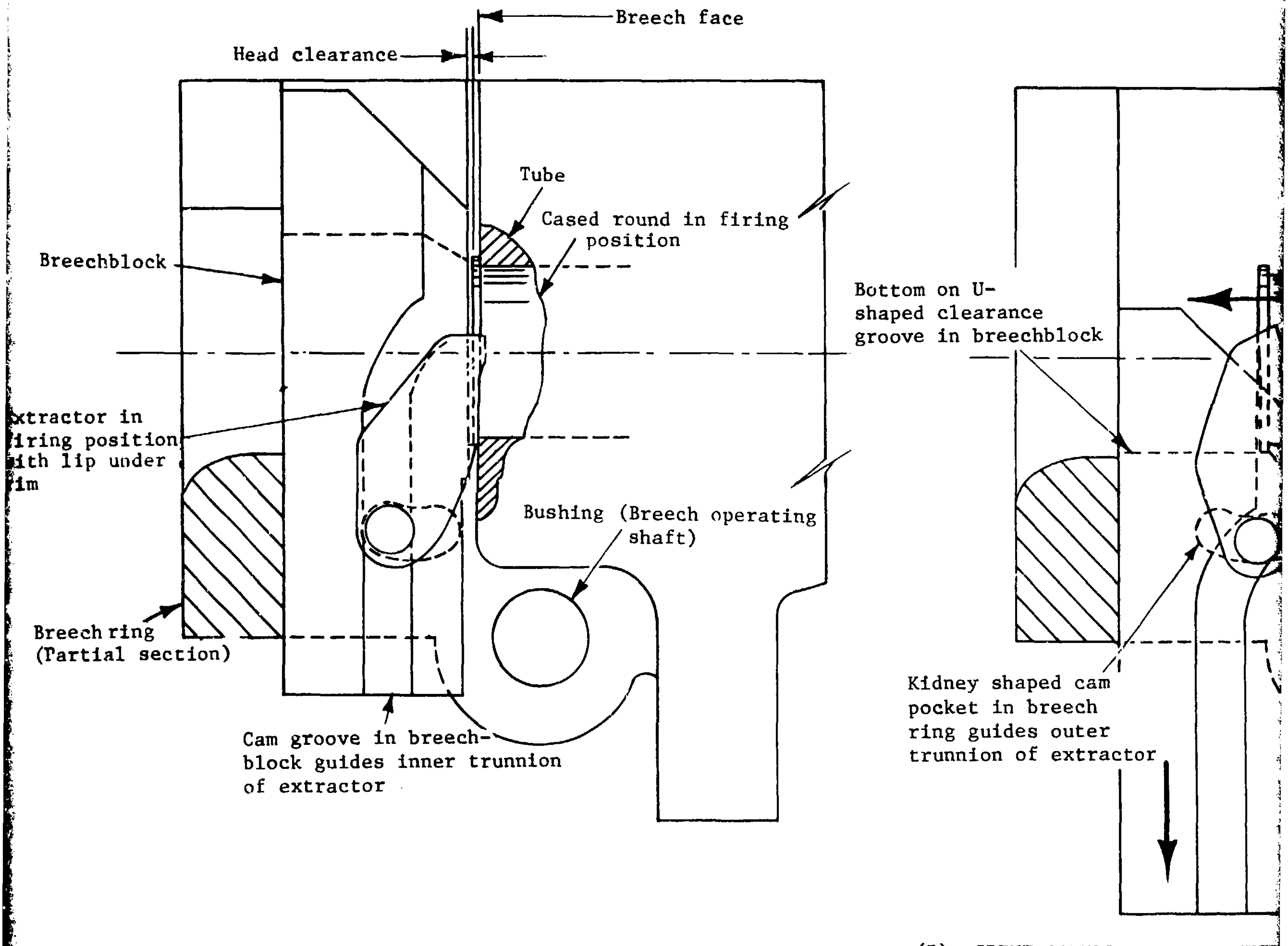


Figure 2-31. Cartridge Case Extractors

Downloaded from http://www.everyspec.com

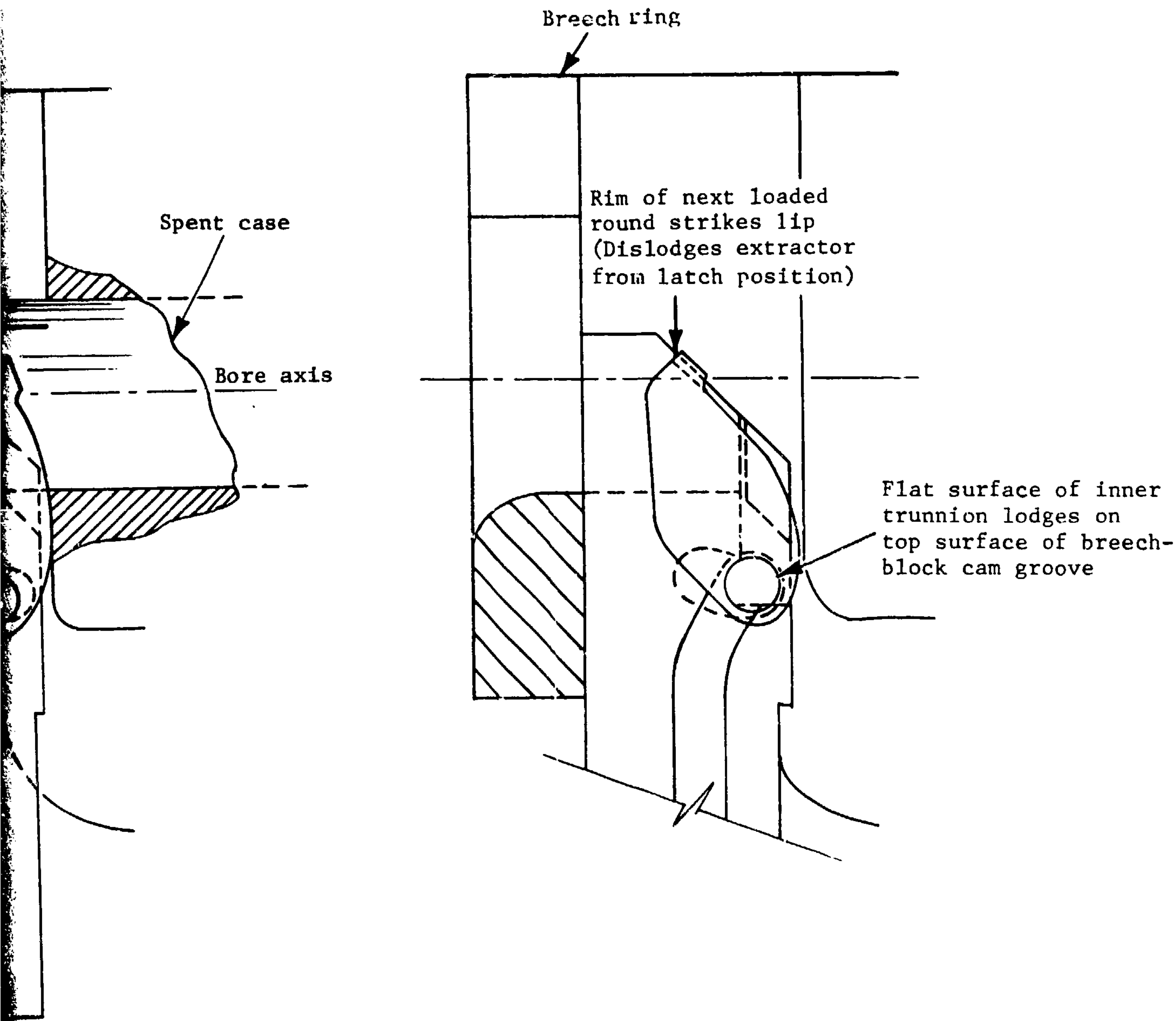


(A) EXTRACTING MECHANISM AND BREECHBLOCK IN FIRING POSITION

(B) SPENT CARTRIDGE BEING EXTR
(BLOCK NEARING FULL OPEN

Figure 2-32. Extracting Mechanism Working Sequence fo

Downloaded from http://www.everyspec.com



RACTED POSITION)

(C) EXTRACTION COMPLETED - BLOCK LATCHED IN FULL OPEN POSITION

or a Vertical Sliding-Wedge Breech

Downloaded from http://www.everyspec.com

Inclosed are pages 2-5, 2-6, 2-29, 2-30, 2-39, 2-40, 2-41, 2-42, 2-53, and 2-54.

This page left blank

blank

Downloaded from http://www.everyspec.com

the outer trunnions through the breech ring wall (e.g., 75 mm Antiaircraft Gun, T83E1).

As soon as the rim of a new round strikes the extractors, the trunnions are dislodged from the groove lands, thereby releasing a closing spring (automated operation) or a counterbalance spring (hand operation). The spring pushes the breechblock upward, closing the breech and [illegible]ing the round. To close the breech without inserting a round, the trunnions are dislodged by suitable release levers provided on cannons with semiautomatic breeches; for weapons with manual breeches, this task is performed by tripping the extractors with an acceptable tool. (Of course, the extraction operation takes place simultaneously with the operating mechanism movements previously shown in Fig. 2-18.) For the sake of clarity, extractor kinematics are isolated from that of other mechanisms in Fig. 2-32.

An extractor that typifies more current design appears in Fig. 2-31(B); only the left member of an extractor pair—as applied on a 105 mm self-propelled howitzer—is shown in slightly less than full size. This extractor was designed to eliminate certain functional and fabrication deficiencies of the previous verison, as well as reduce manufacturing cost (Ref. 55). The changes:

1. Eliminate the forged outer trunnions.
2. Modify the complicated "kidney-shaped" pockets in the breech ring.
3. Replace the separate latching plungers (originally housed in the breech ring and bearing on the outer trunnions).

Breech ring hub inserts—which fit into simple elongated holes in the extractors—are used to retain and establish the motion of the extractors. Also the latching plungers are relocated to the inner trunnions; here, the small spring loaded plungers work together with the trunnion flats to lock the breechblock open, once those flats lodge atop the extractor groove lands.

Newer weapons firing bagged ammunition have a type of firing mechanism which incorporates a small sliding-block breech—e.g., 175 mm Self-propelled Gun M113A1, M107 Vehicle. This makes possible automatic extraction or rather ejection of the small primer cartridge when the firing block is opened. (Ejection is the more appropriate term here since "extraction" of a small arms size component is involved, but the action is distinct from that application.) Much the same technique is used to eject a spent primer as detailed for a full size cartridge case. The action is still produced by a pivoted lever working against the cartridge rim. Downward motion of the firing block trips the lever into extract position, as shown schematically by Fig. 2-30. But the mechanisms needed to obtain the function can be simpler and smaller, commensurate with the size of the part to be ejected. For example, a single extractor lever is sufficient; however, this component is U-shaped and contacts the rim symmetrically in two places.

Symmetric versus asymmetric contact between an extractor and a cartridge brings up a subtle design point regarding earlier discussions. The paired extractor method used with vertical sliding-wedge breeches appears to be superior to a single extractor application, at first sight. Yet, two symmetrically placed extractors do not necessarily work in unison. Due to the tolerance buildup encounted in practice—from realistic fabrication of parts and from assemblies—one extractor can work much harder than the other. Control of actuating force between two extractors is a substantial design problem. A recognized technique in foreign ordnance, but one plagued by prohibitive costs, is the matching of extractor pairs by selective assembly of components. This method is not used in US Army applications.

2-14 OBTURATING MECHANISM

Separate-loading ammunition has no cartridge case to seal the propellant gas in the gun chamber. This type of ammunition imposes the sealing function on the breech mechanism. An introduction to this mechanism was presented in par. 1-6.6, and Fig. 2-20(C) shows the geometric relationship between the obturator and the breechblock. Obturating mechanisms using

Downloaded from http://www.everyspec.com

DeBange type sealing pads are conventionally used in interrupted-thread breech mechanisms.

Table 2-2 lists the principal design requirements associated with DeBange type elastic obturator pads. Qualitative requirements—like the sealing technique itself—are not new, but quantitative demands such as propellant gas pressure and weapon heating effects inevitably increase with time. For the artillery weapon missions being considered, propelling charges are incremented. Thus, maximum chamber pressure is not the only design specification for an acceptable obturator, as indicated in the table. The number and combination of materials tried for this application is an exhaustive topic. Elastic materials, both rigid and flexible, have been considered; these range from metals, to rubbers, to plastics, etc., aside from the fillers or binders which are also necessary. The subject is exhaustive beyond the scope of this handbook; however valuable background information appears in Refs. 56 and 57 on the chronology of developments through World War II. None of these materials has met the application requirements successfully. Special polyurethane elastomers and silicone-asbestos formulations contained in a wire basket envelope are representative of the current materials used. These meet nearly all imposed requirements and are in use; but even they have some shortcomings—for one, loss of resiliency near the low temperature extreme (Ref. 58). Current obturator design receives further treatment in the handbook from the viewpoint of material selection and processing (Chapters 3 and 4, respectively).

The DeBange obturating mechanism consists of the elements shown in Fig. 2-33(A). The rings, pad, and washer disk are assembled under the head of the obturator spindle properly tapered for this purpose. The smooth front shape of the steel mushroom head prevents pinching of the cloth propellant bag when the breech is closed. This also avoids possible damage to the charge (Ref. 56).

The front and rear split rings are triangular in cross section and have conical outer surfaces that correspond to the shape of the gas check seat in the chamber. They are made with an overlapping tapered joint (Fig. 2-33(B)), and slightly oversize to the seat surface (on the order of 0.01 in., diametral measurement when in a free state).

TABLE 2-2 PRINCIPAL DESIGN REQUIREMENTS OF ELASTIC OBTURATOR PADS (Refs. 56 to 58)

Physical Property	Material Requirement
Temperature	1. Remain functional throughout the climatic extremes of the military environment (see Chapter 2). Requirements particularly desired over the wide temperature range are: a. Low coefficient of thermal expansion, and b. Not less than 25% of original resiliency. 2. Withstand heat developed in the gun due to firing (300°F without permanent deformation or physical change).
Compressive Pressure	1. Respond well to the lowest pressure developed in the gun. 2. Withstand the highest pressure developed—while fully constrained. (Pressure range: approximately 8,000 to 60,000 psi.)
Elasticity	1. Remain sufficiently elastic to conform to its seat in the chamber, yet 2. Stay dimensionally stable for long and repetitive use.
Adherence	Make proper contact with the chamber surfaces for sealing, without sticking in place and hindering breechblock operation.
Miscellaneous Properties	1. Producibility—from noncritical materials; with commercial equipment; to reasonable close tolerances (0.020 in.). 2. Immunity to oils, solvents, fungus, and effects of weather. 3. Stable shelf line (≥ 3 yr).

Downloaded from http://www.everyspec.com

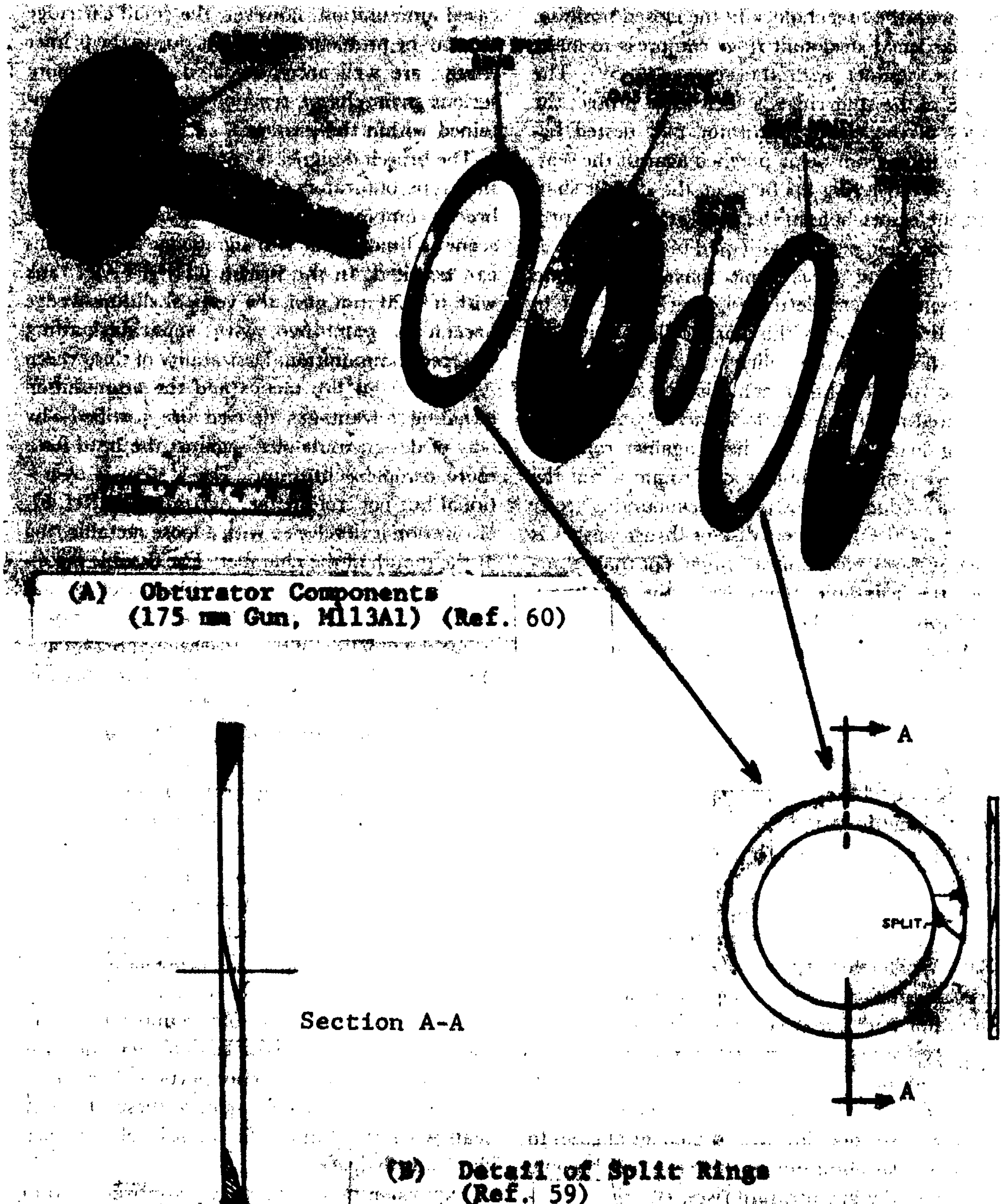


Figure 2-33. DeBange Obturating Mechanism

Downloaded from http://www.everyspec.com

But, with the breechblock in the closed position, the hardened steel split rings compress to make positive contact with the seat (Ref. 59). The shape of the split rings is such as to protect the edges of the elastic obturator pad nested between them from being pinched against the seat. A small inner ring fits between the spindle shaft and the center hole in the obturator pad to prevent extrusion of the elastic pad material (Fig. 2-33(A)). (Solid inner rings have been found satisfactory in modern design practice, but in early breech models this part of the obturating mechanism was also split.)

The obturating mechanism assembly is mounted to the breechblock carrier under axial spring load and keyed there against rotation. However, the breechblock can rotate about the obturator due to its own carrier mounting (refer to Fig. 2-20(C)). A steel disk or thrust washer is the obturator mechanism component that separates the rotatable block from the stationary assembly. The thickness of this disk, closely fitted to the spindle diameter, is sized to put the proper initial compression on the obturator pad when the breech is closed. An additional shim disk may be added to the assembly as necessary, to obtain a tighter seat for the gas check pad. A vent hole through the obturator spindle has the purpose to direct flame from the primer into the main propellant chamber when the weapon is fired (refer to Fig. 2-30).

As previously mentioned, the DeBange system uses a compression principle to obtain the gas seal. When the gun is fired, propellant gas pressure pushes the mushroom-head against the obturator pad, compressing the pad between its axial restraints. In turn, the resilient but confined pad material expands radially—along with the two split rings—against the chamber seat, sealing off the opening against passage of gases to the rear. An obturator of this type will become tighter as the gas pressure rises, effectively sealing all pressures.

Obturation of the breechblock vent hole is performed by the primer seated in this opening. Cartridge case expansion is utilized, much as for cased ammunition; however, the small cartridge size can be problematic. Effects due to the primer charge are well accommodated, but the more serious main charge reaction must also be contained within the passage.

The breech designer is confronted with expansion type obturators when special ammunition-breech combinations come into play. To date the scene is limited but two significant applications can be cited. In the British CHIEFTAIN tank with a 120 mm gun, the vertical sliding-wedge breech is combined with separate-loading (bagged) ammunition. Desirability of this breech type for rapid fire tactics and the ammunition handling advantages derived are justified—by way of design trade-offs—against the need for a more complex obturator. The system is operational but not troublefree. According to Ref. 61, obturation is developed with a loose metallic ring at the mouth of the chamber. The flexible metallic ring is forced against the block face by gas pressure and seals the chamber. Thus, it performs the function of the conventional brass case. Additional details of this obturating mechanism can be found in Refs. 30 and 62.

The 152 mm Gun/Launcher (M81 and M162 versions) in our service employs a flexible metal ring obturator for firing fixed, consumable case ammunition and also a guided missile round. This obturator is similar in operating principle to the preceding application, but has a different geometry which appears schematically in Fig. 2-34. It relies on the radial expansion of the thin tapered ring when exposed to propellant pressure (Ref. 63). The ring is retained in the fixed chamber, but when the separable chamber is closed, the double-taper ring makes contact with gas check seats in each chamber portion. The obturator seal is pressurized against these chamber seats when the round is fired but it relaxes when the load dissipates.

Expansion type obturators have been used in only two US weapons (152 mm M81 and M162) by 1978. This limited use makes it inappropriate to provide design requirements similar to those in Table 2-2 (for elastic type DeBange type pads).

Downloaded from http://www.everyspec.com

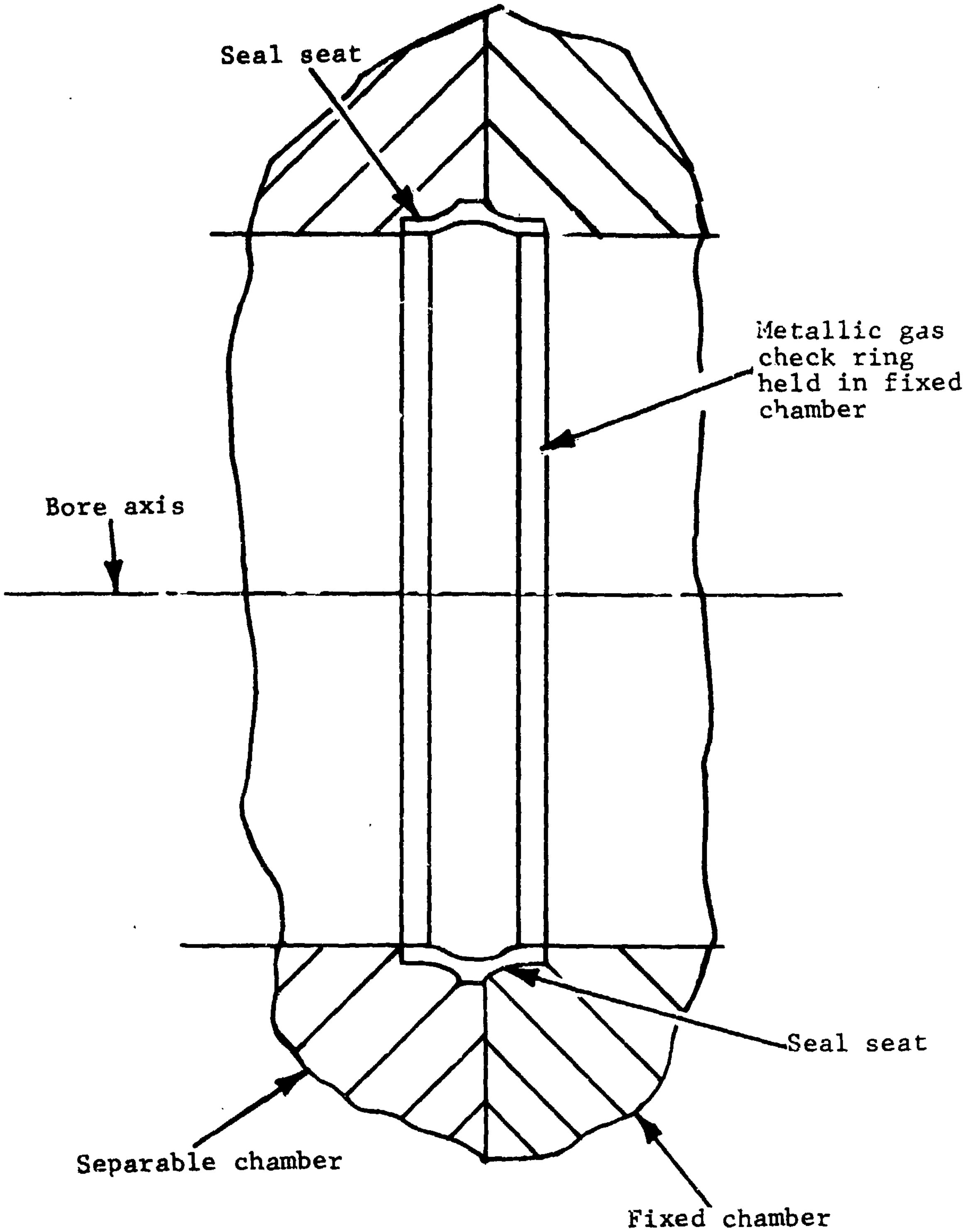


Figure 2-34. Expansion Type Obturator, Separable Chamber Breech Application (Ref. 63)

Downloaded from http://www.everyspec.com

SECTION V. FUNCTIONAL REQUIREMENTS

This section of the handbook expands descriptions of the functional aspects of the breech mechanism. The topics covered are the methods used for operating the breech mechanism, the significance of the interfaces arising from gun elevating and traversing mechanisms, and operating simplicity.

2-15 OPERATING METHODS

Breech mechanisms are operated manually or semiautomatically by means of internal or external power sources. Semiautomated mechanisms are provided with a manual operating capability. This aspect of the breech mechanism was introduced in par. 1-6.2 and is amplified in the subparagraphs of this section.

2-15.1 MANUAL OPERATION

Breech operation in large caliber guns takes place either by manual or semiautomatic means. Hand mode is the classification wherein the energy required to operate the breech mechanism through the cycle of loading, closing, firing, opening, and case extraction is supplied by the operator. Accordingly, design is made as simple as possible for minimum manual effort and maximum convenience of the gun crew. This method of breech operation is most often used with towed weapons where crew size, space allotments, and other offsetting conditions make it competitive with more complex design alternatives.

2-15.2 SEMIAUTOMATIC OPERATION

The term "semiautomatic mode" applies to breech mechanisms in which some portion of the cycle of loading, closing, firing, opening, and case extraction is automatically accomplished. The remainder of functions are performed either manually or by manually controlled external power. Semiautomatic breeches are usually associated with tanks, self-propelled artillery, or other weapon usage for which a more elaborate breech is tactically justified.

Power assistance used for certain breech functions does not constitute "automatic" operation. This has been a misconception in the past, stemming from association of recoil energy actuated breeches with a number of self-propelled weapons. It should be emphasized that for the sizes of weapons under consideration in this handbook, fully automatic operation does not yet exist. The closest approach to full automation has taken place in some large caliber antiaircraft guns. But this has been accomplished only at the expense of great overall weight and size, dependence on supplementary power supplies, and sacrifice of mobility—e.g., the 120 mm Antiaircraft Gun, M1 (see Table 1-1). At the same time, greater problems are also exposed in the areas of availability, reliability, and maintainability.

The use of terms like "automated" and "automatically operated" breech as used in the handbook is just a convenient adoption of the vernacular of the day, and such terms should be interpreted "semiautomatic mode". Power to perform automatic actions can be supplied by energy sources either internal or external to a gun system.

2-15.2.1 INTERNAL POWER

Two sources of internal energy power are available to a weapon system; namely, propellant gas energy and recoil energy. The use of propellant gas involves diversion of a minor quantity of the gas from the chamber into a small cylinder. The gas drives a piston connected to the breech mechanism. When using this method, both the great erosive power and the high pressure exerted by the propellant gas must be taken into account. Propellant gas has been used for driving breech mechanisms in small caliber gun systems—e.g., the 20 mm fully automatic gun—but has not been successfully used for large caliber weapons like the 105 mm howitzer.

Recoil energy is the most common internal power source, to date, for large caliber breech actuation. This method takes advantage of the

Downloaded from http://www.everyspec.com

recoil and counterrecoil movement relative to stationary parts to operate the breech mechanism. Strictly speaking, the counterrecoil portion of the cycle performs the task. The method is most compatible with linear motions of a sliding-type breech. Here, the interaction between stationary camming parts and an operating mechanism moving with the breech in counterrecoil operates a crank to slide the breechblock open. Actually a number of specific functions can be automated which may be summarized as:

1. Breech opening — Direct cam actuation in counterrecoil
2. Firing mechanism reset — Device is cocked by breechblock movement
3. Breech locking — Direct case actuation
4. Case Extraction — Extractor levers work in conjunction with the operating mechanism
5. Breech latching — Extractors lock the breech open to receive the next round of ammunition
6. Breech closing — Stored energy of a closing spring is triggered.

Some examples of recoil energy usage are the 75 mm Antiaircraft Gun T83E1 (towed); the 155 mm Self-propelled Howitzer, M126A1 (M109 vehicle); and a number of tank guns (see Table 1-2). Preference should be given to the development of semiautomatic breech mechanisms which can perform rapid fire without dependence on external power sources which are not always available or dependable.

2-15.2.2 External Power

The availability of external power to operate the breech does nothing to change the operation classification from "semiautomatic mode", as stated previously in par. 1-3.3. The type of weapon under consideration has a great influence regarding the use of external power sources. If power is already available, the use of it to perform breech operations is more attractive. Self-propelled weapons are naturally more easily given power assistance than towed weapons because of the existence of a power plant, but this criterion is not the only one which applies. Type and size of ammunition, fighting compartment space, as well as whether internal power is available are constraints to consider (see par. 1-4 and Chapter 2, Section V).

For the size of weapons considered in this handbook, the types of auxiliary power sources available are

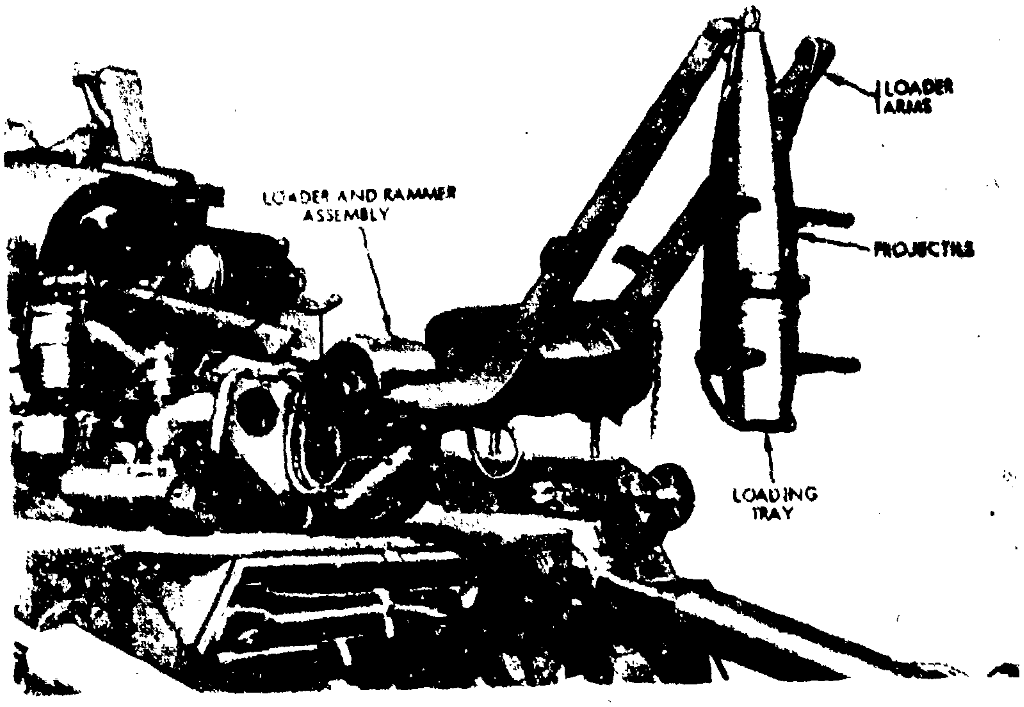
1. Hydraulic or electric
2. Stored gas.

Hydraulic or electric power can be used to accomplish almost all breech functions but its common assignments are breech opening/closing, and loading/ramming tasks. Loading/ramming of ammunition within the context of this handbook is an interface function rather than a primary breech design factor. Nevertheless, this function is a significant example of external power utilization and accordingly is introduced in Fig. 2-35. The system involved is treated later in this chapter.

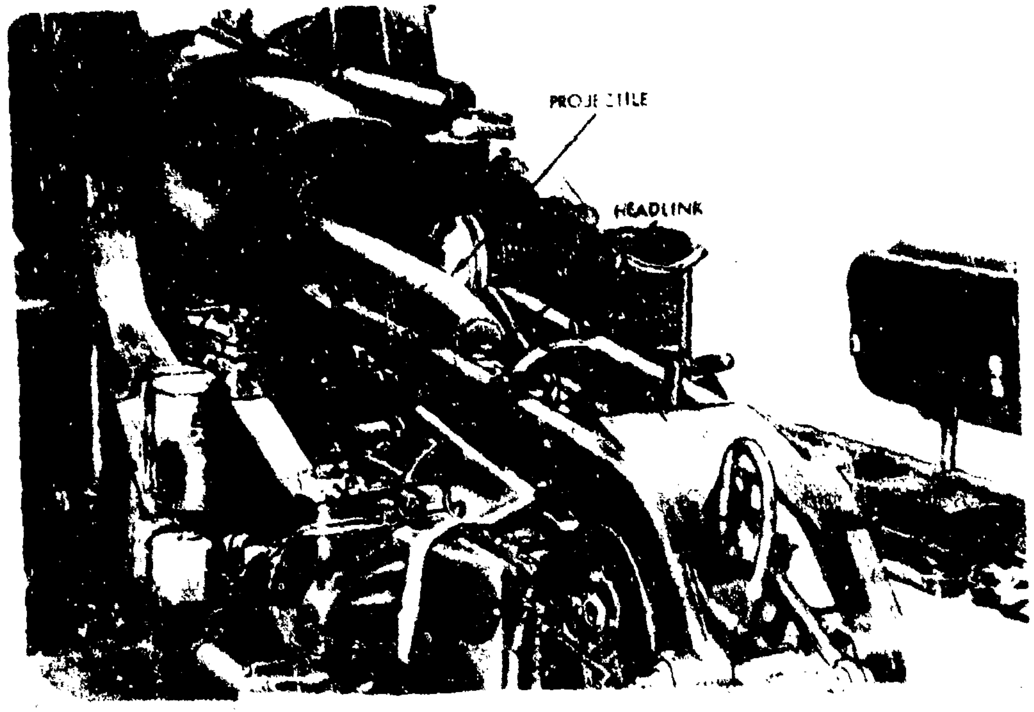
Depending on the weapon application, supplementary power may be required to operate the breech directly. Guided missile weapons are particularly good examples of the need for external power assistance, because of, among other things, the low propellant and recoil energy availability. An example of the most sophisticated and advanced use of breech external power is the 152 mm Gun/Launcher (M81 and M162 versions). It fires dual ammunition, i.e., both guided missiles and conventional medium-velocity projectiles from the same rifled tube. An illustration of the unusual electric-driven breech mechanism is given in Fig. 2-36. The illustration is presented early to give an idea of the complexities that can be expected in breech design. This weapon is further discussed in pars. 1-4.2 and 1-5.4.

Although a definite external power source, stored gas energy is currently limited to another peripheral breech function, e.g., it is used to power scavenger devices for purging propellant residue from the gun chamber in tank applications. Again, the 152 mm Gun/Launcher is cited as an example of such an application. This subject receives additional treatment in par. 2-7 in

Downloaded from http://www.everyspec.com



(A) Projectile being hoisted



(B) Projectile being rammed

Figure 2-35. Externally Powered Breech Interface Function (Hydraulic Loader/Rammer, 175 mm Self-propelled Gun, M113A1—M107 Tracked Vehicle) (Ref. 64)

Downloaded from http://www.everyspec.com

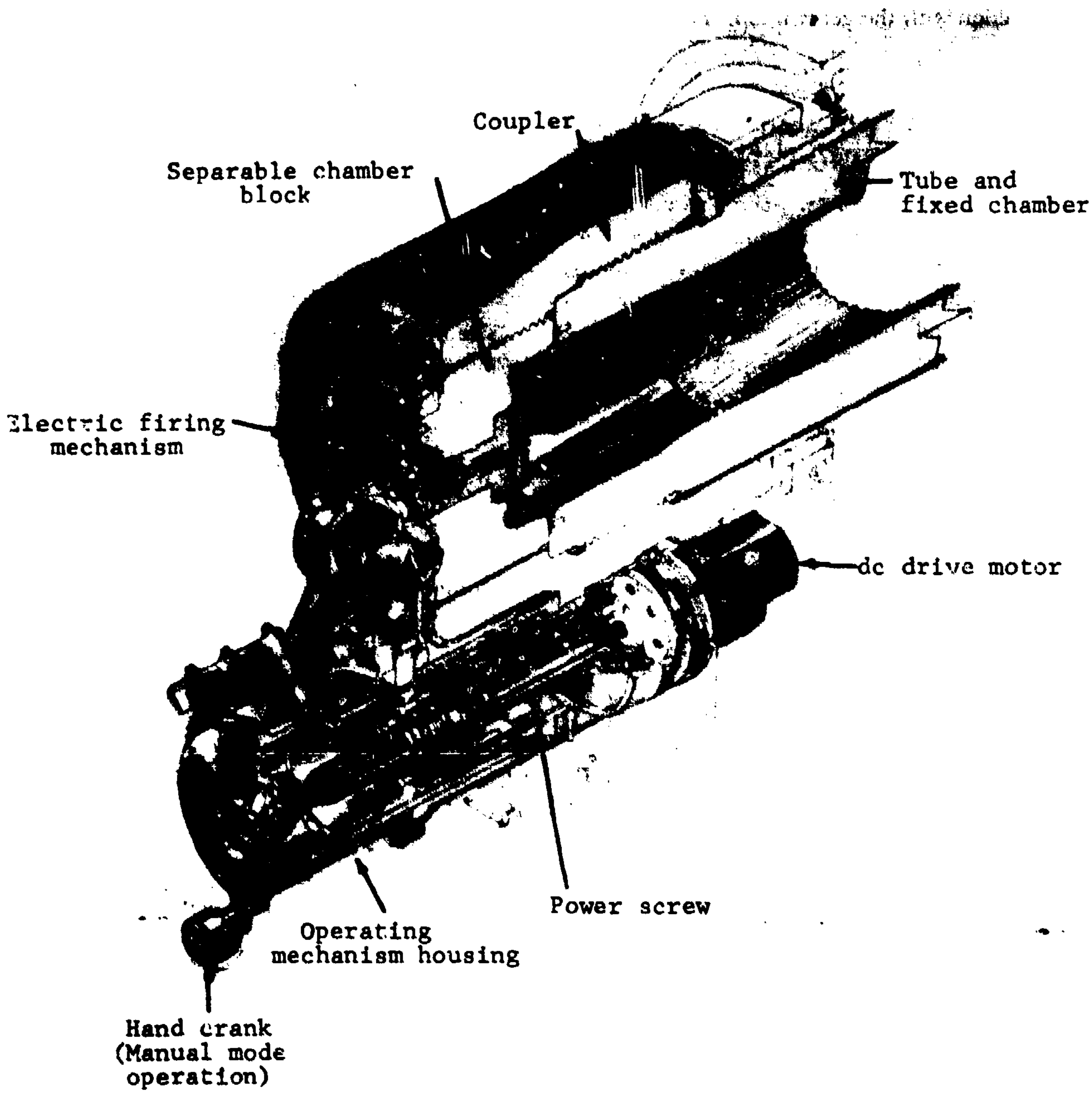


Figure 2-36. Externally Powered Semiautomatic Breech (Separable Chamber Type, 152 mm Gun/Launcher, M162) (Ref. 63)

Downloaded from http://www.everyspec.com

conjunction with the general topic of bore evacuation.

2-16 ELEVATING AND TRAVERSING INTERFACES

Major subsystems of a weapon system include: weapon (gun), fire control, mount, loader/rammer, and ammunition. The mount or carriage, as it is sometimes referred to, has the following subassemblies and for which AMC Engineering Design Handbooks have been published:

AMCP 706-341 *Cradles*
AMCP 706-342 *Recoil Systems*
AMCP 706-343 *Top Carriages*
AMCP 706-344 *Bottom Carriages*
AMCP 706-345 *Equilibrators*
AMCP 706-346 *Elevation Mechanisms*
AMCP 706-347 *Traversing Mechanisms*.

The breech mechanism has an important interface with the gun mount which arises from the elevating and traversing of the gun and the requirements for loading ammunition under all combinations of quadrant elevation and azimuth (traverse). Another interface exists during recoil; the breech mechanism must not contact any portion of the mount or ground during firing at any combination of elevation and azimuth. Tables 1-1 and 1-2 summarize recoil distances, elevation angle extremes, and traverse angle bounds for typical weapons.

The designer should ascertain the geometric relationship between the weapon mount and the extreme combination of traverse and elevation angles as well as the recoil distance. Functional layouts made during the design process (pars. 1-8.1, 3-5, and 3-6) must show that adequate clearance is provided during ammunition loading operations. This clearance includes provision for the gun crew, loading tray and rammer function as applicable, with the breech open. It should also be shown that the firing mechanism can be operated under these conditions.

Initial functional layouts should also be prepared which show the spatial relationship of the breech mechanism (closed) during recoil, the operating mechanism, and other appurtenances. When fired at any combination of elevation and azimuth angles, the breech proper must not come in contact with the ground (or base) or any portion of the mount.

2-17 OPERATING SIMPLICITY

The military environment in which materiel is required to function cannot tolerate elaborate operational procedures. Operations must be as simple as the required functions permit. Operations often take place under adverse conditions. There are extremes of temperature—heat and cold. There are interference problems due to rain, snow, dust, and mud. There are times when equipment suffers from neglect and times when it suffers from abuse and misuse.

Simplicity of the design itself, foolproof functioning, and ease of mechanical operation are goals to aim for. Some practical examples of operating simplicity are:

1. Locating controls and actuators conveniently

2. Providing special devices to facilitate the work of the crew (loading devices, counterbalances for operating mechanisms, etc., depending upon weapon caliber).

As new or different caliber weapons are considered in the future, for requirements of more rapid performance, etc., automated functions will play an even greater role in breech design than now. At that time, the breech mechanism may also be required to absorb functions which at present are external to it. Operating simplicity must also be retained in such new designs.

Operating simplicity will encompass the application of human engineering, maintainability engineering, and design for reliability. Thus, for example, the gun crew operating controls must not only be conveniently located, but should be designed so that in Arctic use the protective clothing worn by the crew will not interfere with

Downloaded from http://www.everyspec.com

operations. This dictates control geometry and motion usable with bulky clothing and hand protection. Conversely, gun operation in extremely hot regions may cause controls to become excessively hot which would also interfere with gun crew efficiency functions.

Just as the crew is adversely affected by climatic extremes, so will the breech operating mechanism. Field use (rough handling) in conjunction with climatic extremes dictates minimum use of "intricate" mechanisms. Those devices which require close tolerances and "fine adjustment" are subject to operation degradation under these conditions. The designer should make himself aware of the in-service operational performance records of weapons similar to the type he is designing or for those which have similar devices employed. Design guidance may be obtained from either good or bad performance records.

SECTION VI. DESIGN REQUIREMENTS

In addition to complying with the specific hardware constraints described, the designer must consider a number of more general but equally important limitations. These are imposed by rate of fire; weight, space, and dynamic loading; by the need for safety and reliability; by the requirements for an effective man/machine relationship; and by conditions imposed by the environment.

2-18 RATE OF FIRE

The broad relationship of the rate of fire to the weapon system was presented in par. 1-4.4. The breech mechanism functions which contribute to the cycle time, and are therefore under the control of the breech designer, are:

1. Locking and unlocking
2. Opening and closing
3. Case extraction
4. Primer initiation
5. Chamber evacuation or scavenging.

Even though the design of the mechanisms which perform these functions are part of the total breech subassembly design, there are significant system imposed constraints.

The ammunition provides one such limitation by virture of the gun pressure curve. There is a distinct pressure decay time which occurs after the projectile exits the gun muzzle and must be recognized before it is safe to initiate the breech mechanism opening sequence of unlocking, opening, case extraction, and gun gas evacuation. Other limits are imposed by the ammunition; i.e., weight, geometry (diameter and length), and muzzle velocity. The power (and associated magnitude) source available for automating breech function also may impose limits.

Ref. 65 presents a British analysis on rate of fire. This analysis had two objectives, to determine: (1) the gun cycle which would have the optimum rate of fire and (2) the dependency of this rate on muzzle velocity, projectile weight, and shape and propellant type. The conclusions which apply in the realm of this handbook are that the weight of the moving breech component and the distance moved through should be minimized to the greatest extent possible. In addition, the synchronization of the recoil cycle and breech opening should be optimized in relationship to the gun pressure decay characteristics.

The breech mechanism design team does not have responsibility for the major contributing factors which control or bound the weapon firing rate. It lies with the ammunition and recoil design groups. However, the breech interfaces relating to the gun crew and the functions cited are important.

2-19 WEIGHT

Weight is one of the strongest constraints imposed on ordnance design. A major design goal is to derive the greatest strength for the lowest

Downloaded from http://www.everyspec.com

weight. Although concern for excess weight in military equipment is not new, modern weapon requirements demand that weight budgets be more closely scrutinized. Mobility—in its own right or to facilitate transport—and versatility are important weight related factors.

Definite weight constraints apply to breech mechanism design. However, the critical strength required of the breech makes substantial weight reductions impossible. In addition, the dictates of the total design must be considered. The lower bound on breech structure weight is defined by the outer dimensions of the tube assembly. When the various functional requirements of the breech itself and the elements necessary for interfacing with other weapon requirements are added, it requires a good deal of ingenuity to limit breech system weight. The desired/required useful weapon life and/or reliability may be impacted by weight factors. These design attributes must be taken into consideration as a constraint on weight.

In certain weapons it may be desirable to increase breech system weight since the overall gun weight distribution becomes of primary importance. Since the breech is located at one extreme of the tipping parts, it can have significant effect on weapon balance. It is impractical to achieve precise balance in large caliber applications and, within acceptable limits, a weapon will have either muzzle or breech preponderance. Modern weapons are usually muzzle heavy. The amount of tolerable unbalance depends on weapon type. Field artillery exhibit tipping parts assemblies that are very muzzle heavy. However, the construction of these pieces, their spatial environment (par. 2-30.2), and little demand for rapid tube attitude change allow the use of equilibrators sufficiently large to correct the unbalance. Remaining unbalance must be limited to a level that permits efficient operation of the elevating and/or traversing mechanism.

Towed weapons pose yet another weight constraint, particularly in the lower calibers. Efforts to develop a class of lightweight weapons tend to concentrate the weight reduction in one element of an overall system with unfavorable results. Rational weight apportionment is more complex and must satisfy the needs of various gun elements. Although recoiling parts often receive such emphasis, the lowest recoiling weight does not necessarily provide best weapon performance (Ref. 66). Breech mechanism weight can, of course, influence the role of recoiling parts and the total weapon weight. Self-propelled artillery can have weight distribution that is characteristic of a field piece or a tank, depending on the particular design. When the weapon is not enclosed in a turret, e.g., the 175 mm Gun, M113A1, equilibrators can be employed exactly as in field artillery (see Fig. 1-1(B) and par. 1-4.2). In other situations, the self-propelled vehicle may be quite tank-like in appearance with the weapon enclosed in a fully rotatable turret, e.g., 105 mm and 155 mm Howitzers, M103 and M126A1—Vehicles M108 and M109.

Tank guns have fundamentally different requirements; they require a greater degree of inherent balance because special construction and space factors exist (par. 2-20.1) which do not allow for separate equilibrators. Permissible unbalance is limited mainly by the elevating device capability but also by recoil mechanism design (Ref. 67). The primary mode of gun elevation is provided by an electric or hydraulic drive. Neither this mechanism nor the emergency hand-operated mode can be encumbered by a large unbalanced load. Actually, a contradictory condition is found in a turret gun installation. While a high degree of balance is desired, some muzzle preponderance must be tolerated since the gun may be placed only so far back in the turret and still permit loading (Fig. 2-37). The problem can be met only via trade-offs between the affected design interfaces.

The breech mechanism weights listed in Tables 1-1 and 1-2 provide data on previous successful designs based on a representative cross section of large caliber weapons. While information of this type offers only very general guidance, it is interesting to relate breech weight to some larger element of a weapon. A unifying factor

Downloaded from http://www.everyspec.com

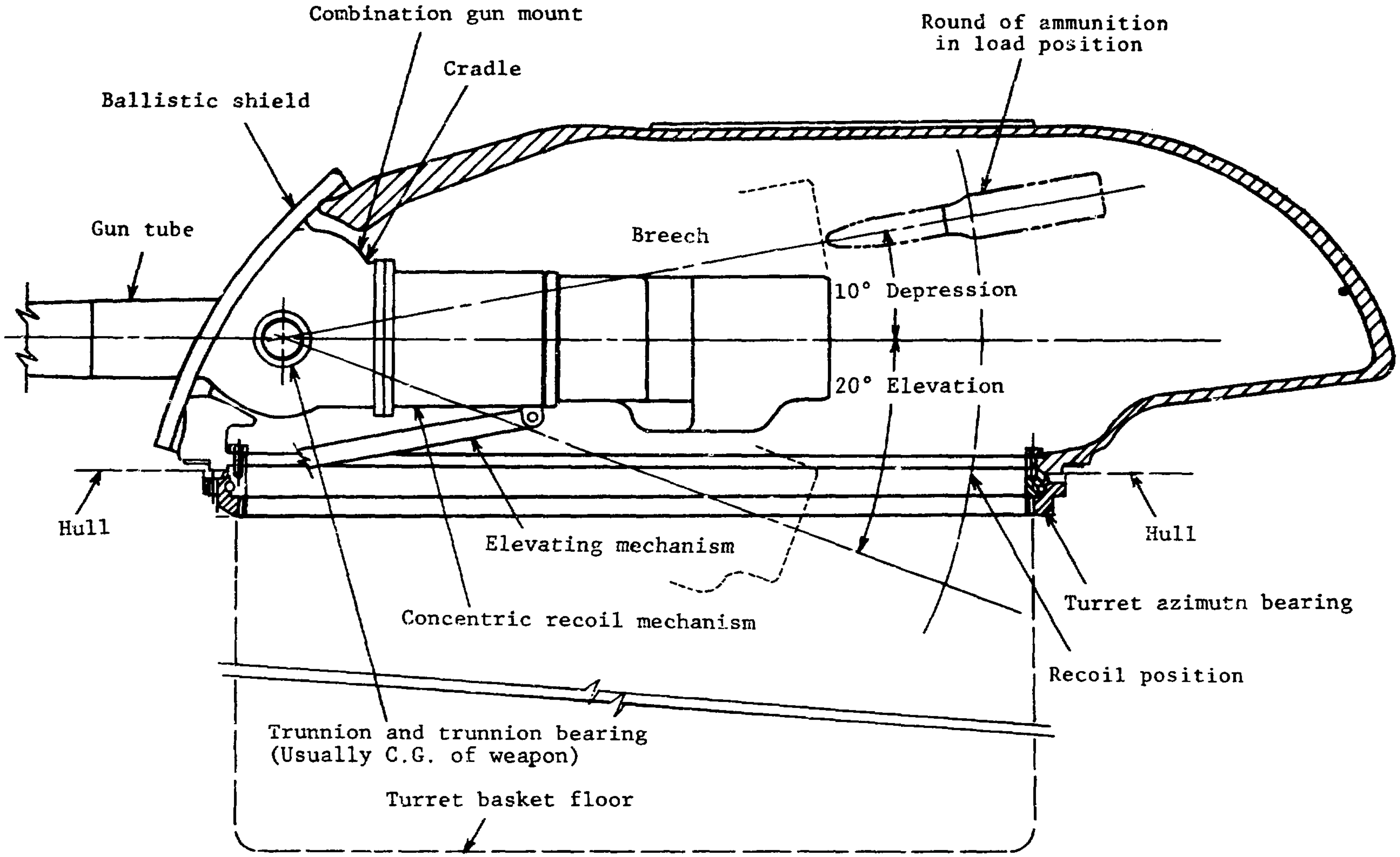


Figure 2-37. Typical Space Constraints in a Turret Gun (Based on M48 Tank) (Ref. 68)

Downloaded from http://www.everyspec.com

among the diverse applications (including towed and self-propelled weapons) is needed, however. Cannon weight has been found to reasonably fulfill this role. Thus, the ratio of breech mechanism weight to cannon weight was found to range from 0.217 to 0.447, based on the weapons given in Tables 1-1 and 1-2.

Although these data are valid for general design guidance, they should be interpreted in proper perspective. The weight ratios reflect both old and new designs; therefore, they can include subtle changes due to new materials, design, and testing techniques. In future designs, a reliable breech that fits below the indicated range would nevertheless be welcome. Similarly, a breech-gun weight ratio somewhat larger than the cited "limit" would be acceptable if justified by offsetting advantages.

2-20 SPACE CONSTRAINTS

Weapon application and equipment function establish the space constraints on breech design. For example, freedom of movement through required gun elevation angles, depression, and traverse all demand space which must be provided by different means in enclosed turrets. In addition, space assignments must consider such functions as loading, ejection and recoil, the man/machine relationship, and equipment maintenance.

2-20.1 TURRET GUNS

Weapons mounted in protective structures aboard self-propelled vehicles pose special space problems. Operating space in the tank turret particularly is limited. Vulnerability requirements dictate that the overall dimensions of a tank be minimized and, because target height is considered especially important, a low vehicle silhouette is sought. The shape of the turret, which is sloped to deflect projectiles away from the structure and afford protection, further restricts the crew in breech operations. Fig. 2-37 shows the limitations of a tank turret that affect breech design.

The tank gun must be fully operable to the maximum required angles of elevation and depression, which usually range from +20 to −10 deg. Relatively flat-trajectory direct fire is provided by the tank weapon system, but the various attitudes of the vehicle make a substantial quadrant angle necessary. Gun depression is important, for example, in situations where the defilade firing position is used but the tank is located on a slope.

Space constraints are more critical with the weapon depressed (Fig. 2-37). Because the gun axis is necessarily close to the turret roof, the vehicle height limits the amount of depression possible. The depression angle is limited to that which allows all the needed mechanism functions—i.e., loading, recoil, extraction—to take place. If necessary, a vehicle height is traded off to provide the required gun depression. The breech designer must limit protrusions, e.g., operating handles, and make sure that all the corners are rounded.

In general, similar restrictions apply to the maximum elevation angle. There is, as Fig. 2-37 shows, more space between the weapon axis and the turret, however. Elevation is limited to prevent interference between the bottom of the breech ring (or recoil guard) and the parts of the elevating mechanism.

Traverse does not present serious space problems. The turret is fully rotatable in azimuth on a single-row ball-bearing assembly (Ref. 69).

Self-propelled artillery with enclosed gun turrets—e.g., 105 mm and 155 mm self-propelled howitzers, M108 and M109 vehicles—pose similar space limits on breech operation. Because of different tactical employment, weapon sophistication, and storage requirements, however, the space constraints are less stringent than for tanks. Also, allowing space to provide maximum elevation and depression is less of a problem in self-propelled weapons. Traverse is accomplished as in tank turrets, although the "turret" is not always enclosed, e.g., Fig. 1-1, or fully rotatable. (See Table 1-2).

Downloaded from http://www.everyspec.com

2-20.2 FIELD GUNS

The space constraints associated with field guns result from the weapon mount and supporting structure. In firing at high quadrant angle where traverse is needed, space constraints are evident. The trails and the breech mechanism in recoil cannot be allowed to interfere. This is one reason why towed field pieces generally have limited traverse capabilities (Table 1-1). The carriage design is more complicated when the design requires more traverse. A noteworthy example of this is the 105 mm Howitzer, M102, with 360 deg traverse capability for close infantry support. In this case, space limitation at the breech end of the gun affects both the breech designer and carriage designer.

The breech designer has limited influence on space constraints. Equipment envelope dimensions are usually restrictive and clearance for breech mechanism components during actuation, loading, ejection, and recoil must be considered. Particular attention must be given to the relationship of the equipment and the operating crew. Human factors involved with turret and breech design are discussed in par. 2-8.

2-20.3 LOADING

The loading of large caliber ammunition poses certain space problems. Again, these problems are considerably more severe in turret-mounted guns. Because of the restricted space in the turret, the breech mechanism must be designed so that the main armament round can be loaded in the minimum space. In most tank applications, this entails the ability to load through the range from +20 deg elevation to −10 deg depression. The breech designer should be aware of the problems of handling ammunition in a cramped turret. Applications may arise where the designer will be involved with load assist devices, e.g., loading trays and ramming troughs, and possibly automatic loaders. The loader has the highest work rate of any crew member in a vehicle fighting compartment, and is, therefore, the one most likely to be affected by the existing spatial and environmental conditions (Ref. 70). His tasks consist of loading the weapon and otherwise assisting gun operations. Ideally, loading clearances, ammunition handling areas, and stowage spaces should accommodate the 5th to 95th percentile loader (see par. 2-22.1 for anthropometric considerations).

In artillery applications a generally greater space availability is reflected in the loading task. Clearances present a problem only at the higher quadrant angles, but that firing mode is a substantial part of weapon employment. For smaller sized weapons—e.g., the 105 mm howitzer—ammunition type, size, and breech space allotment permit loading up to the design limit of elevation. As caliber is increased, both ammunition and weapon factors tend to work against high elevation loading. Projectile size and weight require the use of manual or externally powered assist devices; ammunition type necessitates ramming of the projectile and separate loading of bagged propellant. A prominent example of an externally powered loader rammer is the device used with the 175 mm Gun M113A1/8 in. Howitzer, M2A2, self-propelled weapon system (Fig. 1-1). This hydraulically operated mechanism typifies the requirements for loading the larger size weapons and also the problems encountered therein; the device is detailed in Ref. 64. Weapon configuration for such calibers does not permit loading at higher elevations although this would be a desirable feature. Actually, the breech-loader interface is the specific problem area involving both space constraints and the need to keep actuating devices simple.

Accordingly, the loading procedure calls for the gun tube to be first set at a low elevation which brings the breech recess and ramming trough into alignment. A projectile is then rammed into its seat in the chamber; separate insertion of the bagged propellant, closing of the breechblock, and insertion of the primer cartridge complete the loading process. At this point, the tube can be elevated to the desired firing position—proper ramming develops enough contact force between the projectile rotating

Downloaded from http://www.everyspec.com

band and the start of tube rifling to prevent fall back in the raised position. The added design complexity of accommodating all gun elevations and the likelihood of having to vary the ramming force have not been justified for the current generation of loading mechanisms.

2-20.4 EJECTION

The space problems of ejection are minor relative to those of ammunition loading. With separate-loading ammunition there are no cartridge cases, and primer cartridge ejection does not create a space problem. The metal cases for the smaller caliber ammunition present problems only at high quadrant elevations. If the extracting mechanism does not produce full ejection at extreme gun elevations, time and manpower are required to remove the spent cartridge.

In tanks, the crew is stationed in proximity to the breech. The extractor device must be designed to deflect the spent cases downward, rather than sideways or upward, to protect the crew. Ejection velocity must be controlled to prevent case rebound into the breech ring or other devices (Ref. 70). The development of consumable case rounds eliminates the case ejection problems.

2-20.5 RECOIL

The recoil length of a weapon imposes definite space requirements on the breech mechanism. The breech designer must confine devices and components in a dimensional envelope that is compatible with the recoil distance.

In turret emplacements, the breech mechanism must clear the full recoil distance of the gun through the entire quadrant and range from maximum elevation to depression (Fig. 2-37). It will not be possible to use auxiliary procedures for clearance at the extreme tube positions. Because of turret space limitation and the increased vehicle mass aiding stability, recoil systems for self-propelled weapon systems are designed for shorter strokes (Tables 1-1 and 1-2). In some towed field weapons, breech clearance cannot be met by design alone. After the piece is fully emplaced and elevated, a recoil pit must be dug to ensure proper breech clearance including the limits of traverse (Ref. 71). A pit covering is needed for efficient operation of the piece when not engaged in high angle fire.

2-21 DYNAMIC LOADING

The projectile is accelerated by the force exerted on its base by the pressure generated by the burning propellant. To this force, there must be an equal and opposite force exerted against the breech of the weapon. This reaction force causes stresses to which the gun mount, breech, recoil mechanism, and cam actuating mechanism are subjected. The gun design must provide for absorption of these stresses, which in large weapons becomes a major problem. The internal pressure in the chamber applies an axial force on the breechblock and a radial force to the chamber walls. Whether the breech is the threaded- or sliding-wedge type, a combination of radial displacement of the chamber wall and high axial force can cause serious structural damage or gas leakage if not designed for. Inertial loads applied during the recoil cycle also act in the axial direction. This should be considered in any analysis of stresses on the threaded members of the breech. Recoil dynamics has been rigorously covered in the literature (Refs. 72 and 73).

2-21.1 PRESSURE

When a charge is ignited, gases develop from the surfaces of each propellant grain and the pressure in the chamber rises rapidly. Because of friction and resistance of the rotating band (shot start), the projectile does not move until the pressure behind it reaches from several hundred to a few thousand pounds per square inch. After motion starts, the pressure continues to rise until (1) the burning area ceases to increase, and (2) the volume of the chamber and breech behind the projection reaches the point where the rates of gas generation and volume increase behind the projectile are equal. The projectile accelerates provided there is a net force acting upon it. When

Downloaded from http://www.everyspec.com

the projectile reaches the muzzle, the pressure inside the tube has fallen to about a tenth to a fifth of the maximum pressure—depending upon the expansion ratio of the cannon.

Interior ballistics include combustion mode of the powder, pressure developed, velocity of the projectile along the bore, and the calculation of the dimensions of chamber volume for the powder which, for any particular design of gun and projectile, will give the required muzzle velocity while not exceeding the permissible interior pressure. The powder-pressure curve is used to determine the gun and breech wall thickness needed to withstand expected pressures.

The greatest interior pressure that a gun may withstand without exceeding the elastic limit of the metal is known as the "elastic strength pressure" which varies along the bore. An allowance is made for safety and a curve of "permissible pressure" is established which must not be exceeded (Ref. 74). In practice, actual pressures generally lie below this curve. Fig. 2-38 shows these relationships.

Seal and obturator design is of great importance to assure that the breech will be protected from the erosive action of the high-velocity, high-temperature gases developed in the bore under high pressures. If any passage in the breech is open to the gases, they are forced through it. The threads and other parts of the breech mechanism subject to this gas action are eroded, channeled, and worn away to such an extent that the breech mechanism is soon ruined and the gun is rendered useless.

2-21.2 FORCE

The stresses to which a gun carriage is subjected are caused by the action of the powder gases. Since the powder gas pressure is transmitted equally in all directions, the force tending to move the gun to the rear is very large—amounting to several million pounds in the major caliber weapons. If the gun were rigidly mounted, without any recoil system, it would be impossible to build a carriage strong enough to withstand the stresses without rupturing or overturning.

To reduce the carriage stresses to a reasonable value and to ensure stability, a recoil system is interposed betweeen the gun and the carriage. The recoil system absorbs the energy of the recoiling parts over a certain convenient length, returning the gun into position for further firing. The recoiling parts are the gun and those parts of the recoil mechanism and carriage which move in recoil and counterrecoil with the gun.

The higher the resistance offered by the recoil brake(s), the shorter will be the total length of recoil. The system is usually designed so that throughout recoil the resistance offered will be approximately the same at each instant; however, the resistance may be variable. Since the work performed in each case is the same, the value of the constant total resistance will be less than the maximum value of a varying total resistance. Accordingly, for a given length of recoil, the constant total resistance will produce less strain in the carriage.

The permissible length of recoil is often limited by the dimensions of the carriage, maximum angle of elevation, or other considerations. The path of recoil must then be limited by applying sufficient resistance by the brake to absorb the energy of recoil over that distance.

The breech designer must provide for attachment of the recoil mechanism to the breech, and design breech operating mechanisms that are compatible with the allowable recoil distance and vehicle envelope. Counterrecoil forces are often used to activate automatic features of the breech operational cycle.

Typical curves showing recoil travel velocity and pressure as functions of time are given in Fig. 2-39.

2-21.3 TEMPERATURE

In the brief period of propellant burning and projectile ejection, the high temperature of the accumulating gases can transmit heat into the bore more rapidly than it can be dissipated.

Downloaded from http://www.everyspec.com

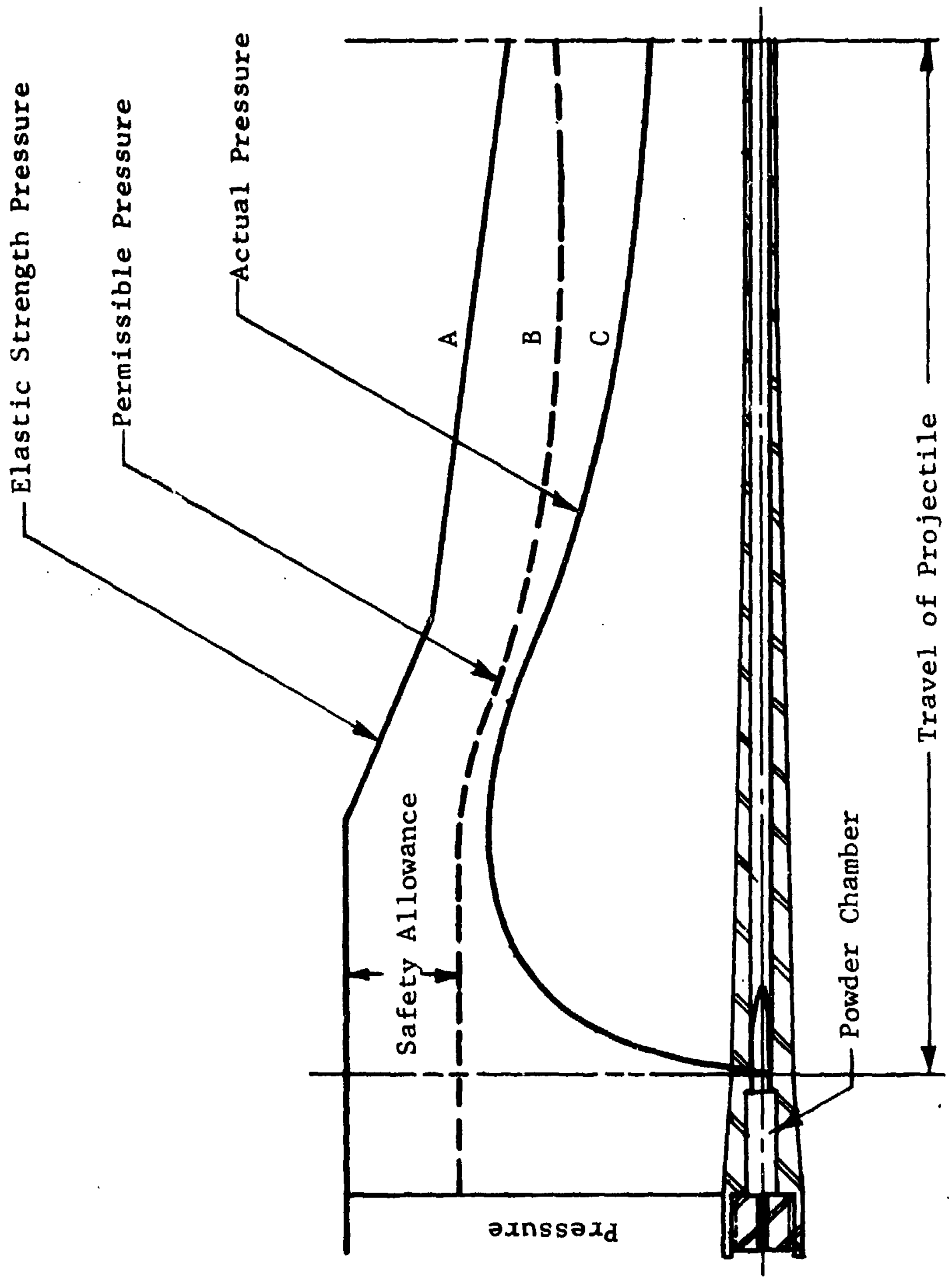


Figure 2-38. Elastic Strength Curve Compared to Actual and Permissible Pressures (Ref. 74)

Downloaded from http://www.everyspec.com

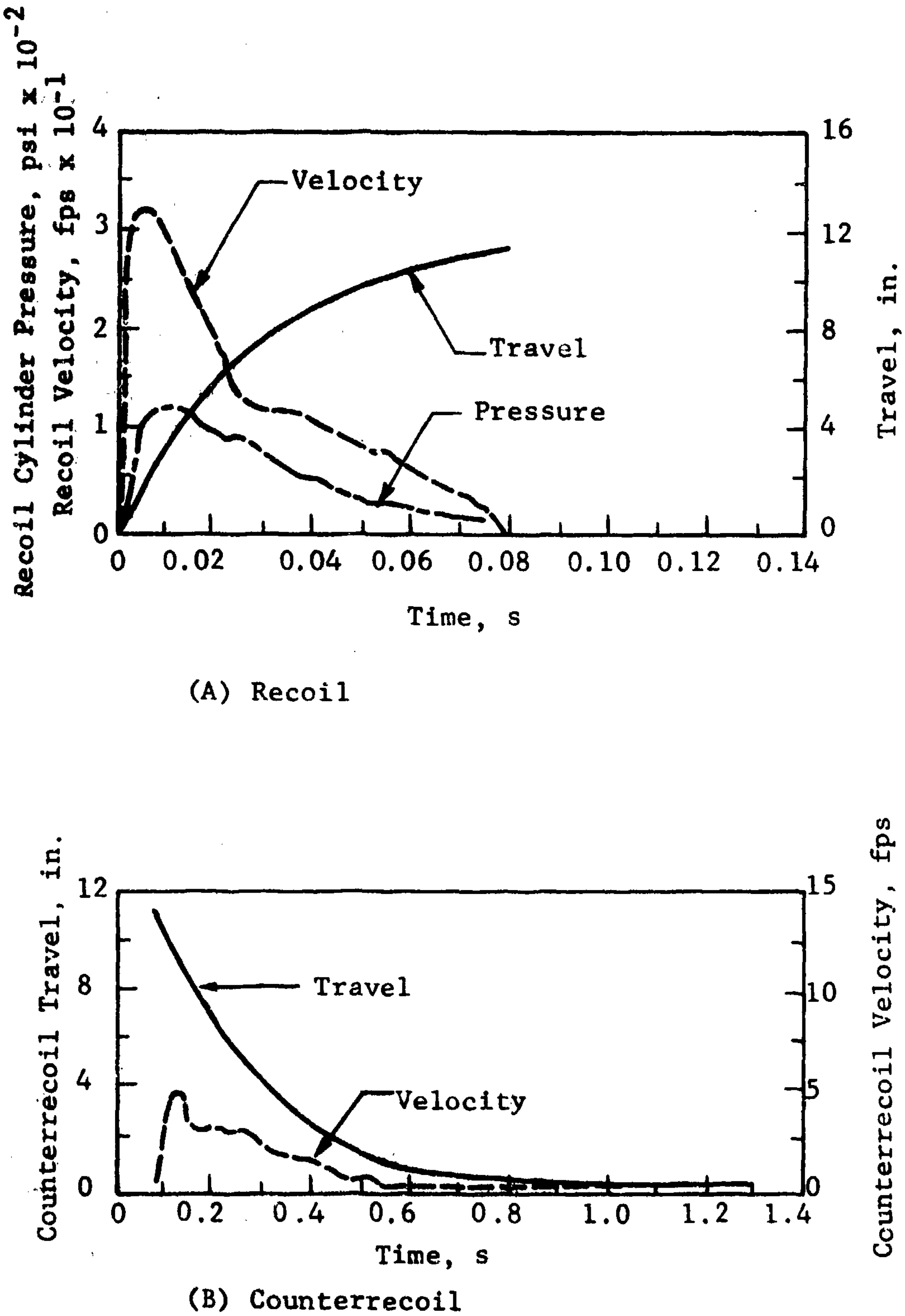


Figure 2-39. Typical Recoil Travel, Velocity—Pressure Versus Time

Downloaded from http://www.everyspec.com

There is danger of overheating of the inner surface metal and consequent flaking of eroded metal particles. If firing is repeated before the surface metal has cooled sufficiently to regain normal strength and wear resistance, the weakened metal will be subject to wear by the second projectile, the firing stresses, and an additional increase in temperature.

In general. thermal load is not considered a factor in breech design of large caliber weapons (Ref. 75). Large bore diameters facilitate heat loss and the greater barrel thicknesses provide more heat-absorbing metal per unit of bore surface. As weapon requirements are tending toward higher firing rates and lighter weights, thermal loading may become a more significant breech design consideration.

2-22 MAN/MACHINE RELATIONSHIPS

The relationship of the crew and breech mechanism during operation and maintenance is of great importance. A number of factors that will increase the effectiveness of this relationship must be considered in designing the breech mechanism, i.e.:

1. To make sure equipment is properly used, it must be designed for a specific user population. This constraint upon design is an obvious, although perhaps unconscious, primary consideration of the designer.

2. Designers must design for men who will, in tactical situations, be under conditions of stress and fatigue from many causes. In the tactical situation, there may be a performance decrement that is not caused by any basic inability of the troops to perform but by the fact that the individual soldier is overloaded both physically and mentally.

3. Equipment must be designed to be as simple as possible to operate, and it should not require intellectual data transformation where personnel may be distracted. Equipment should also be kept simple to meet requirements for reliability and maintainability.

2-22.1 HUMAN ENGINEERING

Human engineering is that area of human factors that applies scientific knowledge of human characteristics to the design of items to achieve effective man-machine integration and utilization (Ref. 76). The capabilities and limitations of the men who serve as crew members are the baseline for weapon system design. The official Army selection procedures are found in AR 611-201 (Ref. 77) and AR 600-200 (Ref. 78). We will consider some of the aspects of breech design in which human capability plays an important role.

Manual or semiautomatic breech operation modes require that certain functions be performed by the operator. The following human engineering related factors, extracted from Ref. 79, should be considered in their design:

1. Handles, levers, pedals, knobs, wheels, and toggle switches should be designed so that personnel from the 5th through 95th percentile, wearing Arctic clothing can operate them effectively.

2. All controls should be designed, oriented, and located in accordance with normal work-habit patterns, customary reaction, and human reflexes.

3. Stereotyped relationships between controls and displays should be observed to take advantage of crew members' previous learning, maximize transfer of training, and minimize error. For example, the conventional directions for various movements listed in Table 2-3 should be recognized.

4. The direction of movement of the control should be consistent with the movement of the controlled object.

5. The most frequently used hand controls should be placed between elbow and shoulder height. Where "blind" reaching is required, the control should be located forward and slightly below shoulder height.

Downloaded from http://www.everyspec.com

TABLE 2-3
CONVENTIONAL CONTROL MOVEMENTS (REF. 79)

Function	Direction of Movement
On	Up, right, forward, clockwise, pull (push-pull type switch)
Off	Down, left, rearward, counterclockwise, push
Right	Clockwise, right
Left	Counterclockwise, left
Raise	Up, back
Lower	Down, forward
Retract	Up, rearward, pull
Extend	Down, forward, push
Increase	Forward, up, right, clockwise
Decrease	Rearward, down, left, counterclockwise
Open Valve	Counterclockwise
Close Valve	Clockwise

6. The use of one control should not interfere with the use of another control unless they are purposely interlocked in sequence. This is particularly important since the sighting and fire control functions may be performed in the areas occupied by the loader and breech operator. Serious interference problems, affecting overall performance and rate of fire, could result.

7. Controls should be designed so they will neither cause injury nor entangle clothing or equipment.

8. Controls should be designed and located so that they cannot be put into operation accidentally.

9. Controls should be identifiable by feel for operation in darkness. This can be done by varying shape and finishes.

10. Precautions should be taken to avoid the accidental release of stored mechanical energy (for example, the energy stored in an automatic closing breechblock is sufficient to severly injure a hand).

11. When possible, loading procedures should be reversible for efficient and safe round removal.

12. The breechblock should be capable of being exercised without damage to the system or danger of injury to crew members.

13. The controls for power operated breeches should be located away from the breech to protect crew members when the breech is in operation.

14. When manual removal is required, the weights of the breech components should not exceed 30 lb.

15. For manual breech operation, the force required should not exceed 30 lb for one-handed operation and 50 lb for two-handed operation.

16. The 5th to 95th percentile crew member should be able to disassemble the breech for cleaning.

Downloaded from http://www.everyspec.com

17. Case ejection should not endanger personnel or equipment.

18. The breech should be designed to provide drains to preclude the trapping of cleaning fluids and water.

The Army Human Engineering Laboratories have compiled a large body of data on all aspects of human factors, both physical and psychological. This information should be studied by the breech mechanism designer (see biographical listings).

2-22.2 OPERATING EFFORTS AND RANGE OF MOTION

The maximum amount of force or resistance that can be designed into a control should be determined by the greatest amount of force that can be exerted by the weakest person likely to operate it. The maximum force that can be applied will depend on such factors as the type of control, the body member being used to operate the control, the position of this member during operation, the general position of the body, and whether or not support (e.g., back rests) is provided.

Maintenance requirements become more complicated when special tools and lifting equipment are required. Whenever possible, equipment should be designed to be lifted by one man. Two men may be required to perform certain lifting tasks, e.g., removing the breechblock of a 155 mm weapon, but this is not normally desirable. Leg muscles, rather than arm or back muscles, should accomplish heavy lifting. The approximate safe lifting capacity of one man is shown in Fig. 2-40. These values should be reduced considerably under the following conditions:

1. When the object is very difficult to handle; e.g., bulky, slippery
2. When access and work space are less than optimum
3. When the force required must be continuously exerted for more than 1 min
4. When the object must be finely positioned or delicately handled
5. When the task must be repeated frequently, e.g., many times on a given day.

The forces that can be exerted by 95% of the male personnel are listed in Fig. 2-41 in terms of the direction of movement and the body member used.

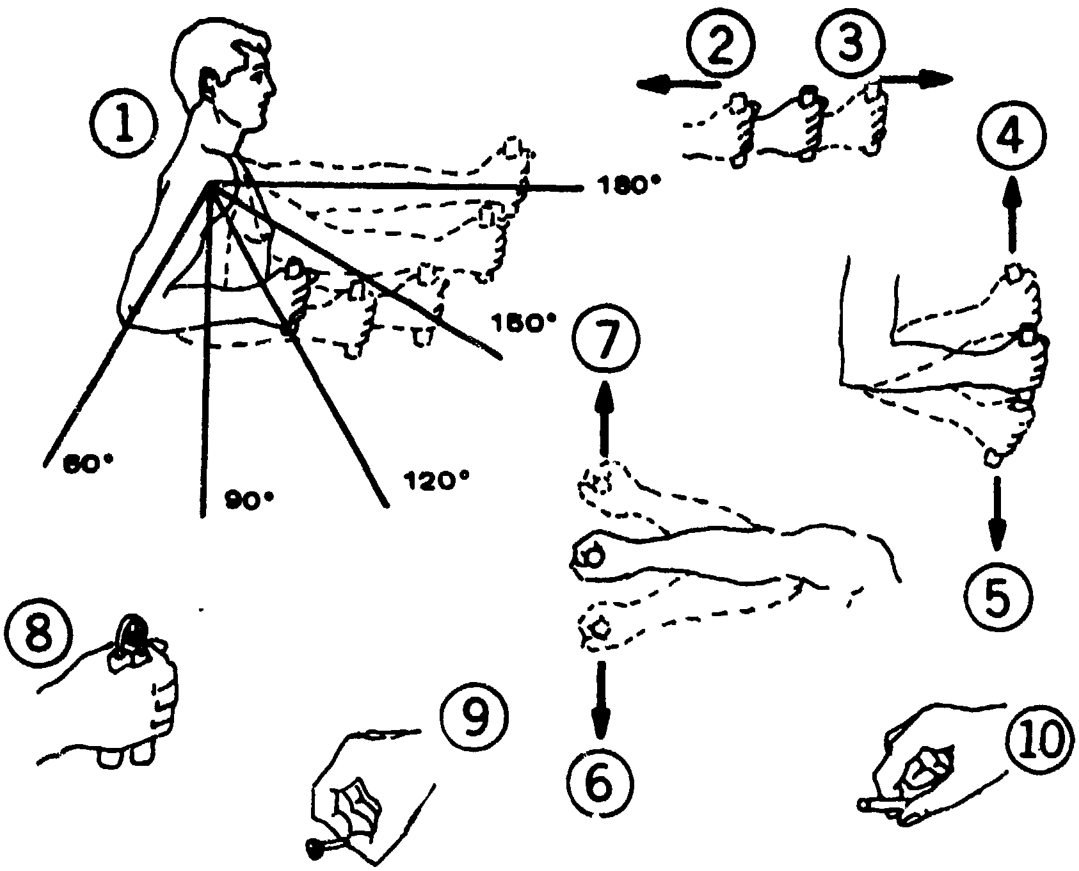
All operating positions should allow freedom to move the trunk of the body. When large forces (in excess of 30 lb) or large control displacements (in excess of 15 in. in a fore-aft direction) are required, the operator should be provided with sufficient space to move his entire body. Table 2-4 shows the ranges for each type of voluntary movement possible at the joints. The designer must keep in mind that these ranges are for nude persons, and thus, do not allow for the restrictions imposed by clothing. If the range of voluntary movement is used as a direct function in operating or maintaining the equipment, the maximum allowable angular value should be the lower-limit value. This allows 90% of the population, i.e., 1.3 standard deviations below the mean value, to perform the voluntary movement. If the range of voluntary movement is used to design for body freedom of movement, then the upper-limit angle should be used.

2-23 SAFETY

Safety for both the crew and the weapon are necessary. Requirements for safety in military combat situations are not comparable to those for industrial safety, but nevertheless they exist. Since the operating crew of a gun works in close proximity to the equipment during all of the operations, its members must be protected from injury so they can continue to perform their work. The use of safety interlocks, guards, and the careful placement of parts and mechanisms reduce the possibility of accidents or injuries. However, design safety must be accomplished without adverse results on weapon effectiveness or operation. Prevention of equipment breakdown is also a protection for the personnel in a combat situation.

Locking devices are also needed to prevent unintentional firing and to keep breech operation in

Downloaded from http://www.everyspec.com



ARM STRENGTH (POUNDS) FOR SITTING MAN

1 ELBOW FLEXION	2 PULL R	PULL L	3 PUSH R	PUSH L	4 UP R	UP L	5 DOWN R	DOWN L	6 IN R	IN L	7 OUT R	OUT L
180°	52	50	50	42	14	9	17	13	20	13	14	8
150°	56	42	42	30	18	15	20	18	20	15	15	8
120°	42	34	36	26	24	17	26	21	22	20	15	10
90°	37	32	36	22	20	17	26	21	18	16	16	10
60°	24	26	34	22	20	15	20	18	20	17	17	12

HAND AND THUMB-FINGER STRENGTH (POUNDS)

HOLDING TIME	8 HAND GRIP RIGHT	HAND GRIP LEFT	9 THUMB-FINGER GRIP (PALMAR)	10 THUMB-FINGER GRIP (TIPS)
MOMENTARY HOLD	59	56	13	13
SUSTAINED HOLD	35	33	8	8

Figure 2-40. Arm, Hand, and Thumb-Finger Strength (Pounds) (5th Percentile Male) (Ref. 80)

Downloaded from http://www.everyspec.com

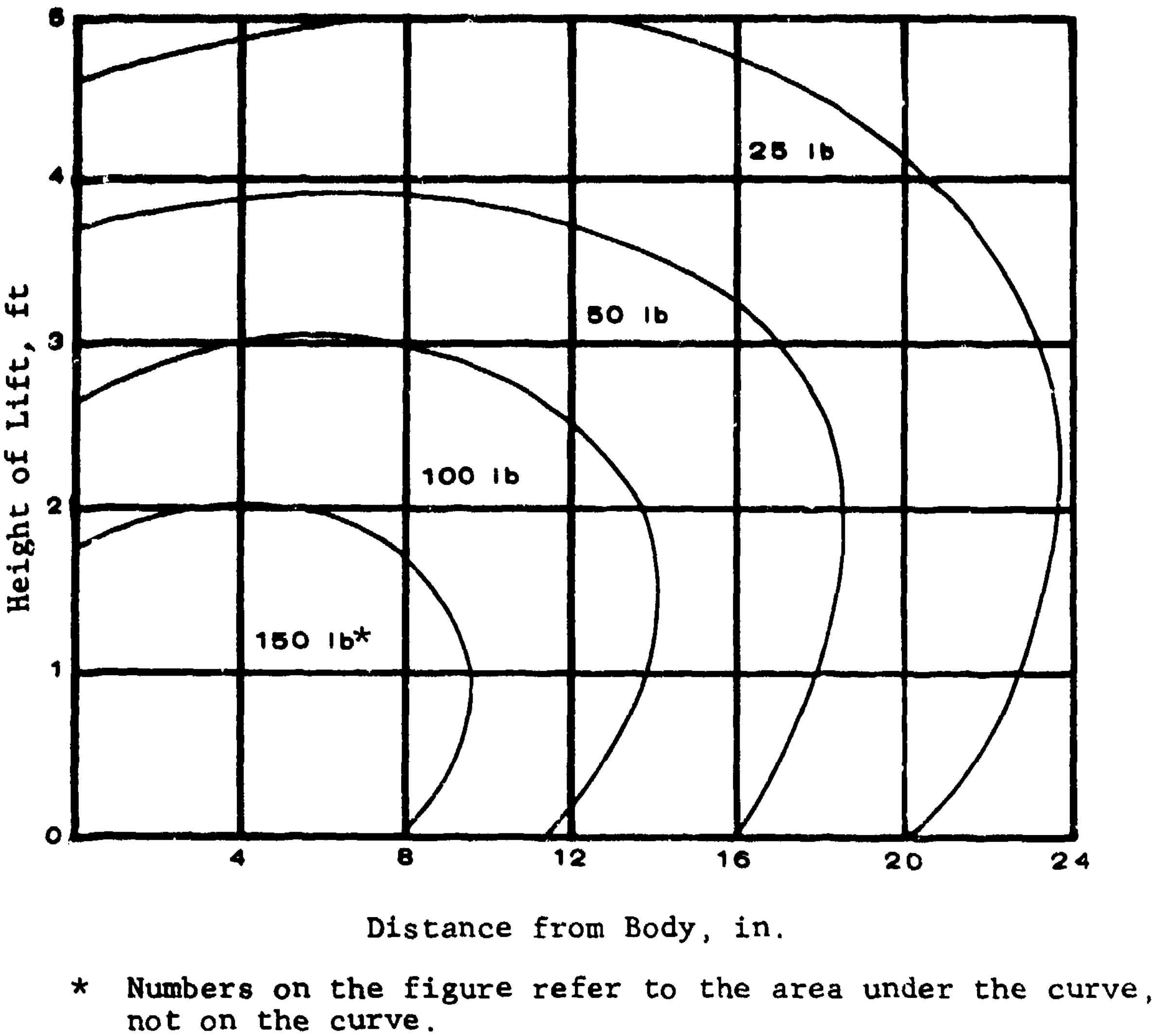


Figure 2-41. Manual Lifting Capacity: Lifting Forces That Can Be Exerted by 95% of Personnel, Using Both Hands (Ref. 79)

the proper sequence. The latter is especially important for controlling functions of a semiautomatic breech. Breech mechanism safety devices are treated at length in par. 1-6.4. Ref. 81 outlines the requirements of a safety program for military equipment development.

2-23.1 SAFETY PROGRAM

System safety programs are now required in all military system design and development programs. Although such guidelines are necessarily general, several specific safety criteria apply directly to breech design. Specific requirements for system safety programs are detailed in MIL-STD 882 (Ref. 81.) These considerations include:

1. Controlling and minimizing hazards to personnel, equipment, and material that cannot be avoided or eliminated
2. Incorporating "fail-safe" principles where failures would disable the system or cause serious injury to personnel, damage to equipment, or inadvertent operation of critical equipment
3. Locating equipment components so personnel will not be exposed to such hazards as electrical shock, sharp cutting edges, sharp points,

Downloaded from http://www.everyspec.com

TABLE 2-4 RANGE OF HUMAN MOTION (REF. 79)

Body Member	Movement	Lower Limit, deg	Upper Limit, deg	Average, deg
A Wrist	1. Flexion	74	102	90
	2. Extension	82	112	99
	3. Abduction	15	36	27
	4. Adduction	38	54	47
B. Forearm	1. Supination	84	135	113
	2. Pronation	46	101	77
C. Elbow	1. Flexion	129	152	142
D. Shoulder	1. Lateral Rotation	17	47	34
	2. Medial Rotation	68	119	97
	3. Flexion	172	200	188
	4. Extension	43	75	61
	5. Adduction	36	57	48
	6. Abduction	112	151	134

Definitions: Flexion: Bending, or decreasing the angle between parts of the body.
Extension: Straightening, or increasing the angle between parts of the body.
Adduction: Moving toward the midline of the body.
Abduction: Moving away from the midline of the body.
Medial Rotation: Turning toward the midplane of the body.
Lateral Rotation: Turning away from the midplane of the body.
Pronation: Rotating the palm of the hand downward.
Supination: Rotating the palm of the hand upward.

and toxic atmospheres during operation, maintenance, repair, or adjustment

4. Providing suitable warning and caution notes in operation, assembly, maintenance, and repair instructions. Hazardous components, equipment, and facilities should be marked distinctively for personnel protection

5. Minimizing damage or injury to personnel and equipment in the event of an accident.

Several safety features are included in the design of breech mechanisms. All are closely related to the operating cycle of the weapon and the hazards to the men interacting with the system.

Safety latches are included on most screw-type breeches. These make it necessary to remove the firing lock or open the firing mechanism before opening the breech. Safety latches prevent the inadvertent firing of the primer while the breechblock is open.

The chamber must be inspected for debris such as fragments of bags before the insertion of each round of ammunition. Visible accessibility is required when the breech is opened.

Loading the round during semiautomatic operation requires quick reactions by the loader to ensure that the automatic closing action of the breech does not injure personnel (e.g., catch fingers). The stored energy in the breech and extractor is a potential hazard. The designer must consider these factors when specifying spring strength and closing times. It may be possible to incorporate equipment guards during particularly hazardous operation.

To an appreciable degree, interlocks and linkages prevent firing while out of battery. The

Downloaded from http://www.everyspec.com

inability of a gun to return to battery is an indication of a fault in the recoil mechanism or an interference with the gun movement.

2-23.2 MALFUNCTIONS

The prevention of malfunction is considered in detail in par. 3-15. Even the best designed breech will malfunction through no fault of the breech or firing mechanism design. The breech also must be designed to facilitate extraction of misfired rounds. It is critical that the designer be aware of the procedures used when malfunctions occur and that he design the equipment to accommodate the safe removal of misfired rounds. Figs. 2-42 to 2-44 outline possible malfunction conditions and the appropriate actions to be followed in the various contingencies.

2-24 CLIMATIC ENVIRONMENT

Sand, dust, heat, humidity, ice, snow, rain, and exposure to salt water are climatic factors that effect the breech. It is important to recognize and evaluate the effects such factors will have and how these effects can be controlled.

AR 70-38, Ref. 82, recognizes four broad types of climate subdivided into eight categories:

Climatic Type	Climatic Category
A. Hot-dry	1. Hot-dry
	2. Wet-warm
B. Hot-wet	3. Wet-hot
	4. Humid-hot Coastal Desert
C. Intermediate	5. Intermediate Hot-dry
	6. Intermediate Cold
D. Cold	7. Cold
	8. Extreme Cold

AR-70-38 requires the material developed to be capable of acceptable performance throughout the ambient range of +110° to −25°F with no aids or assistance other than standard accessories, and +125° to −65°F with specialized aids in kit form.

The natural and induced environments are important to the military because of their effects on men, material, and operations. Principal effects and types of failures induced by various environmental factors are suggested in Table 2-5. These factors are of primary importance to the breech designer. Also listed in Table 2-5 are typical criteria for the transport phase of weapon operational life. As is often the case, the transport of equipment induces a more severe environment on the weapon than its operational environment.

There are many sources from which an environmental engineer can obtain reliable data concerning the environment or environmental factors to which equipment will be subjected, for example, Refs. 82, 83, 84, and 85. These data are to be found frequently in military regulations, standards, and specifications. It is not unusual, however, for the designer to feel that none of the specific environmental parameters is suitable for his needs.

The designer must be aware of the needs of the end item user and of the complete environment which his item will face from "stockpile to target". He may often prepare an environmental envelope for his item of materiel, examples of which are shown in Table 2-5.

2-25 RELIABILITY, AVAILABILITY, MAINTAINABILITY, AND DURABILITY (RAM-D)

Weapon design has always considered, implicitly, these four characteristics to be important. However, they have been recently reemphasized; and these categories now form an integral part of design requirements set forth for a given piece of materiel.

Each category is distinct from the others. Reliability is a probabilistic quality and relates to functional aspects of breech systems. Availability refers to the concept of whether an item will be ready (available) when it is needed. Maintainability refers to the concept of being able easily to

Downloaded from http://www.everyspec.com

MISFIRE UNDER POSSIBLE COOK-OFF CONDITION

Round retained in gun and breech completely closed

Cool barrel and breech with water for 5 min

Follow procedure for respective ordinary misfire

Round jams, breech does not close, or round retained in gun where breech closure cannot be instantly ascertained

Place all personnel within following danger zone under adequate cover

Guns	Inert	HE
Up to 75 mm incl.	200 yd	400 yd
Over 75 mm to 105 mm incl.	300 yd	600 yd

For Aircool Period of Gun

Aircool guns for 30 min

Follow procedure for respective ordinary misfire

Figure 2-42. Procedure for Dealing With Misfire Under Possible Cook-Off Conditions (Rock Island Arsenal)

Downloaded from http://www.everyspec.com

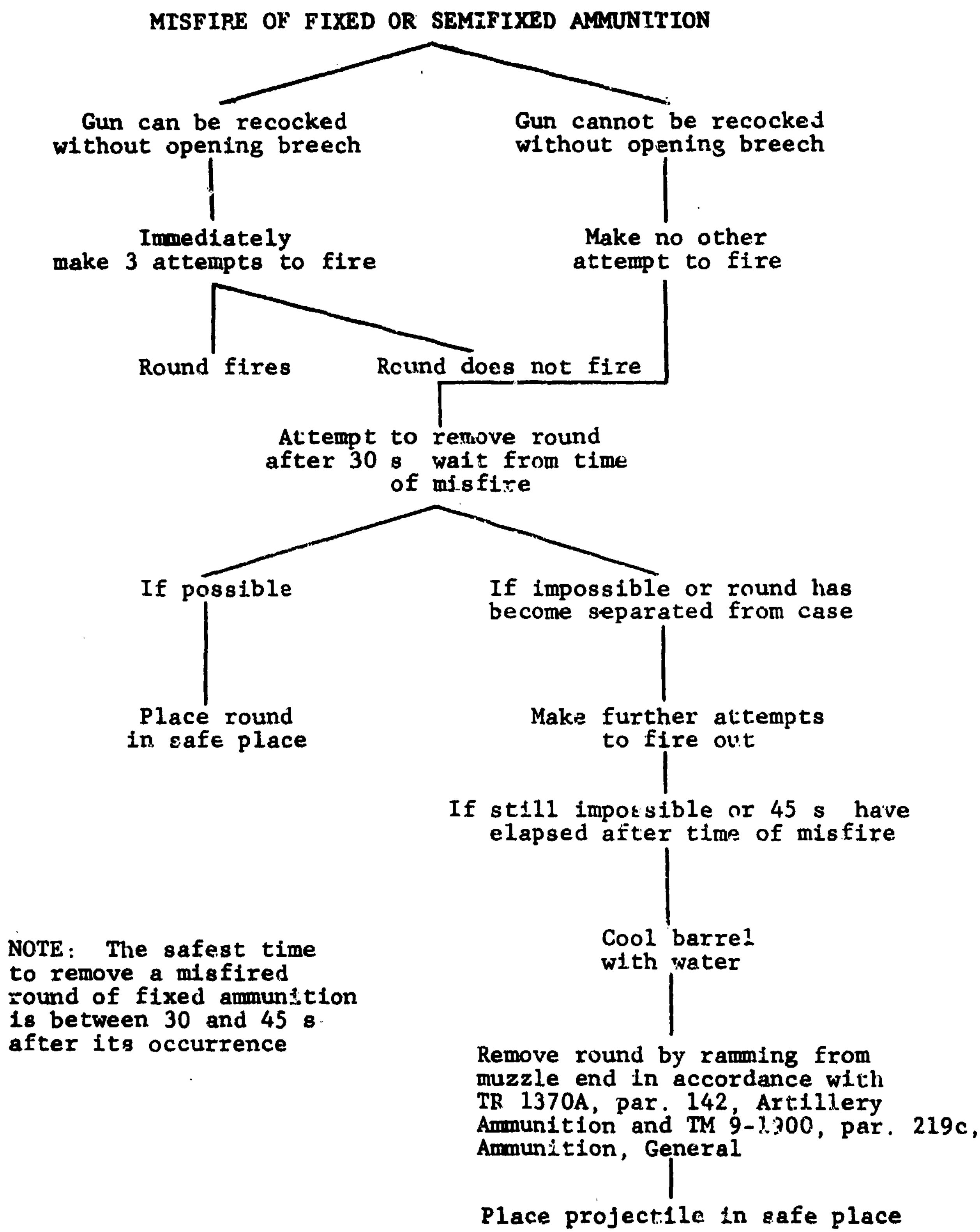


Figure 2-43. Procedure for Dealing With Misfire of Fixed or Semifixed Ammunition (Rock Island Arsenal)

Downloaded from http://www.everyspec.com

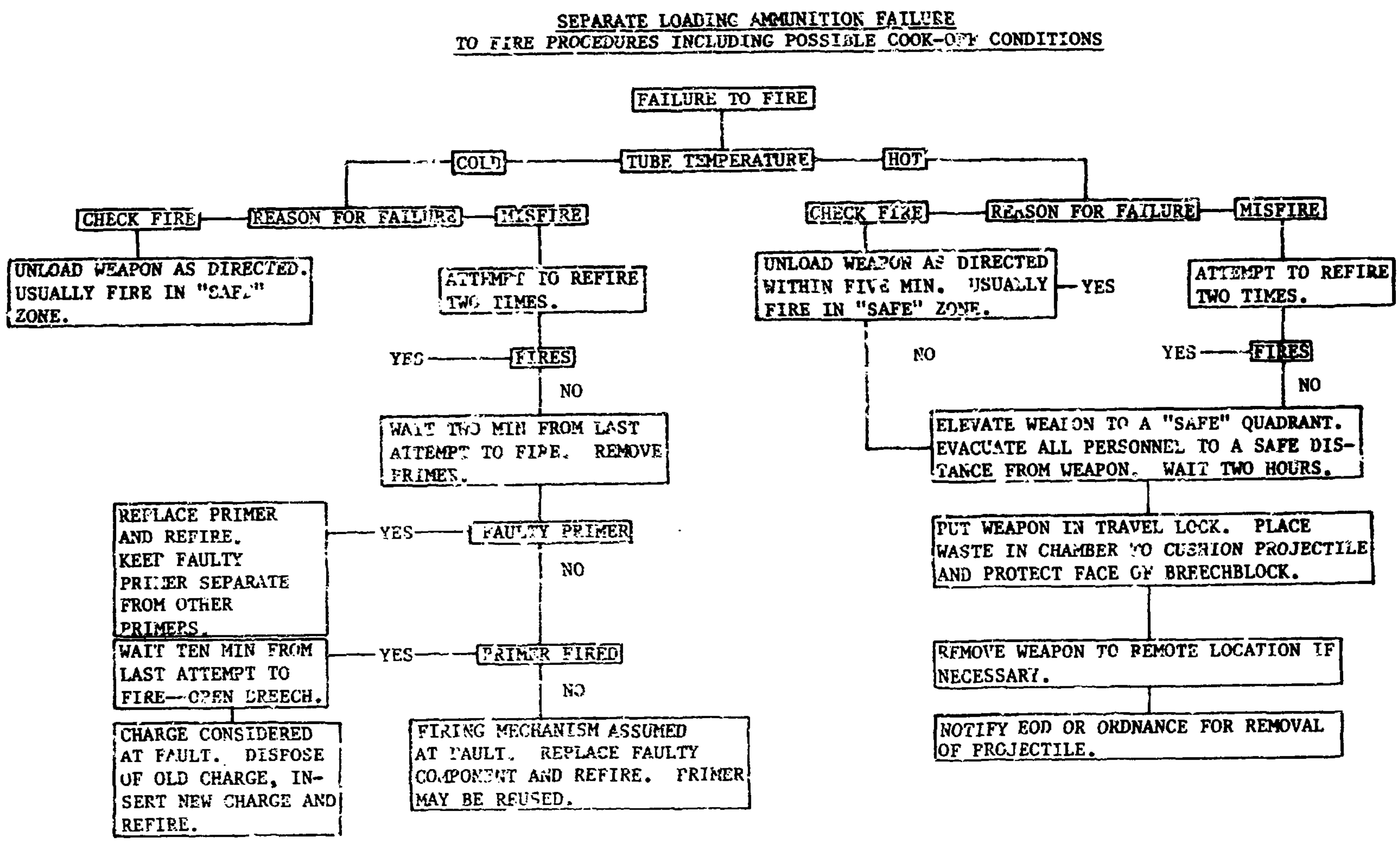


Figure 2-44. Procedure for Dealing With Misfire of Separate-Loading Ammunition (Rock Island Arsenal)

Downloaded from http://www.everyspec.com

TABLE 2-5
EFFECTS OF ENVIRONMENTAL FACTORS ON BREECH MATERIALS

Factor	Principal Effect	Criteria for Transportability	Type Failure Induced
High temperature	Viscosity reduction and evaporation Physical expansion	120°F for 3 h	Loss of lubrication properties Structural failure Increased mechanical stress Increased wear on moving parts
Low temperature	Increased viscosity viscosity and solidification Embrittlement Physical contraction	−10°F for 36 h	Loss of lubrication properties Cracking, fracture Structural failure Increased wear on moving parts
High relative humidity	Swelling, rupture Physical breakdown Loss of mechanical strength	100% at −10°F 95% at 95°F 45% at 120°F	Corrosion
Low relative humidity	Loss of mechanical strength Structural collapse		Embrittlement Compression
Sand and dust	Abrasion Clogging	45 kt wind 0.001-0.062 in. diam particles	Increased wear Interference with function
Wind	Force application Deposition of materials Heat loss (low velocity) Heat gain (high velocity)		Structural collapse Interference with function Loss of mechanical strength Mechanical interference and clogging Abrasion accelerated Acceleration of low-temperature effects Acceleration of high-temperature effects
Rain	Physical stress Water absorption and immersion Erosion	2 in./h for 1 h	Structural collapse Increase in weight Partial heat removal Electrical failure Structural weakening
Blowing snow	Corrosion Abrasion Clogging	1 in./h 2 in. buildup	Removal of protective coatings Structural weakening Surface deterioration Enhancement of chemical reactions Increased wear Interference with function
Shock	Mechanical stress	3.5 g for 25-50 ms Half-sine wave	Structural collapse
Vibration	Mechanical stress Fatigue	± 1 g at 1-60 Hz	Loss of mechanical strength Interference with function Increased wear Structural collapse

Downloaded from http://www.everyspec.com

maintain an item. It is distinguished from maintenance which is the physical act of maintaining an item. Durability generally refers to the concept of being usable (durable) for a long period of time until the item is not worth maintaining any longer; it is a special case of reliability—see par. 4-5.2 for further discussion.

2-25.1 RELIABILITY

Reliability is the probability that the breech performs all of its required functions under stated conditions for a stated period of time. The basic quantitative reliability indicator of a given device is considered to be the average mean time between trouble-free operation from the correction of one malfunction failure to the appearance of the next (MTBF). To a certain extent, operating reliability of a weapon depends upon its complexity. The more complex the design—and the more devices, assemblies, and mechanisms there are in it—the greater is the probability that failures will occur from time to time.

A high degree of reliability is of course very important in guns. Failure of a minor component can make an entire weapon inoperative under circumstances where neither time nor replacement parts is available to the crew in action. Of course, under ideal operating conditions, a stock of replacement parts is kept available; but even if this ideal is achieved, the facts still remain that there is an interruption in weapon availability, and time and labor are required to perform repairs. As practicable in design, reliability can be increased by the use of redundant or "back-up" components. For example, a manually operating device is provided to back up a breech operating in the semiautomatic mode in the event it fails.

Durability, of course, is important in order to justify the total investment. As mentioned in par. 2-17, the military environment is harsh and is particularly demanding for a breech. In contrast with some other weapon operations (adjustment of traverse, adjustment of elevation, etc.), the breech has to operate each time a round of ammunition is fired. Under these conditions, the equipment must be designed to last a reasonable length of time.

Reliability is enhanced by good design practice and by cognizance of maintenance requirements. As presented in par. 2-25.2, design for maintainability and the establishment of realistic maintenance schedules will maintain the reliability of the breech mechanism. Proper parts division and the use of easily accessible wear inserts are examples of maintainability design features which, under a proper inspection and maintenance schedule, can maintain the reliability, designed into the breech mechanism.

2-25.2 MAINTAINABILITY

Maintainability is a characteristic of design and installation which is expressed as the probability that an item will be retained in or restored to a specified condition within a given period of time, when the maintenance is performed in accordance with prescribed procedures and resources. Accordingly, maintainability is controlled by the designer. Despite the best efforts of the logistic system, too often poorly designed equipment compounds the maintenance problem. Accordingly, a tenet for design engineers might be: "If we can't design equipment to last forever, let us at least design it so we can keep it going as long as possible, and so we can fix it in a hurry when we need to, with the men available and the tools available" (Ref. 86).

Maintenance enables the equipment to be restored and kept in operation with minimum effort. Repairs must be infrequent and procedures must be kept convenient, otherwise the weapon becomes impractical and its cost becomes too high for justification. If repairs take too long, the availability of the weapon is reduced. The goal, of course, is replaceable and easily accessible components. These subjects are treated further in Chapters 3 and 4.

Design engineers engaged in the development of weapon systems should be concerned with the following objectives:

1. Reducing the frequency of preventive (cyclic) maintenance: Reliability improvements

Downloaded from http://www.everyspec.com

will often save time and manpower by reducing the frequency of the preventive maintenance cycle. This also allows more operational time for the component concerned.

2. Improving maintainability to reduce downtime: Test and repair procedures must be simplified to reduce the time required to locate and correct faults by providing ease of access and simplification of adjustments and repair.

3. Reducing the requirements for highly trained specialists: This can be accomplished by simplifying the operation and equipment maintenance.

Factors that affect ease of maintenance include:

1. Simplicity
2. Accessibility
3. Interchangeability.

Simplification, although the most difficult criterion of any design, is the most productive. Simplification can transform a complex monstrosity into a piece of working equipment. The essential functions of the equipment should be incorporated into the design, using the minimum number of parts consistent with good design practice and use criteria. In addition to simplifying normal operation, preventive and corrective maintenance should be simplified whenever possible. Only reduction in downtime will increase the availability of a weapon system.

Inaccessibility is a prime maintenance problem. The mechanic (technician) will tend to delay or omit maintenance actions, make mistakes, and accidentally damage equipment he cannot adequately see, reach, and manipulate. The greater the number of accessory steps and the amount of discomfort involved, the more readily the technician/mechanic will perform other less demanding tasks. Periodic maintenance activities such as checks, adjustments, and troubleshooting in inaccessible locations may be unduly postponed or neglected entirely.

Rapid, easy replacement of critical parts under the pressures of combat situations is essential. The breech designer must give special attention to the working environment of the weapon system when designing such components as the firing pin assembly and the obturating ring.

Access is additionally complicated by the limited space in which to make repairs and the simple tools available to the crew. The designer must consider these limits and those imposed by personnel protective equipment such as Arctic gloves.

Where it is possible and practical without the degradation of performance or reduction of maintainability or reliability, equipment should be designed with the minimum number of sizes, types, and components or parts that must be replaced. Standard fasteners (nuts, bolts, retaining rings) should be used when possible. Parts requiring frequent servicing or replacement should be interchangeable with similar parts in other units. Like assemblies, subassemblies, and replaceable parts should be designed according to MIL, AN, or MS standards, where these are applicable. A more explanative treatment of maintainability is provided in AMCP 706-134 (Ref. 87).

2-26 PRODUCIBILITY

In simple terms, to make a design producible requires a comprehension of:

1. The specific end use of the equipment or mechanism

2. How to make if efficiently and economically.

The first item influences the selection of materials; while the second involves the choice of manufacturing processes.

With few exceptions, breech design must be practical in the light of manufacturing capability at the time of consideration. It is possible to design a breech and not be able to have it manufactured (i.e., not without a great deal of manufacturing research and development). Obviously, such a design does not meet the requirement "practical". Producibility considerations enter into examples of breech components cited in Section III of this chapter (e.g., extracting mechanisms, par. 2-13).

Downloaded from http://www.everyspec.com

Production processes yield the maximum economic effect when the design itself is efficient. This is achieved by minimizing the number of parts, simplifying their shapes, and prescribing only the precision and the finishing required by the conditions under which a device will operate. A most important point to be emphasized is that, if possible, a design should be adopted which is not limited to only one particular manufacturing method.

The designer must also be aware of the eventual constraints of his design—such as meeting production schedules, material procurement (possibly involving conservation of material), and production costs. A more comprehensive discussion of producibility takes place in Chapter 4, including coverage of production planning and standardization.

2-27 THREAD CONNECTIONS

Threaded connections occur frequently in breech mechanism design. They are particularly used to:

1. Fasten the gun tube to the breech ring.
2. Lock the breechblock to the ring.
3. Hold the firing mechanism assembly in the breechblock.

Interrupted threads are used on the breechblock and frequently are used on the gun tube to allow rapid barrel changes.

Interrupted threads in the simplest form are manufactured similarly to continuous complete threads, except that the mating surfaces are machined to remove half the threads around the circumference. The circumference is first divided into an even number of segments. The threads are removed in alternate segments, and the two surfaces are mated in their threaded and machined areas. Assembly is performed by bringing the threads of one surface through the machined segments of the other and then rotating one piece a fractional turn to obtain full engagement of the threaded areas. The amount of rotation is the reciprocal of the number of segments in each piece.

The pitch of the threads is such that under the force of the propellant pressure inside the chamber, friction will prevent the locked breechblock from rotating and opening except when it is unlocked and a force is exerted by the operating mechanism. The operating mechanism also prevents further rotation of the block when the breech is open, and maintains proper alignment between the threaded sectors. Clearance channels always are maintained as the block is inserted and removed from the recess. In addition to the machining operation just mentioned, suitable clearance cuts are made in both the breechblock and ring of the interrupted-screw thread to permit the block to move into and out of the chamber opening on its hinged mounting.

The advantages of the interrupted-screw breech are strength, more uniform distribution of the longitudinal stresses, and relative ease of obturation. Several variations of this type of threading exist, namely:

1. Single-cut threads (the simplest form)
2. Conical-taper threads (Bofors)
3. Stepped threads (Welin).

Information on their characteristics is provided in par. 1-6.1 and Fig. 1-7. With respect to the simplest form of interrupted-thread, it is recognized that the introduction of clearance channels necessitates an increased length of threaded engagement surface in order to restore the original strength value. This demand is alleviated somewhat by the techniques employed in the other two variations. The conical taper is an improvement, but it requires some retraction for the hinge action and there is more difficulty in fabrication. The stepped-thread principle enables a larger diameter and resultant shorter block for the same surface engagement as the single-cut. Since the stepped-thread design permits more than 50% of the breechblock surface to be used for thread engagement, the angle of turning for locking and unlocking is decreased.

The thread forms generally used for the threaded connections are acme, buttress, and square threads. The latter two are the most often used in small arms. The tooth profiles of these

Downloaded from http://www.everyspec.com

basic thread types are shown in Fig. 2-45(A). The maximum load on these threads is based on the maximum propellant gas pressure and the rear chamber area for separately loaded ammunition, and on the internal area of the base of the cartridge case for fixed ammunition.

Threads should never be used to align and position a component during assembly. Wear resulting from continued takedown and reassembly, and local failure at the entering end will advance the travel of the threaded joint at each tightening. Continued alignment and positioning can be assured by machining off the incomplete thread so that the two mating pieces mutually (Ref. 88) butt against finished surfaces, and by providing sleeve contact (Fig. 2-45(B)). The pressure and force acting on the breech were described in par. 2-21 and a sample analysis of a threaded connection is presented in par. 3-17.7.

Large caliber artillery are frequently designed using the thread profiles described in Table 2-6 and Fig. 2-46. These threads employ a 20-deg pressure angle on the face and have proved to be capable of extended life. Whenever possible, threads should be designed according to Refs. 89 and 90. Part I of this reference presents standards for the more common thread forms and Part II for acme, buttress, and square forms.

2-28 MATERIAL SELECTION

Material selection is an important aspect of the total design procedure. Par 1-8.3 introduced material selection and additional narration is provided by pars. 3-8 and 4-10.2. As indicated, material selection is a highly specialized process in many cases. The entire design team should participate jointly. The material specialist should not make the material selection by himself. The most cogent recommendations for material selection are that:

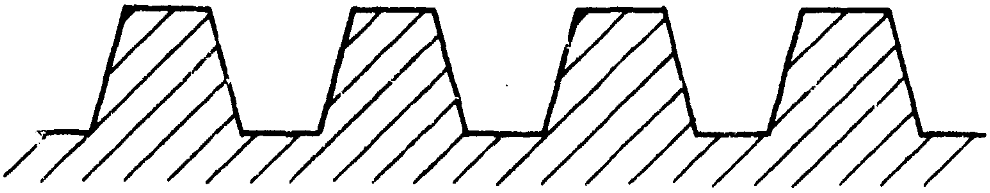
1. Material used in like parts in previous designs be screened carefully for applications in a new design.

2. The breech mechanism design staff at Watervliet Arsenal, Watervliet, NY, (or the responsible Army agency) be consulted in regard to material selection—especially for the critical components, e.g., breech ring and breechblock.

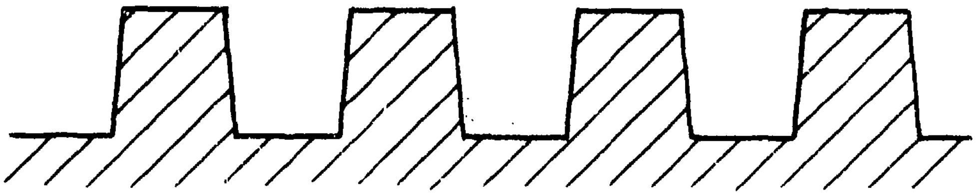
Each military weapon system is provided with a technical data package which includes a list of specifications. Table 2-7 presents such a list prepared for Cannon, 155 mm, Howitzer, XM199 (July 1976) (Ref. 91). It may be noted that of the 66 specifications listed, some 44 are directly related to materials (25), material inspection (7), and protective finish (12). Probably the greatest number of breech parts are covered by FED STD. No. 66, *Steel: Chemical Composition and Hardenability* (Ref. 92). MIL-R-10185, *Rings, Breech, Steel Forgings For* (Ref. 93) and MIL-S-500, *Steel, Chrome-Nickel-Molybdenum, Bars and Reforging Steel* (for the breechblock body) (Ref. 94) are also key steel specifications.

Materials are chosen for critical parts based upon having a high fracture temperature, good ductibility, and exhibiting ductile fractures. High strength, light weight, and long fatigue life are also very important characteristics. Breechblock bodies are fabricated from AISI E4340 steel per MIL-S-5000 (Ref. 94). Breech ring bodies are made from alloy steel per MIL-R-50185 (Ref. 93). Many of the smaller breech mechanism important parts are made from alloy steel per FED STD. No. 66 (Ref. 92). Extractors are made from steel 0.23 C (carbon) maximum (with protective finish type 1, phosphate, MIL-P-16232, (Ref. 95)). Cover plates are made similarly but with up to 0.34 C maximum. Levers, stops, and brackets are made with 0.38 to 0.53 C while cranks use a maximum of 0.50 C. C ranges in alloy steel from 0.28 to 0.50 are used for pins, shafts, and adjusters. Forged breech ring brackets are also made with this range of carbon. Parts with 0.5 in. thick sections and good allowance or those 1 in. thick with less allowance are specified with 0.28 C minimum and 0.34 C maximum. Thick sections are more difficult to harden reliably in the center

Downloaded from http://www.everyspec.com



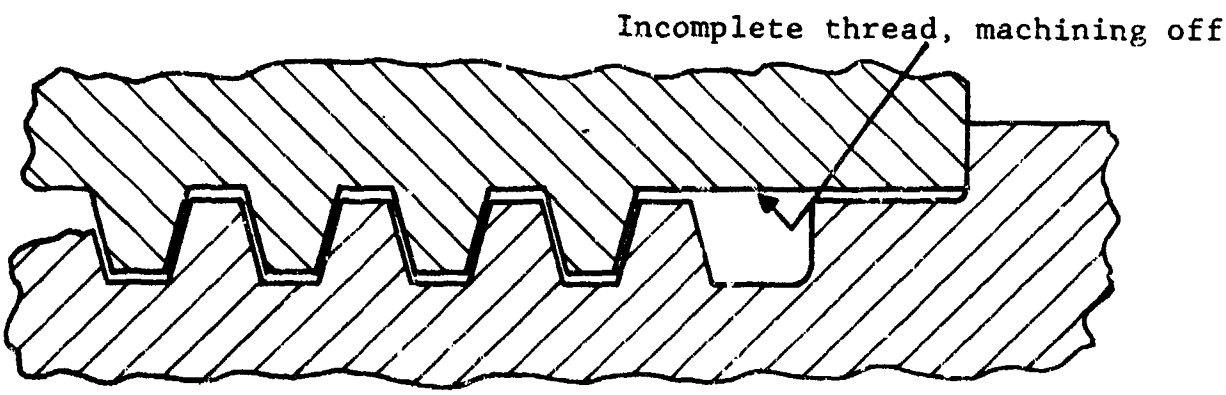
ACME Thread



Square Thread

Buttress Thread

(A) Thread Profile Types



(B) Threaded Joint With Butted End

Figure 2-45. Threads Used to Attach Breech Ring and Tube

Downloaded from http://www.everyspec.com

TABLE 2-6
20-DEG PRESSURE ANGLE THREAD DIMENSIONS*
(DIMENSIONS LOCATED IN FIG. 2-46)

Item	Dimension, in.			
Pitch	0.250	0.375	0.500	0.750
Bearing Height	0.051	0.095	0.142	0.232
*R*1*	0.12	0.18	0.25	0.37
*R*2	0.015	0.018	0.020	0.025
*R*3	0.033	0.050	0.066	0.100
*L*1**	3/8	1/2	5/8	7/8
*L*2	0.037	0.056	0.074	0.112
*a*1 for *DE*1♯	−0.166	−0.241	−0.311	−0.449
*a*2 for *DE*2	−0.154	−0.223	−0.293	−0.431
*a*3 for *DE*3	−0.139	−0.208	−0.278	−0.416
*a*4 for *DE*4	+0.101	+0.151	+0.202	+0.302
*a*5 for *DE*5	−0.177	−0.246	−0.316	−0.454
*a*6 for *DE*6	+0.167	+0.236	+0.306	+0.444
*a*1 for *DI*1	+0.160	−0.233	−0.309	−0.447
*a*2 for *DI*2	+0.195	+0.264	+0.354	+0.472
*a*3 for *DI*3	+0.139	+0.208	+0.278	+0.416
*a*4 for *DI*4	−0.101	−0.151	−0.202	−0.302
*a*5 for *DI*5	+0.154	+0.223	+0.293	+0.431
*a*6 for *DI*6	+0.169	+0.238	+0.308	+0.444

* *RX* = radii, in.; ** = length, in.

♯ External diameter, *DEX* = *DD* + *AX*, in.
Internal diameter, *DIX* = *DD* + *AX*, in.
DD = Datum Diameter, in.; *X* = Location of dimension, e.g., 1, 2, 3, etc.
a = distance from *DD*, in.

* Provided by Watervliet Arsenal

of a forging than thin sections. Firing pins are made from AISI 4340 or 4140 steel. They are hardened to be R_C 42 to 48.

These commonly used steels, AISI 4340 or 4140, are heat treated to Rockwell hardness 34 to 40 corresponding to yield strengths, at 0.1% offset, of 120 ksi to 180 ksi. The specified strength depends upon the part, alloy, and hardness. Breech rings are heat treated in the lower range of strengths, 120/130 ksi or 140/150 ksi. Breech-blocks are designed in the upper range of strength, 160/180 ksi. The Charpy "V-Notch"

Downloaded from http://www.everyspec.com

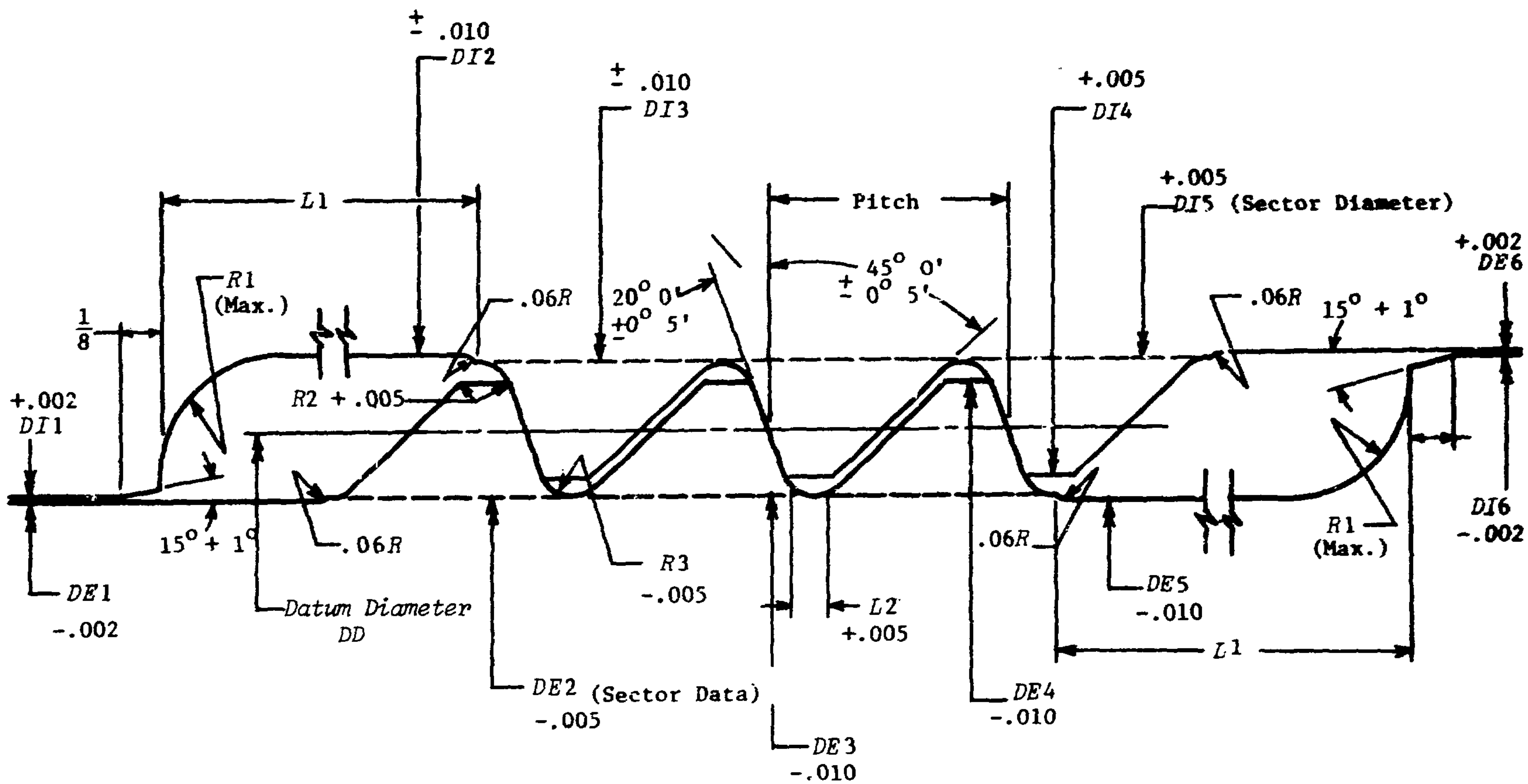


Figure 2-46. 20-deg Pressure Angle Thread Form Dimension Locator Diagram for Table 2-6. (Watervliet Arsenal)

Downloaded from http://www.everyspec.com

TABLE 2-7
LIST OF SPECIFICATIONS FOR: CANNON, 155 mm, HOWITZER, XM199 (REF. 91)

Item No.	Title	Number
1.	*Painting Ferrous Metals*	A7309995
2.	*Painting (Large Items)*	A7309997
3.	*Protective Finish (Springs)*	A7309993
4.	*Protective Finish*	A7309999
5.	*Magnetic Particle & Visual Inspection of Thick Walled Cannon Tubes*	B8768747
6.	*Magnetic Particle Inspection of Breech Rings and Couplings (Screw Type)*	B8768748
7.	*Magnetic Particle Inspection Criteria for Breechblocks (Screw Type)*	A8768761
8.	*Magnetic Particle Inspection of Minor Cannon Components*	B8769067
9.	*Magnetic Particle Inspection Criteria for Muzzle Devices*	A8769123
10.	*Touch-up of Phosphated Surface Finish After Benching*	A8769450
11.	*General Data Covering Application of Dry Film Lubricant*	B8769470
12.	*Steel Castings*	B11577275
13.	*General Data for 6000 Series Aluminum Alloys*	A11577279
14.	*Swage Autofrettage Procedures*	B11577708
15.	*Aluminum Alloy Casting Medium Strength*	B11578020
16.	*Surface Texture*	ANSI-B46.1
17.	*Interpretation of Drawing Requirements and Geometric Characteristic Symbols*	ANSI-Y14.5
18.	*Steel Sheets, Carbon, Cold-Rolled, Commercial Quality*	ASTM-A366
19.	*Carbon Steel Sheet, Cold-Rolled, Drawing Quality*	ASTM-A619
20.	*Carbon Steel Sheet, Cold-Rolled, Drawing Quality, Special Killed*	ASTM-A620
21.	*Compound and Sample Preparation for Physical Testing of Rubber Products*	ASTM-D15
22.	*Tension Testing of Vulcanized Rubber*	ASTM-D12
23.	*Low Temperature Impact Test for Fabrics Coated With Flexible Polymeric Materials*	ASTM-D2137
24.	*Indentation Hardness of Rubber and Plastics by Means of a Durometer*	ASTM-D2240
25.	*Steel Castings up to 2 in. in Thickness*	ASTM-E446
26.	*Welding Symbols*	AWS-A2.0-68
27.	*Steel, Chemical Composition and Hardenability*	FED-STD-66
28.	*Metals, Test Methods*	FED-STD-151
29.	*Color (Requirements for Individual Chips)*	FED-STD-595
30.	*Plastic Molding Material, Cellulose Acetate*	L-P-397
31.	*Anodic Coatings, for Aluminum and Aluminum Alloys*	MIL-A-8625

(cont'd on next page)

Downloaded from http://www.everyspec.com

TABLE 2-7 (cont'd)

Item No.	Title	Number
32.	*Adhesive: Epoxy Resin With Polyamide Curing Agent*	MIL-A-81236
33.	*Brakes, Muzzle, Cannon, Steel Castings for*	MIL-B-12253
34.	*Cannons, General Specifications for*	MIL-C-13931
35.	*Cord, Nylon, Solid Braid, General Purpose*	MIL-C-43307
36.	*Cannon, 155 mm Howitzer, XM199*	MIL-C-45975
37.	*Nitrided Steel Parts*	MIL-N-22061
38.	*Plates, Identification or Instruction, Metal Foil, Adhesive Backed*	MIL-P-19834
39.	*Plastic Sheet, Polycarbonate, Transparent*	MIL-P-83310
40.	*Rope, Nylon, Climbing Type*	MIL-R-1688
41.	*Rubber, Synthetic, Sheets, Strips, Molded or Extruded Shapes*	MIL-R-6855
42.	*Radiographic Inspection, Qualification of Equipment, Operators and Procedures*	MIL-R-11470
43.	*Steel, Chrome-Nickel-Molybdenum Bars and Reforging Stock*	MIL-S-5000
44.	*Steel, Corrosion-Resistant (18-8) Plate, Sheet and Strip*	MIL-S-5059
45.	*Springs, Helical, Compression and Extension*	MIL-S-13572
46.	*Sealing, Locking, and Retaining Compounds: Single-Component*	MIL-S-22473
47.	*Steel, Forgings, Tubular Parts for Cannon High Yield Strength (160-180 ksi)*	MIL-S-46119
48.	*Steel Forgings*	MIL-S-46172
49.	*Varnish, Moisture-and-Fungus-Resistant*	MIL-V-173
50.	*Welding Joint Design*	MIL-STD-22
51.	*Spring, Steel, Mechanical Drawing Requirements for*	MIL-STD-29
52.	*Engineering Drawing Practices*	MIL-STD-100
53.	*Marking for Shipment and Storage*	MIL-STD-129
54.	*Identification Marking of US Military Property*	MIL-STD-130
55.	*Inspection, Radiographic*	MIL-STD-453
56.	*Welding Procedures for Constructional Steels*	MIL-STD-1261
57.	*Chromium Plating (Electrodeposited)*	QQ-C-320
58.	*Wire, Steel, Alloy (General Purpose for Mechanical Springs)*	QQ-W-412
59.	*Wire, Steel, Carbon, Spring, Music*	QQ-W-470
60.	*Paint, Stencil Flat*	TT-P-98
61.	*Toluene, Technical*	TT-T-548
62.	*Rubber, Silicone*	ZZ-R-765
63.	*Material Requirements for Carrier Housings*	B8769925
64.	*Rings, Breech, Steel Forgings for*	HIL-R-10185
65.	*Plating, Cadmium (Electrodeposited)*	QQ-P-415
66.	*Enamel, Alkyd Gloss*	TT-E-489

Downloaded from http://www.everyspec.com

Toughness test at 15 ft•lb and −40°F is used for fracture toughness. AISI 4340 breech rings are chrome plated for reduced wear and friction.

An important coating used for some breech mechanism components has been designated as "solid film lubricant". General data covering application of solid film lubricant are given on Watervliet Arsenal drawing B8769470, sheets 1 through 6, 2 August 1963 (original date) (code 192B). The solid film lubricant is specified by MIL-G-46010(MR). It is applied to steel at 40°F ±10 deg F for 60 min ±2 min. The method of application is by spray gun which deposits a coating 0.0002 to 0.0005 in. thick per layer. A 15-min air dry time is required between successive layers. Final coating thicknesses are 0.0004 to 0.0010 in. thick. This coating is essentially an epoxy phenolic paint.

Four protective finishes which are items 1 through 4, other than the "Solid Film Lubricant", are identified in Table 2-7. Table 2-8 provides the general data applicable to these and one other finish. The drawings included in the Technical Data Package for the 105 mm M68 gun (Ref. 96) were used to prepare Table 2-9. This table lists a range of typical breech mechanism parts with the material used, hardness specified, and final protective finish. This matrix may be used as a guide for both material and coating selection.

TABLE 2-8
PROTECTIVE FINISH — DRAWING NUMBER MATRIX (REF. 96)

Drawing No.*	Data Governing:	General Data
A7309995	Painting Ferrous Metals	The item shall receive a final protective finish in accordance with the following: Phosphate coat all surfaces, MIL-P-16232*, type M, Class 3 or type Z, Class 3 Unless otherwise specified, paint all surfaces, TT-E-485, type II or IV, two coats, olive drab. Surfaces specified not to be painted shall receive a supplementary oil treatment, VV-L-800. *Reference MIL-P-16232. Tensile testing after hydrogen embrittlement relief treatment is not required. Salt spray testing after application of supplementary oil treatment is not required.
A7309997 (cont'd)	Painting Large Items	The following shall apply when painting large items: 1. Solvent clean surface by immersion, spray, direct application or vapor degreasing with the following appropriate solvent: A. Dry cleaning solvent (stoddard), spec. P-D-680, type I; B. Thinner, paint (petroleum-spirits), spec. TT-T-291, grade I; C. Tetrachloroethylene (perchloroethylene), spec. O-T-236; D. Trichloroethylene, spec. O-T-634, type II. 2. Pretreat cleaned surface with: Primer, pretreatment, spec. MIL-P-15328.

*Department of the Army, Watervliet Arsenal, Watervliet, NY

(cont'd on next page)

Downloaded from http://www.everyspec.com

TABLE 2-8 (cont'd)

Drawing No.	Data Governing:	General Data
		3. Apply two (2) coats to pretreated surface with: Enamel, semigloss, rust-inhibiting, spec. TT-E-485, type IV, olive drab no. X24087.
A7309998	Protective Finish Springs	The following shall apply: Final protective finish for springs, other than BREECH closing springs. 1. Black oxide coating, class 1, spec. MIL-C-13924. 2. Following the chromic acid dip, springs shall be thoroughly dried and coated with lubricating oil, preservative, general purpose spec. VV-L-800.
A7309999	Protective Finish	1. The protective finish shall be type M, class 1, phosphate coating conforming to specification MIL-P-16232. 2. The supplementary preservative oil shall conform to specification VV-L-800. The weight per unit area requirement of MIL-P-16232 is not required. 3. Following the chromic acid rinse (stage 5) the items shall be thoroughly dried before application of the preservative oil. 4. Cleaning shall be per TT-C-490 method I and/or II for surface finishes of 63 microinch and coarser. 5. Cleaning shall be per TT-C-490 method II for suface finishes finer than 63 microinch. No abrasive blast shall be used. 6. Surface finishes finer than 16 microinch shall not require phosphate coating. If surface finishes finer than 16 microinch are phosphate coated they shall be maintained or shall be restored to their specified finish 7. Unless otherwise specified, braze shall have a fine line of brazing material visible at the joints after application of the protective finish. 8. Salt spray testing after application of the preservative oil is not required. 9. Embrittlement relief (tensile) testing shall not be required unless specified on the applicable drawing. 10. Articles shall comply with dimensional requirements of the drawings before application of the phosphate coating.
A11577717	Aluminum Painting	Item shall receive a protective finish as follows: Base coat (for applicable drawing*) A. ANODIZE per MIL-A-8625, type I, class 1** B. ANODIZE per MIL-A-8625, type II, class 1** C. ANODIZE per MIL-A-8625, type III, class 1** Unless otherwise specified, paint all surfaces as follows: One (1) coat primer per MIL-P-15328 One (1) coat paint per TT-E-485 or olive drab. *When more than one base coat is specified, the contractor has the option of which one to use. **Seal in boiling deionized water. The applicable drawing shall contain the following minimum information for protective finish: DWGA11577717 Base ____

Downloaded from http://www.everyspec.com

TABLE 2-9
BREECH MECHANISM PART MATRIX (REF. 96)

Part	Material		Hardness	Final Protective Finish-Dwg. No.
	Carbon Range or AISI No.	Specification		
Body, Breech-Block	AISI E4340	MIL-S-5000	R_C 34/38	A7309999
Pivot (3/4 D x 2-1/2 L)	0.28/0.50 C	FED-STD-66	R_C 35/41	A7309999
Plunger	0.28/0.50 C	FED-STD-66	R_C 34/38	A7309999
Lever	0.28/0.50 C	FED-STD-66	R_C 35/41	A7309999
Bushing	0.28/0.50 C	FED-STD-66	R_C 25/31	A7309999
Retractor	0.23 C max	FED-STD-66	R_A 79/84	A7309999
Spring	Music wire	QQ-W-470	NA*	A7309998
Trigger	0.23 C max	FED-STD-66	R_A 79/84	A7309999
Sear	0.23 C max	FED-STD-66	R_A 79/84	A7309999
Guide	0.38/0.53 C	FED-STD-66	R_C 40/46	A7309999
Pivot (5/8 D x 13/32 L)	0.38/0.53 C	FED-STD-66	R_C 40/46	A7309999
Key	0.28/0.50 C	FED-STD-66	R_C 35/40	A7309999
Stop	0.38/0.53 C	FED-STD-66	R_C 40/46	A7309999
Detent	0.28/0.50 C	FED-STD-66	R_C 30/35	A7309999
Retainer	0.28/0.50 C	FED-STD-66	R_C 25/31	A7309999
Bushing	0.38/0.50 C	FED-STD-66	R_C 35/41	A7309999
Crank	AISI 4140 or AISI 4340	FED-STD-66	R_C 35/41	A7309999
Cover, Disc	0.34 C max	FED-STD-66	NA	A7309995
Body, Breech Ring	0.28/0.50 C			A7309999
Bracket, Breech Ring	0.28/0.50 C	FED-STD-66	B_H 248/350	A7309999
Adjustor	0.28/0.50 C	FED-STD-66	R_C 25/31	A7309999
Crank	0.38/0.50 C	FED-STD-66	R_C 35/40	A7309999
Pin	0.28/0.50 C	FED-STD-66	R_C 35/41	A7309999
Shaft	0.28/0.50 C	FED-STD-66	R_C 25/31	A7309999
Spring	Steel wire Lamp 2 Type II	QQ-W-412	R_C 50/33	A7309998
Lever	0.38/0.53 C	FED-STD-66	R_C 35/41	A7309999
Stop	0.38/0.53 C	FED-STD-66	R_C 35/41	A7309999
Grip	Aluminum 606186	A11577279	NA	A11577717
Cover Strip	0.34 C max	FED-STD-66	NA	NA
Latch	0.38/0.53 C	FED-STD-66	R_C 34/48	A7309999
Extractor	0.23 C max	FED-STD-66	R_A 79/84	A7309999

*Not Applicable

REFERENCES

1. TM 9-1900-203, *Artillery Ammunition*, April 1967, Fig. 1-1, p. 1-3
2. AMCP 706-3-3, Engineering Design Handbook, *Complete Round Charts-Artillery Ammunition*, December 1967.
3. TM 9-1300-200, *Ammunition, General*, October 1969, Chapter 4, pp. 4-1, -36.
4. AMCP 706-252, Engineering Design Handbook, *Gun Series-Gun Tubes*, Fig. 2, p. 4.
5. TM 9-1900-203, *Artillery Ammunition*, April

Downloaded from http://www.everyspec.com

REFERENCES (cont'd)

1967, Fig. 1-11, p. 1-19.

6. Maj. Gen. W. K. Ghormley, "*The Combustible Case*", Ordnance, September-October 1962, p. 231.
7. IIT Research Institute Private Files
8. US Army Photograph
9. MIL-HDBK-698, *Copper and Copper Alloys*.
10. AMCP 706-252, Engineering Design Handbook, *Gun Series-Gun Tubes*, Fig. 17, p. 23.
11. AMCP 706-252, Engineering Design Handbook, *Gun Series-Gun Tubes*, p. 24.
12. AMCP 706-252, Engineering Design Handbook, *Gun Series-Gun Tubes*, Fig. 18, p. 24.
13. AMCP 706-250, Engineering Design Handbook, *Gun Series-Guns General*, Fig. 6-2, p. 6-5.
14. AMCP 706-251, Engineering Design Handbook, *Gun Series-Muzzle Devices*, p. 7-4.
15. AMCP 706-251, Engineering Design Handbook, *Gun Series-Muzzle Devices*, Chapter 7, pp. 7-1, -9.
16. AMCP 706-342, Engineering Design Handbook, *Carriages and Mounts Series-Recoil Systems*.
17. AMCP 706-250, Engineering Design Handbook, *Guns-General*.
18. AMCP 706-340, Engineering Design Handbook, *Carriages and Mounts-General*.
19. AMCP 706-327, Engineering Design Handbook, *Fire Control Series-Fire Control Systems-General*, Fig. 1-5, p. 1-13.
20. AMCP 706-327, Engineering Design Handbook, *Fire Control Series-Fire Control Systems-General*, Fig 1-13, pp. 1-19.
21. FM 6-94, *175 mm Gun M107 Self-Propelled and 8-Inch Howitzer M110 Self-Propelled*, May 1968, Fig. 10, p. 19.
22. FM 6-94, *175 mm Gun M107 Self-Propelled and 8-Inch Howitzer M110 Self-Propelled*, May 1968, Fig. 11, p. 22.
23. AMCP 706-331, Engineering Design Handbook, *Compensating Elements*, p. 53.
24. AMCP 706-327, Engineering Design Handbook, *Fire Control Series-Fire Control Systems-General*, Fig. 1-55, p. 1-70.
25. TM 9-3007, *105 mm Howitzer*, October 1963, Fig. 31, pp. 72-73.
26. TM 9-3305-1, *Principles of Artillery Weapons*, November 1956, Figs. 44-46, p. 41.
27. TM 9-3007, *105 mm Howitzer*, October 1953, Fig. 32, p. 74.
28. TM 9-361, *75 mm Gun, T83E1*, November 1951, Fig. 18, p. 28.
29. G. D'Andrea, *Short Recoil Breech Actuating Mechanism*, Watervliet Arsenal, NY, WVT-6517, pp. 6-7, July 1965, AD-470 443.
30. T. K. Warwick, *The Design and Development of the Gun, 120 mm, TK., L11A2 (U)*, Royal Armament Research and Defense Establishment, Ft. Halstead, England, R.A.R.D.E. Memo-1/64, January 1964, AD-348 023 (CONFIDENTIAL).
31. US Army Ordnance Dept., *A Symposium on Breech Mechanisms, Part II*, Ord. Project No. TR-1000L, The Franklin Institute, Philadelphia, PA, March 1949, pp. 2-27, -42.
32. TM 9-2300-216-10, *Operators Manual for Gun, Field Artillery, Self-Propelled: Fully Tracked, 175 mm, M107 (T235E1) (2350-436-6535) and Howitzer, Heavy, Self-Propelled: Fully Tracked, 8-Inch, M110 (T236E1) (2350-439-6243)*, June 1962, Fig. 10, p. 124.
33. US Army Ordnance Dept., *A Symposium on Breech Mechanisms, Part II*, Ord. Project No. TR1-1000L, The Franklin Institute, Philadelphia, PA, March 1949, pp. 2-2.7-42.
34. US Army Ordnance Dept., *A Symposium on Breech Mechanisms, Part III*, Ord. Project No. TR1-1000L, The Franklin Institute, Philadelphia, PA, March 1949, Fig. 2-125.
35. TM 9-2300-216-10, *Operators Manual for Gun, Field Artillery, Self-Propelled: Fully Tracked, 175 mm, M107 (T235E1) (2350-435-6635) and Howitzer, Heavy, Self-Propelled: Fully Tracked, 8-Inch, M110 (T236E1) (2350-439-6243)*, June

Downloaded from http://www.everyspec.com

REFERENCES (cont'd)

1962, Fig. 96, p. 120.

36. MIL-C-45525 (WC), *Cannon, 155 mm Howitzer: M126A1*, June 1972, p. 2.
37. TM 9-2350-217-10, *Howitzer, Light, Self-Propelled: 105 mm, M108 and Howitzer, Medium, Self-Propelled: 155 mm, M109.*
38. TM 9-2350-217-25P/1, *Howitzer, Light, Self-Propelled, 105 mm, M108 and Howitzer, Medium, Self-Propelled: 155 mm, M109*, Organization, DS, GS and Depot Maintenance Manual.
39. TM 9-3305-1, *Principles of Artillery Weapons*, November 1956, Fig. 49, p. 45.
40. T. J. Hayes, *Elements of Ordnance*, John Wiley & Sons, Inc., New York, NY, 1949, p. 239.
41. TM 9-3007, *105 mm Howitzer, M101A1*, October 1953, pp. 72-73.
42. TM 9-361, *75 mm Gun, T83E1*, November 1951, pp. 31-3.
43. TM 9-3305-1, *Principles of Artillery Weapons*, November 1956, Fig. 16, p. 46.
44. AMCP 706-250, Engineering Design Handbook, *Guns-General*, p. 3-9.
45. TM 9-350, *155 mm Gun, M2*, May 1945, pp. 38, 61, 62, 100, 122, 124, 131-4.
46. TM 9-3305-1, *Principles of Artillery Weapons*, November 1956, Figs. 52 and 53, p. 48.
47. US Army Ordnance Dept., *A Symposium on Breech Mechanisms, Part II*, Ord. Project No. TR1-1000L, The Franklin Institute, Philadelphia, PA, March 1949, pp. 2-2.5, 2.8-33.
48. TM 9-350, *155 mm Gun, M2*, May 1945, p. 131.
49. TM 9-350, *155 mm Gun, M2*, May 1945, Fig. 87, p. 133.
50. TM 9-2300-216-10, *Operators Manual for Gun, Field Artillery, Self-Propelled: Fully Tracked, 175 mm, M107 (T235E1) (2350-436-6635) and Howitzer, Heavy, Self-Propelled: Fully Tracked, 8-Inch, M110 (T236E1) (2350-439-6243)*, June 1962, pp. 123-7.
51. TM 9-361, *75 mm Gun, T83E1 and 75 mm AA Gun Mount T-20*, November 1951, Fig. 21, p. 30.
52. TM 9-1015-234-12, *Operator and Organizational Maintenance Manual, Howitzer, Light, Towed: 105 mm, M102 (1015-086-8164)*, March 1965, Fig. 30, p. 56.
53. US Army Ordnance Dept., *A Symposium on Breech Mechanisms, Part II*, Ord. Project No. TR1-1000L, The Franklin Institute, Philadelphia, PA, March 1949, pp. 2-2.6-1—2-2.7-12.
54. TM 9-361, *75 mm Gun, T83E1*, November 1951, pp. 29-30.
55. US Army Ordnance Dept., *A Symposium on Breech Mechanisms, Part III*, Ord. Project No. TR1-1000L, The Franklin Institute, Philadelphia, PA, March 1949, p. 3-1-5.
56. US Army Ordnance Dept., *A Symposium on Breech Mechanisms, Part II*, Ord. Project No. TR1-1000L, The Franklin Institute, Philadelphia, PA, March 1949, pp. 2-2.4-1, 2-2.4-3, -26.
57. US Army Ordnance Dept., *A Symposium on Breech Mechanisms, Part III*, Ord. Project No. TR1-1000L, The Franklin Institute, Philadelphia, PA, March 1949, pp. 3-1-26,-73.
58. J. T. Hynes, *Silicone-Asbestos Obturator Pads for 175 mm Gun, M113A1, A Product Improvement*, Watervliet Arsenal, NY, WVT-7101, February 1971, AD-720 988.
59. T. J. Hayes, *Elements of Ordnance*, John Wiley & Sons, Inc., New York, NY, 1949, pp. 224-6.
60. TM 9-2300-216-10, *Operators Manual for Gun, Field Artillery, Self-Propelled: Fully Tracked, 175 mm, M107 (T235E1) (2350-436-6635) and Howitzer, Heavy, Self-Propelled: Fully Tracked, 8-Inch, M110 (T236E1) (2350-439-6243)*, June 1962, Fig. 99, p. 123.
61. R. M. Ogorkiewicz, "Chieftain Tank", *The Engineer*, pp. 259-62, (16 August 1963).
62. L.T.J. Moss and H. D. Warwick, *The Development of the Obturator for the Gun, 120 mm Tk, L11A2 (U)*, Royal Armament Research and Defense Establishment, Ft. Halstead, England, R.A.R.D.E. Memo-55/63, 1963 (CONFIDENTIAL).

Downloaded from http://www.everyspec.com

REFERENCES (cont'd)

63. *Breech Mechanisms for Tank Cannon*, Armour Research Foundation (now IIT Research Institute) Final Report Project K-100, WVT Arsenal Contract DA-11-022-ORD-2182, 20 October 1958.
64. TM 9-2300-216-10, *Operators Manual for Gun, Field Artillery, Self-Propelled: Fully Tracked, 175 mm, M107 (T235E1) (2350-436-6635) and Howitzer, Heavy, Self-Propelled: Fully Tracked, 8-Inch, M110 (T236E1) (2350-439-6243)*, June 1962, F[illegible] 71 and 72, p. 73.
65. US Ar[illegible] Ordnance Dept., *A Symposium on Breech Mechanisms, Part III*, Ord. Project [illegible].1-1000L, The Franklin Institute, Philadelphia, PA, March 1949, pp. 3-1-372,-474.
66. R. E. Seamands and R. J. Toering, *Selecting Best Recoiling Parts Weight in an Artillery System*, US Army Weapons Command, Rock Island, IL, April 1971, p. 24, AD-882 471.
67. R. Rossmiller, *Alternate Armament Combinations for the M551 Vehicle*, US Army Weapons Command, Rock Island, IL, May 1967, AD-814 948.
68. TM 9-2350-224-10, *Operators Manual, Tank, Combat, Fully Tracked; 90 mm Gun, M48A3, W/E (2350-895-9154)*, January 1966, Fig. 1-5, p. 1-9.
69. AMCP 706-357, Engineering Design Handbook, *Automative Bodies and Hulls*, p. 2-46.
70. N. F. Dickinson, et al., *The Influence of Breech Orientation on the XM 150 E4 Gun on the Loaders Task as Related to the M60A1E1 Tank*, TN 10-66, Human Engineering Laboratory, Aberdeen Proving Ground, MD, 1966.
71. FM 6-81, *155 mm Howitzer, M1*.
72. AMCP 706-342, *Carriage and Mounts Series-Recoil Systems*.
73. T. J. Hayes, *Elements of Ordnance*, John Wiley & Sons, Inc., New York, NY, 1949, pp. 232, 240, 247, 252, 254, 257, 264, 265.
74. T. J. Hayes, *Elements of Ordnance*, John Wiley & Sons, Inc., New York, NY, 1949, Fig. 15, p. 65.
75. AMCP 706-252, Engineering Design Handbook, *Gun Series-Gun Tubes*, pp. 9-12.
76. MIL-STD-721B, *Definition of Effectiveness Terms for Reliability, Maintainability, Human Factors, and Safety*.
77. AR 600-200, *Enlisted Personnel Management System*.
78. AR-611-201, *Enlisted Career Management Fields and Military Occupational Specialties*.
79. HEL Standard S-2-64A, *Human Factors Engineering Design Standard for Vehicle Fighting Compartments*, Aberdeen Proving Ground, MD, June 1968, Table 5 (p. 42), Fig. 4 (p. 19), Fig. 5 (p. 20), Table 4 (p. 22), AD-691 331.
80. MIL-HDBK-759, *Human Factors Engineering Design for Army Material*, Dept. of Defense, March 1975, Fig. 47, p. 155.
81. MIL-STD-882, *Requirements for Systems Safety Program for Systems and Associated Subsystems and Equipment*, July 1969.
82. AR 70-38, *Research Development, Test and Evaluation of Materiel for Extreme Climatic Conditions*.
83. MIL-STD-210, *Climatic Extremes for Military Equipment*.
84. AMCP 706-115, Engineering Design Handbook, *Environmental Series, Part One, Basic Environmental Concepts*.
85. E. C. Theiss, et al., *Handbook of Environmental Engineering*, McGraw-Hill Book Company, Inc., New York, NY, 1961.
86. *Engineers Design Guide*, US Army Signal Research and Development Laboratory, Ft. Monmouth, NJ, 1962.
87. AMCP 706-134, Engineering Design Handbook, *Maintainability Guide for Design*.
88. AMCP 706-252, Engineering Design Handbook, *Gun Series-Gun Tubes*, p. 64.
89. ANSI Y14.5-1973, *Dimensioning and Tolerancing*, The American Society of Mechanical Engineers, New York, NY.
90. Handbook H28 (1969), *Screw-Thread Standards for Federal Services*, Parts I and II,

Downloaded from http://www.everyspec.com

REFERENCES (cont'd)

National Bureau of Standards, March 1970.

91. MIL-C-45975, *Cannon, 155 mm Howitzer: M199.*
92. Fed. Std. No. 66, *Steel: Chemical Composition and Hardenability.*
93. MIL-R-10185, *Rings, Breech, Steel Forgings for.*
94. MIL-S-5000, *Steel, Chrome-Nickel, Molybdenum Bars and Reforging Stock.*
95. MIL-P-16232, *Phosphate Coatings, Heavy, Manganese or Zinc Base (for Ferrous Metals).*
96. Technical Data Package, *Cannon, 105 mm Gun: M68 (MIL-C-45504).*

BIBLIOGRAPHY

R. S. Bucher, *M107/M110 Self-Propelled Artillery Loader-Rammer Review Program*, US Army Weapons Command, Rock Island, IL, June 1971, AD-891 656.

H. P. Van Cott and R. G. Kinkade, *Human Engineering Guide to Equipment Design*, McGraw-Hill Company, New York, NY, 1972.

MIL-STD-1473-A, *Human Engineering Design Criteria for Military Systems, Equipment and Facilities.*

Technical Memorandum 3-57, *Physical Force Problems: 1. Hand Crank Performance for Various Crank Radii and Torque Load Combinations*, Human Engineering Laboratory, Aberdeen Proving Ground, MD, March 1957.

Technical Memorandum 9-60, *The Effects of Missile Length and Weight on Loading Time*, Human Engineering Laboratory, Aberdeen Proving Ground, MD, July 1960.

Technical Memorandum 9-62, *A Loading Rate Evaluation of a Pivot Chamber Breech and an XM102 Howitzer Breech*, Human Engineering Laboratory, Aberdeen Proving Ground, MD, March 1967.

Technical Memorandum 8-60, *Human Factors Engineering Evaluation of the M60 Main Battle Tank*, Human Engineering Laboratory, Aberdeen Proving Ground, MD, June 1960.

C. L. Woodward and N. F. Dickinson, *Human Factors Review of Product Improved Breech Mechanisms, 105 mm Howitzer: M137A1*, Human Engineering Laboratory, Aberdeen Proving Ground, MD, August 1972.

Technical Note 7-67, *A Loading Study of the XM138 Self-Propelled Howitzer*, Human Engineering Laboratory, Aberdeen Proving Ground, MD, December 1967.

Technical Note 10-66, *The Influence of Breech Orientation of the XM150E4 Gun on the Loaders Task as Related to the M60A1E1 Tank*, Human Engineering Laboratory, Aberdeen Proving Ground, MD, December 1966.

Technical Memorandum 14-62, *A Human Factors Evaluation of the Main Battle Tank, 105 mm Gun, M60E1*, Human Engineering Laboratory, Aberdeen Proving Ground, MD, June 1962.

Downloaded from http://www.everyspec.com

CHAPTER 3

DESIGN CRITERIA AND PROCEDURES — INITIATION THROUGH PROTOTYPE

3-0 LIST OF SYMBOLS

A_c = breech chamber area, in.^{2}

A_s = shear area, in.^{2}

a_1, a_2, a_4 = distances, in.

b_1 = distance from rear face of block to neutral axis, in.

b_2 = distance from front face of block to neutral axis, in.

C = tooth clearance, in.

$C_1, C_2,$
C_3 = distances, in.

D_1, D_2 = pitch diameters of threaded sectors, in.

D_c = rear chamber diameter or equivalent, in.

d = beam width, in.

d_c = displacement of breech operating cam from point of initial contact with follower, in.

$d_1, d_2, d_3,$
d_4, d_5, d_6 = distances, in.

E = modulus of elasticity, psi

E_f = free recoil energy, ft•lb

F_g = propellant gas force, lb

F_r = total resistance force to recoil, lb

F_t = thread force, lb

FS = factor of safety, dimensionless

g = acceleration due to gravity, ft/s^2

h = half thickness, in.

h_1 = height of jaw, in.

h_2 = height of tie bar, in.

h_3 = minimum distance of thrust surface from rear face of breech, in.

h_4 = height of cross section, in.

h_s = spring force lever arm distance, in.

$I_1, I_2, I_3,$
I_4, I_5 = moments of inertia, in.^{4}

K_{11} = coefficient, in.$^{-3}$

$K_{12}, K_{13},$
K_{21} = coefficients, in.$^{-2}$

K_{22}, K_{23} = coefficients, in.$^{-1}$

K_B = bending stress concentration factor dimensionless

K_T = tensile stress concentration factor, dimensionless

k = spring constant for closing spring, lb/deg

$L_1, L_2, L_3,$
L_4, L_5 = lengths, in.

M = applied bending moment, in.•lb

M_1 = maximum internal bending moment, in.•lb

M_2 = outward bending moment, in.•lb

M_3 = eccentric bending moment, in.•lb

M_4 = torque on breech operating crank shaft, in.•lb

M_b = mass of breechblock and components, lb•s^2/in.

M_v = mean of material strength distribution, psi

m_g = propellant mass, lb•s^2/ft

m_p = projectile mass, lb•s^2/ft

m_r = recoiling mass, lb•s^2/ft

N = number of rounds fired during service, rounds

n = number of threads engaged

P_1 = horizontal load per jaw, lb

P_2 = αP_1 = horizontal load per jaw perpendicular to P_1, lb

P_c = chamber pressure, psi

P_e = end thrust, lb

P_p = peak chamber pressure, psi

P_s = probability of survival, dimensionless

Downloaded from http://www.everyspec.com

p = thread pitch, in.
Q = momentum at shot ejection, lb•s
q = modified pressure intensity, psi
q^* = pressure loading on breechblock, psi
R = radius of breechblock crank, in.
R_b = radius of breechblock operating crank, in.
R_c = radius of breech operating cam, in.
R_f = fillet radius, in.
R_I = radius at point I, in.
R_r = cam roller radius, in.
r = generalized radius, in.
r_1 = inner radius of breechblock, in.
r_2 = external radius of breechblock, in.
r_3 = radius defining limits of breechblock loading function, in.
r_4 = T-slot roller radius, in.
S = recoil stroke, ft
S_1 = direct tensile stress, psi
S_2 = outward bending stress component, psi
S_3 = eccentric bending stress component, psi
S_A, S_B, S_C, S_D, S_E, S_G, S_H, S_I = stresses at subscripted points, psi
S_{max} = maximum tensile stress in jaw, psi
S_b = bending stress, psi
S_r = radial stress, psi
S_s = shear stress, psi
S_θ = tangential stress, psi
T = period of operation, time units
t = period of operation, h
v_f = free recoil velocity, ft/s
v_g = propellant gas velocity, ft/s
v_p = projectile velocity, ft/s
W_r = recoiling part weights, lb
w = width of cross section, in.
x = breechblock displacement, in.
y = distance between bore axis and midheight of breech rings, in.
Z = section modulus, in.^{3}
α = seat angle, rad
α_b = fixed angle between the horizontal and the T-slot in the breechblock, deg
β = r_2/r_1 = dimensionless ratio of external to inner radius
δ_{HB} = horizontal deflection, in.
δ_{VB} = vertical deflection, in.
δ_H = horizontal deflection of reaction loading, centerline remaining fixed, in.
δ_V = vertical deflection of block center, in.
ϵ = strain, in./in.
η = h/r_1 = dimensionless ratio of half thickness to inner radius
θ = instantaneous crank angle, deg
θ_A = angular deflection of jaws about point A, rad
θ_B = angular deflection of breechblock load bearing surfaces, rad
θ_T = total angular rotation of crank, deg
θ_c = initial angular preload on closure spring, deg
θ_1 = initial crank angle, deg
$\bar{\theta}$ = mean time between failures, time units
λ = failure rate, failures/(unit time)
$\mu_{h_4^2}$ = mean of distribution of h_4^2, in.
μ_S = mean stress, psi
μ_T = mean strength, psi
μ_w = mean of distribution of w, in.
μ_Z = mean of distribution of Z, in.^{3}
ν = Poisson's ratio, dimensionless
ρ = r/r_1 = dimensionless ratio
σ = normal stress, psi
$\sigma_{h_4^2}$ = standard deviation of h_4^2 distribution, in.
σ_r = S_r/q = dimensionless radial stress
σ_S = standard deviation of stress, psi
σ_T = standard deviation of strength, psi
σ_w = standard deviation of w distribution, in.
σ_Z = standard deviation of Z distribution, in.^{3}

Downloaded from http://www.everyspec.com

$\sigma_\theta = S_\theta/q$ = dimensionless tangential stress

τ_{ave} = average shear stress, psi

τ_{max} = maximum shear stress, psi

ϕ = angle between a line drawn from the center of the crank follower in the initial contact position at the cam radius starting point to the origin of R_c and any position of the crank follower to R_c, deg

ψ = elevation angle, deg

SECTION I. TACTICAL INPUTS TO DESIGN

3-1 REQUIRED OPERATIONAL CAPABILITY

A statement of the "requirement" or "need" is the logical starting point for an orderly design process. The military equipment designer receives inputs to the problem through design specification or performance goals specified in terms of allowable bands prepared by the US Army Materiel Development and Readiness Command (DARCOM). These inputs are communicated to the design agency or contractor in the form of a request for proposal (RFP) and are reiterated in the design contract. Quantitative performance bands or specifications are emphasized in the preparation of these documents. The design specifications have a more basic, tactical origin stemming from documents generated by the Department of the Army (Ref. 1).

3-2 WEAPON APPLICATION AND MISSION

To the breech mechanism designer, many of the design options have already been defined prior to his entry into the design process. The availability of external power to perform breech operational functions is dictated by the type of weapon system specified (i.e., self-propelled versus towed). When no external power is available, recoil energy usually is employed to perform semiautomated breech functions. Use of recoil energy necessitates the use of cam-actuated breech operations. A high required burst or sustained fire rate may dictate use of the sliding-wedge breech. This breech is more ammenable to simple, quick cam-actuated operations. Closing and opening sequences are simplified, thereby reducing cycle time. Complicated automatic loading features may be required to reduce the load cycle time.

3-3 RATE OF FIRE

Specification of the gun rate of fire defines the degree of sophistication needed in the breech system as well as the need for auxiliary mechanisms. Low rates of fire allow manual operation of the breech mechanisms while higher rates of fire may require automatic or semiautomatic operation using either an external power source or power tapped from the normal operation of the weapon.

3-4 AMMUNITION REQUIREMENTS

The specification of the type (or types) of ammunition required to be fired from a given weapon is a major input to the breech design process. The size, weight, and type of ammunition and the propellant characteristics and energy content are determining factors in the breech system preliminary proportions (breech recess dimensions, outside dimension, breechblock size, etc.). It is important to note that more than one ammunition type may be specified. For example, the SHERIDAN Weapon System fires both conventional rounds and guided missiles.

Downloaded from http://www.everyspec.com

SECTION II. DESIGN PROCESS

3-5 ESTABLISHING FEASIBILITY

The structure of the design process, while composed of orderly elements and carried out in a logical manner, is not easily described in a simple list of steps. Indeed, the act of designing is a complex creative process from design specifications to idea to reality. At an early point in the design procedure, the designer must begin to assimilate the various inputs (specifications, data, constraints) and synthesize a feasible concept. To establish feasibility, the design concept must be committed to paper in the form of functional design layouts, preliminary material selections, breech mechanism interfaces with the total weapon, and mathematical analyses of critical components. These various items are discussed in pars. 1-8 and 3-6 through 3-10.

3-6 FUNCTIONAL DESIGN LAYOUTS

Design feasibility is not fully established until a set (or sets) of functional layouts of the breech system has been produced, incorporating the several inputs previously mentioned. These layouts are only the initial drawings, showing the overall breech system geometry; they include space requirements for major breech elements and working motions of the various mechanisms. The functional design layouts provide a visual identification of mechanism motion and spatial considerations to be further developed.

Human factors, producibility, reliability, and maintainability can be introduced most effectively into the design at this early phase. Formal design reviews will be used at a later time to ensure that such goals are achievable. Much wasted time and effort can be saved if the designer, in addition to establishing functional feasibility, also considers all factors that contribute to a successful design. A design checklist prepared using the guidance provided in Chapter 2 may be appropriate.

The initial layouts provide the basis for obtaining analytical support. The analyst requires general configurational characteristics and material properties before the design analysis can be initiated. These analyses indicate specific material requirements and alterations in the configuration requiring changes in the initial layout. The process is obviously iterative, requiring close cooperation between the designer and analyst.

3-7 SUBASSEMBLY LAYOUTS; COMPONENT DETAILS

As feasibility of a concept is shown and support from collaborating sources continues to be positive, the design sequence can move into a firmer stage. Here the subassemblies which will perform each breech function are formulated and developed, and their components designed or selected.

Subassembly layouts will correspond roughly to the major mechanism and elemental breakdowns of the breech system. Typical (but not all inclusive) subassemblies are:

1. Breech structure and block
2. Operating mechanism
3. Firing mechanism
4. Safety mechanism
5. Obturator.

Examples of subassembly and component drawings are presented in Figs. 3-1 and 3-2. The examples are Watervliet Arsenal drawings of the firing pin block assembly with details for the 8 in. Howitzer, M2A1E1, and 175 mm Gun, M113. The figures illustrate the level of detail required as the design progresses. Component drawings must specify concentricity and flatness requirements, dimensional tolerances, materials, and protective finishes. Manufacturing capabilities must be carefully considered (see Chapter 4) in addition to the more subtle impact of surface finish or flatness on mechanical failure modes (e.g., galling and misalignment). Selection of proper breech materials is considered in detail in the paragraphs that follow.

Downloaded from http://www.everyspec.com

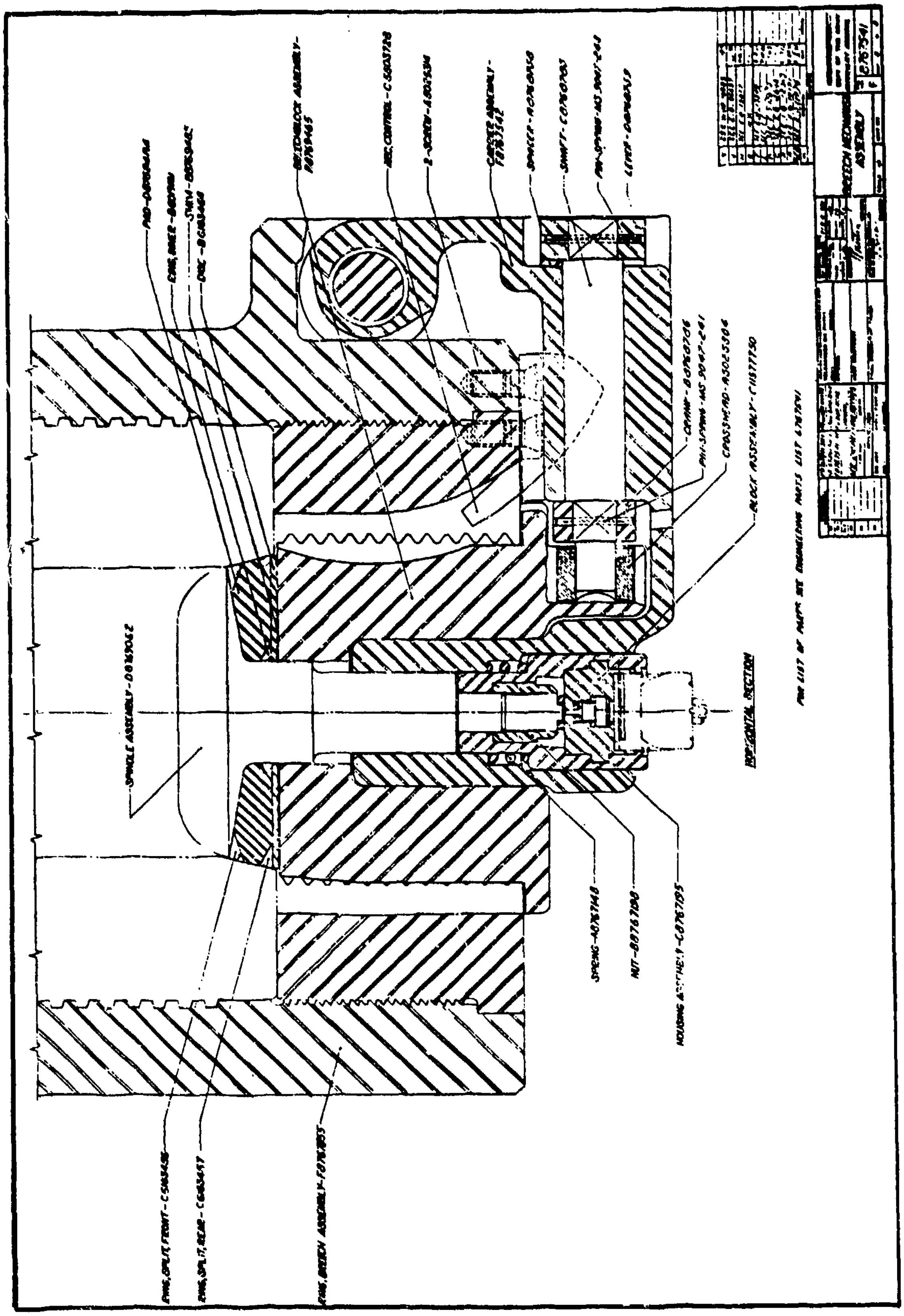


Figure 3-1. Breechblock Assembly

Downloaded from http://www.everyspec.com

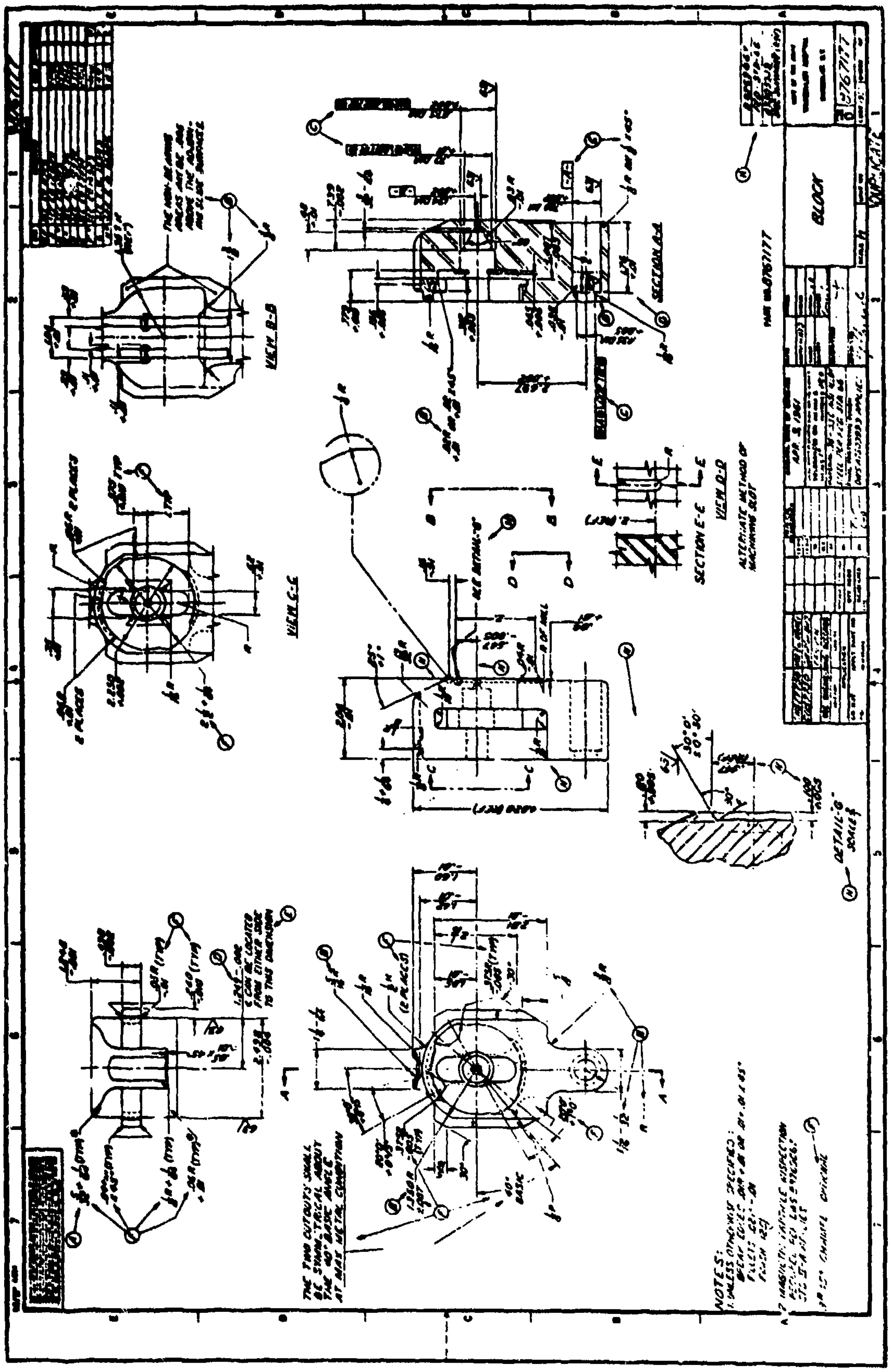


Figure 3-2. Breechblock

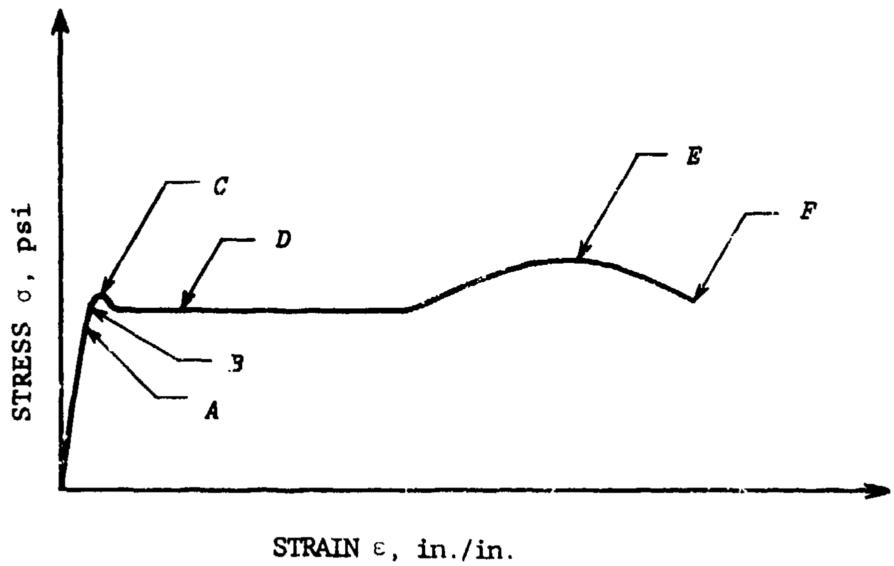
Downloaded from http://www.everyspec.com

3-8 MATERIALS

The selection of suitable materials is an important aspect of breech mechanism design. From the increasing number of materials coming into usage, the designer must choose those materials which have the optimum mechanical properties for the requirements of breech mechanism components. These requirements include environmental spectra of the weapon and the geographical location, loads, and rate of loading. Coupled closely with material selection are manufacturing process, heat treatment, surface finishing, and potential failure modes. Pars. 1-8 and 2-28, and Chapter 4 provide additional information.

A mechanical property is a measure of some behavior of a material when subjected to a given type of loading. A stress-strain curve for a member subjected to direct axial tensile and compressive loads is used in the determination of many of the common mechanical properties. A typical stress-strain curve for mild steel is given in Fig. 3-3.

Important mechanical properties shown in this curve are the proportional limit *A*, the elastic limit *B*, the upper and lower yield points *C* and *D*, the ultimate stress *E*, and the breaking stress *F*. The slope of the stress-strain curve for stresses below the proportional limit is defined as the material modulus of elasticity. The modulus of



A Proportional Limit

B Elastic Limit

C Higher Yield Point

D Lower Yield Point

E Ultimate Stress

F Breaking Stress

Figure 3-3. Stress—Strain Diagram in Mild Steel

Downloaded from http://www.everyspec.com

resilience is the amount of energy stored in a unit volume of material which is stressed to the proportional limit, i.e., the area under the stress-strain diagram up to the proportional limit. The toughness of a material is the energy absorbed by a unit volume of the material in loading to fracture, i.e., the area under the complete stress-strain diagram. Ductility is the ability of a material to withstand large permanent deformation without failure. The strain at fracture is one good measure of ductility.

Other important material mechanical properties include Poisson's ratio, the ratio of transverse to axial strain in uniaxial stress; endurance limit, the stress causing failure under infinite cyclic loading; notch sensitivity, sensitivity of a material to stress concentrations under fatigue loading; and hardness, the resistance of a material to scratching, abrasion, cutting, or penetration.

A factor that influences material performance is surface treatment which is applied to the member to improve one or more of the properties of the material. In most cases the process is used primarily to increase such properties as wear and corrosion resistance. The commonly used processes are:

1. Cold working (shot peening, cold rolling, stretching)
2. Surface hardening (carburizing, nitriding, cyaniding, flame hardening, induction hardening)
3. Plating (chromium, zinc, cadmium)
4. Surface finishing (Parkerizing, Parco Lubrite, Lubrite).

3-9 BREECH MECHANISM INTEGRATION WITH WEAPON SYSTEM

The design sequence cannot proceed very far before the several interfaces of the breech mechanism with other gun subsystems must be fully taken into account. Effectiveness of the total weapon and realization of desired requirements will not be met—no matter how well any one subsystem is designed (including the breech)—if design integration between affected interfaces or collaborating groups is not made. The groundwork of presenting the various important interfaces between breech mechanisms and the rest of the weapon, including the user, is described in Chapters 1 and 2. Proper integration of all subsystems of the weapon requires systematic liaison with the other engineering groups throughout the design sequence.

3-10 INTERFACE WITH ANALYSIS

Mathematical analysis is a tool of great importance in breech mechanism design. The designer must frequently use the results of mathematical analysis during the performance of his tasks. A free interplay between design and analysis during prototype development provides the best ground for success. Section III provides examples of the analytical techniques commonly used to confirm that performance and reliability requirements will be achieved. Although these analyses often are performed by analytical groups, the designer should be familiar with the analyst's capabilities and limitations.

SECTION III. DESIGN ANALYSIS

The importance of mathematical analysis to the design of breech mechanisms cannot be overemphasized. The high firing loads and accelerations imposed on the breech components must be determined to allow sizing of parts and material selection. Several kinds of mathematical analysis are conducted during the design process. These include kinematic, kinetic, stress, weight, and reliability analyses. The paragraphs that follow discuss each of these types of analysis.

Par. 3-16 presents a brief discussion of the role of the digital computer in mathematical analysis.

Downloaded from http://www.everyspec.com

The section concludes with illustrative calculations applied to typical breech component designs.

3-11 KINEMATIC ANALYSIS

Kinematics is that branch of mechanics which is concerned with the motion of a body without consideration of the forces required to produce that motion. Kinematics treats the relationships between displacement, velocity, and acceleration.

Kinematic analysis plays an important role in the design of breech mechanisms. Definite relations must be maintained between the motions of the various subcomponents of the breech as well as between breech motions and firing and recoil of the weapon.

Breechblocks that are operated manually, usually the interrupted-thread type, generally consist of relatively low speed mechanisms. Velocities and accelerations are unimportant in the design of these mechanisms. Therefore, the kinematic analysis takes the form of determining the displacements of the various breech components to ensure proper functions and clearances between parts. The design layouts (pars. 3-6 and 3-7) and prototype models (par. 3-19) are sufficient for these purposes and no detailed mathematical analysis is necessary.

Automatic or semiautomatic operation of a weapon places stringent requirements on the kinematics of the breech components. High velocities and accelerations are frequently required to meet the specified firing rates. A thorough mathematical kinematic analysis is required to ensure satisfactory operations of the breech mechanism for this case. Par. 3-1 1 contains a typical example of the type of kinematic analysis required for the determination of the motion of the breech operating crank of the 75 mm, T83 Gun. This gun has a sliding-wedge type of breech as do most automatically operated weapons. The general operation of this type of breech is described in par. 2-11.

3-12 KINETIC ANALYSIS

Kinetics is that branch of mechanics which is concerned with the action of unbalanced forces acting on a body and the motion produced by these forces. Kinetics and kinematics (discussed in par. 3-11) form the general area of mechanics called dynamics. Various procedures are available for the analysis of bodies subjected to unbalanced forces. All of these procedures have Newton's laws of motion as their basis. The particular procedure most useful for solving a given problem depends on the forces acting (constant or variable) and the results to be obtained (displacements, velocities, accelerations, forces, etc.). Kinetic analyses by force, mass, and acceleration; by work and energy; and by impulse and momentum are all commonly used in the development of breech mechanisms.

As in the case of mathematical kinematic analysis, kinetic analysis of breech mechanisms is confined mainly to breeches which are automatic or at least partially automatic in operation. The forces and torques necessary to activate the various components of the breech mechanism are found by kinetic analysis so that they can in turn be used to determine the stresses in these components. A sample kinetic analysis of the breech operating crank of the 75 mm, T83 Gun is given in par. 3-17.2. Work-energy and impulse-momentum procedures are used in par. 3-17.3 to obtain recoil parameters which are necessary for the breech analysis.

3-13 STRESS ANALYSIS

Stress analysis is the determination of the internal force intensities (stresses) in a member subjected to mechanical, thermal, and/or inertial loading. The techniques used in stress analysis of breech components vary from the simple methods of elementary strength of materials (see, for example, Ref. 2) to highly sophisticated computerized finite element procedures (see par. 3-16).

Although high temperatures are involved at the breech firing chamber interface, thermal

Downloaded from http://www.everyspec.com

stresses are normally quite low in the breech components and are seldom calculated. Mechanical and inertial loads are high in many of the breech components and must be determined to insure the design will meet all specifications. Sample stress calculations for typical breech components are given in pars. 3-17.4 through 3-17.8 for open and closed breech rings, a sliding block, an interrupted-thread block, and the threads of an interrupted-thread block.

3-14 WEIGHT ANALYSIS

One aspect of the analytical effort which frequently is neglected is consideration of weight, material distributions, and material efficiency (Ref. 3). This is unfortunate since weight requirements are extremely important to the concepts of land and air mobility. The analytical techniques of determining part weight and center of gravity location are well known and will not be documented here; however, some comments on the importance of weight control as it affects the breech mechanism design are in order.

The breech mechanism, particularly the block, is a part of the recoiling weight of the weapon. Furthermore, the total recoiling weight is established from consideration of firing rate and weapon stability. This means that the breech weight must be established relatively early in the design process and, once established, is not easily changed. Therefore, the breech designer frequently is faced with the task of designing a block with the restraint of a fixed value of weight, in addition to the usual restraints of space, strength, and symmetry.

It is recommended that individual part and assembly weights be computed during the design phase and updated as necessary. Similarly, the center of gravity location should be calculated for the breech assembly as input to the weapon dynamics and stability efforts. For more detailed information, the reader is referred to DARCOM-P 706-193, Engineering Design Handbook, *Computer Aided Design of Mechanical Systems, Part Two*, for weight economy (Ref. 3).

3-15 RELIABILITY ANALYSIS

Reliability is the probability at a given confidence level that an equipment will perform a specific mission without failure for a specified time period and under specified load/stress conditions.

Reliability depends to a large extent on proper manufacturing procedures and quality control tests, but the weapon design engineer makes major contributions in this field—reliability must be designed into the weapon; it cannot be built, analyzed, or tested in. Consequently, it is extremely important that the designer understand reliability concepts and methodology so that he can enlist the support of the analyst, the test engineer, and the manufacturer.

Modern reliability methodology is derived from the mathematics of probability and statistics and, when effectively applied, demands the close cooperation of all engaged in the design, production, and testing of the item. A detailed discussion cannot be presented here; the reader is referred to such books as Lloyd and Lipow (Ref. 4) and to the DARCOM Handbook series on reliability, particularly handbooks identified by Ref. 5-8. However, various means of achieving reliability are summarized.

The more complex a system, the greater the chance of failure (other things being equal). If reliability is expressed as the probability of successful operation, then the reliability of the system is equal to the product of the probabilities of successful operation of its parts, provided they are statistically independent. Thus, it is possible to increase the reliability of a breech mechanism by making it as simple as its performance requirements permit—by using as few subsystems and components as possible that must function to carry out the mission of the system as a whole.

Redundancy by overdesigning or providing alternate systems often provides a direct counter to the product rule of reliability, i.e., the more alternate subsystems there are, the greater the probability that one of them, and therefore the whole system, will operate satisfactorily. Redundancy of mechanical equipment such as breech

Downloaded from http://www.everyspec.com

mechanisms and firing mechanisms is difficult and frequently impossible to achieve; however, it should not be dismissed without consideration. By carefully designing for maximum strength-to-weight ratio, the designer often can improve "safety" or "overdesign" factors without increasing size and weight.

Components, subsystems, and materials which have demonstrated field reliability should be used whenever possible. This will increase the probability that these items will be reliable in the new design. Designs which are "at a limit of experience" should only be used when this is necessary to achieve a specific requirement. New systems or components should be subjected to accelerated life and environmental tests whenever possible as part of the design development and reliability demonstration.

Reliability is further increased in the detail design phases by specifying the proper materials and protective finishes, by designing against the extreme environments encountered (particularly climatic extremes, shock, and vibration), and by providing the best and most practical types of lubrication for field conditions.

3-15.1 MECHANICAL SYSTEM LIMITATIONS

In spite of the rapid growth and wide usage of reliability analysis, the techniques presently available have severe limitations in their application to mechanical systems. It is generally conceded that the state of the art of reliability prediction for nonelectronic components is not nearly as far advanced as the techniques used for electronic components and systems. To the extent that reliability predictions in the electronics field are based upon data obtained from large-scale reliability tests, there is, with few exceptions, no parallel to be found in the case of mechanical elements. The reason is simply the complexity of mehanical failure phenomena such as:

1. Excessive elastic deflection
2. Elastic buckling
3. Plastic deformation
4. Creep and relaxation
5. Fracture
6. Fatigue
7. Wear.

Furthermore, the accumulation of failure-rate data for mechanical elements is slow due to the necessarily long time and high cost involved. Nevertheless, some understanding of the operational life of equipment is useful to the modern gun designer.

Mortality curves attempt to describe the various phases in the life cycle of a product. Fig. 3-4(A) shows the cumulative total number of failures plotted against the life of the product; the zero on the abscissa refers to the product being completed. Shortly after that, as various performance and acceptance tests are run, failures occur at a rapid rate. These failures, known as the "infant mortality" phase in the life of the part, are caused by workmanship errors, major design errors, etc. As these initial defects are remedied, failures drop off to a lower rate which represents the normal operating conditions. In this phase (constant-hazard-failures), failures occur mainly as a result of some other part within the system. These failures are truly random. This lower rate of failure occurrence continues for a relatively long time throughout the useful life of the product. Finally, the end of the normal life span is reached and the parts begin to wear out, raising the rate of failure accumulation.

In Fig. 3-4(B), instead of plotting accumulated failures, the mean time between failures (MTBF) is shown. The MTBF is relatively low in early life, higher during the normal life span of the product and again lower during the wear-out phase. In Fig. 3-4(C) "failure rate" is plotted against time.

In view of the fact that the region of constant hazard failures (useful life) has demanded major attention in the study of reliability, attempts were made to formulate it numerically. For this purpose reliability was stated quantitatively as the probability that a part of a system will perform a specified function, under specified conditions, for a specified time. This probability may

Downloaded from http://www.everyspec.com

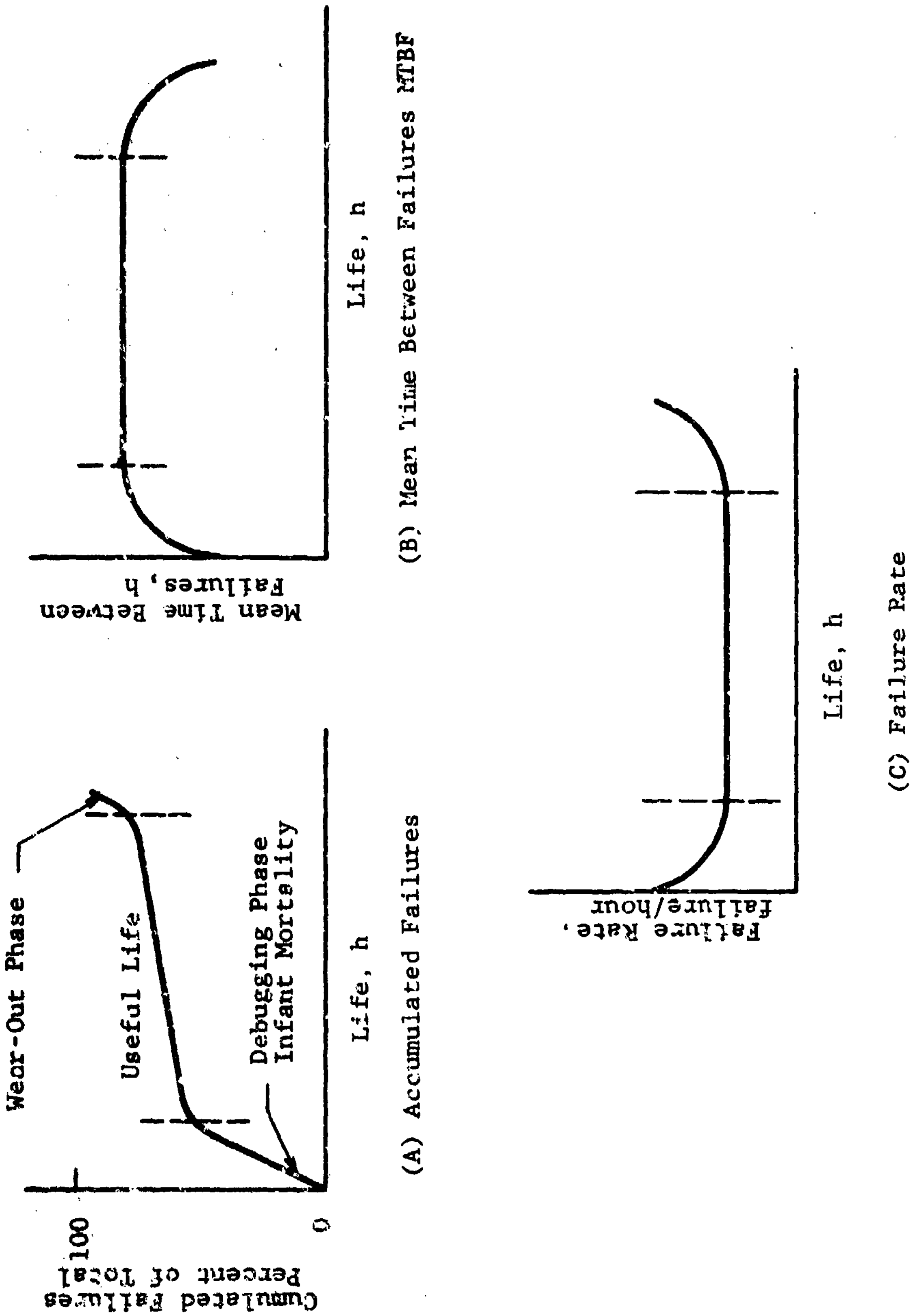


Figure 3-4. Mortality Curves

Downloaded from http://www.everyspec.com

be assumed to be an exponential function relating the constant failure rate of the system to time for which the reliability is to be estimated. This "exponential failure law" gives the probability of survival P_s as

$$P_s = \exp(-\lambda T) \qquad (3\text{-}1)$$

where λ is the failure rate (number of failures per unit of time) and T is the period of operation for which the probability of survival is being solved. Since failure rate is the reciprocal of MTBF, the reliability can also be stated as

$$P_s = \exp(-T/\bar{\theta}) \qquad (3\text{-}2)$$

where $\bar{\theta}$ is the MTBF expressed in the same time units as T (usually hours).

Thus, if the failure rate of a part or a system is known, one can predict its reliability. This, of course, is based on the assumption that the exponential failure law holds. The reliability nomograph (Fig. 3-5) allows a rapid solution to Eqs. 3-1 and 3-2. A sample reliability analysis based on constant failure rate is given in par. 3-17.9.

3-15.2 STANDARD PREDICTION TECHNIQUES

The real value of any numerical expression lies in the information it conveys and the use made of that information. Reliability predictions do not, in themselves, contribute significantly to the reliability of a system. Rather, they constitute criteria for selecting courses of action that affect reliability. Persons making reliability predictions should be aware of the role of prediction in improving and assuring reliability.

The techniques of making reliability predictions on mechanical equipment such as breech mechanisms are many and complex. Therefore, the designer is referred to various books on the subject (Refs. 5-8, and 9-20). A very general step-by-step procedure is presented.

1. Define the system.
2. Define failure.
3. Define operating and maintenance conditions.
4. Construct reliability block diagram(s).
5. Develop reliability formula.
6. Compile parts lists.
7. Perform stress analyses.
8. Assign failure rates or probabilities of survival.
9. Combine part failure rates (or probabilities of survival.)
10. Modify preliminary block failure rates or reliabilities.
11. Compute system reliability.

3-15.3 PROBABILISTIC DESIGN

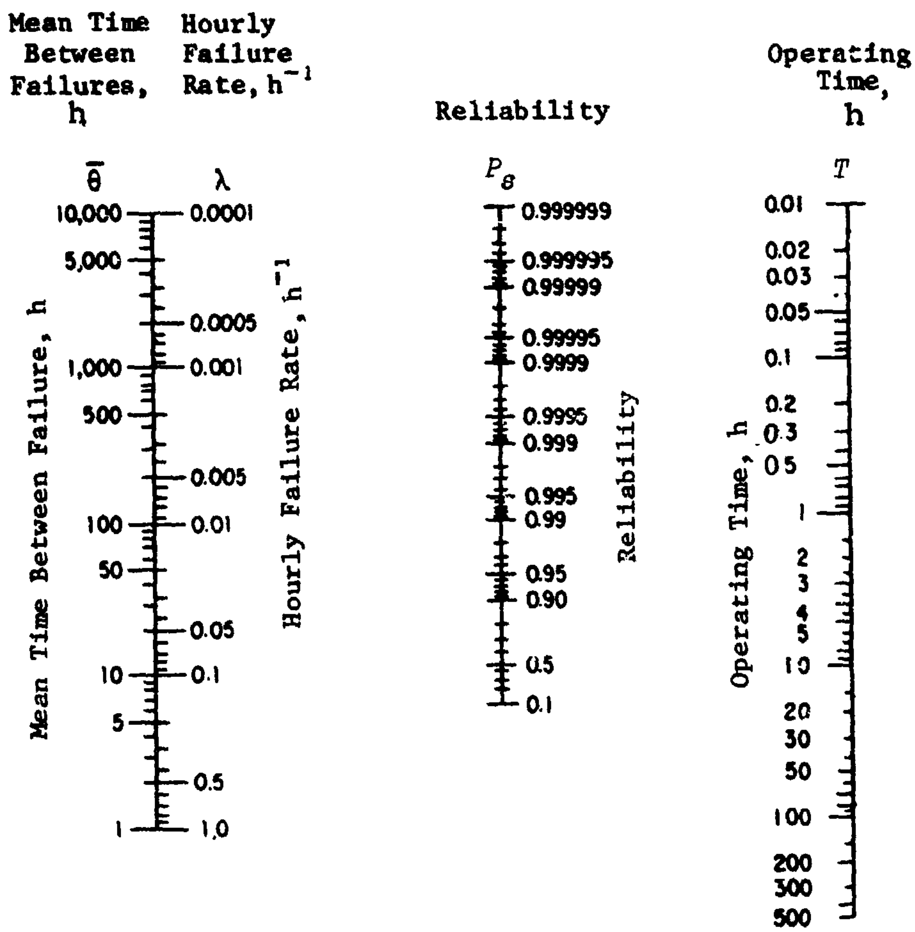
Probabilistic design is one of the more recent developments of reliability methodology. It is particularly applicable to mechanical reliability problems in the form of a stress/strength interference theory. Unfortunately the theory results in procedures that are, in most cases, difficult to conduct, time-consuming, and expensive. In addition, the lack of adequate information on the variance of mechanical properties frequently renders the technique useless.

A complete discussion of the stress/strength interference theory is beyond the scope of this design handbook, and the reader is referred to Refs. 9-16. However, the basic ideas involved are of interest to the breech mechanism designer and particularly useful in the assignment of safety factors.

The basic idea behind reliability is that a given part has certain physical strength properties which, if exceeded, will result in failure. Further, this property, as all properties of nonhomogeneous materials, varies from specimen to specimen. Thus, for a particular part or material an estimate of the mean value and of dispersion of the strength property may be found by testing.

The operating stress imposed on a part varies as well as the strength. These stresses vary from time to time in a particular part, from part to part in a particular design, and from environment to environment. An estimate of the mean value and of the dispersion value of the operating stress must be determined by test, analysis, or experiment.

Downloaded from http://www.everyspec.com



To solve equation $P_S = \exp(-T/\bar{\theta})$ connect T and $\bar{\theta}$ with a straight line and read value of P_S.

Figure 3-5. Reliability Nomograph

Thus, two consistent distributions are available (refer to par. 3-17.9). By referring to Fig. 3-6 it is seen that these distributions can be placed side by side graphically at their respective means and compared. Note, however, that the shaded area of the distribution represents a pseudoarea of interference. This area is only representative of the interference and is not a measure of the interference, i.e., the probability of a particular stress exceeding a particular strength is itself a distribution. The determination of the interference distribution is difficult for most assumed distributions of stress and strength, and random techniques such as Monte Carlo must be used. However, for normal distributions, the interference distribution function can be obtained mathematically (Ref. 17).

3-16 COMPUTER USAGE

The role of the digital computer in the analysis and design of equipment is well established. The advantages offered to analytical design—i.e.,

Downloaded from http://www.everyspec.com

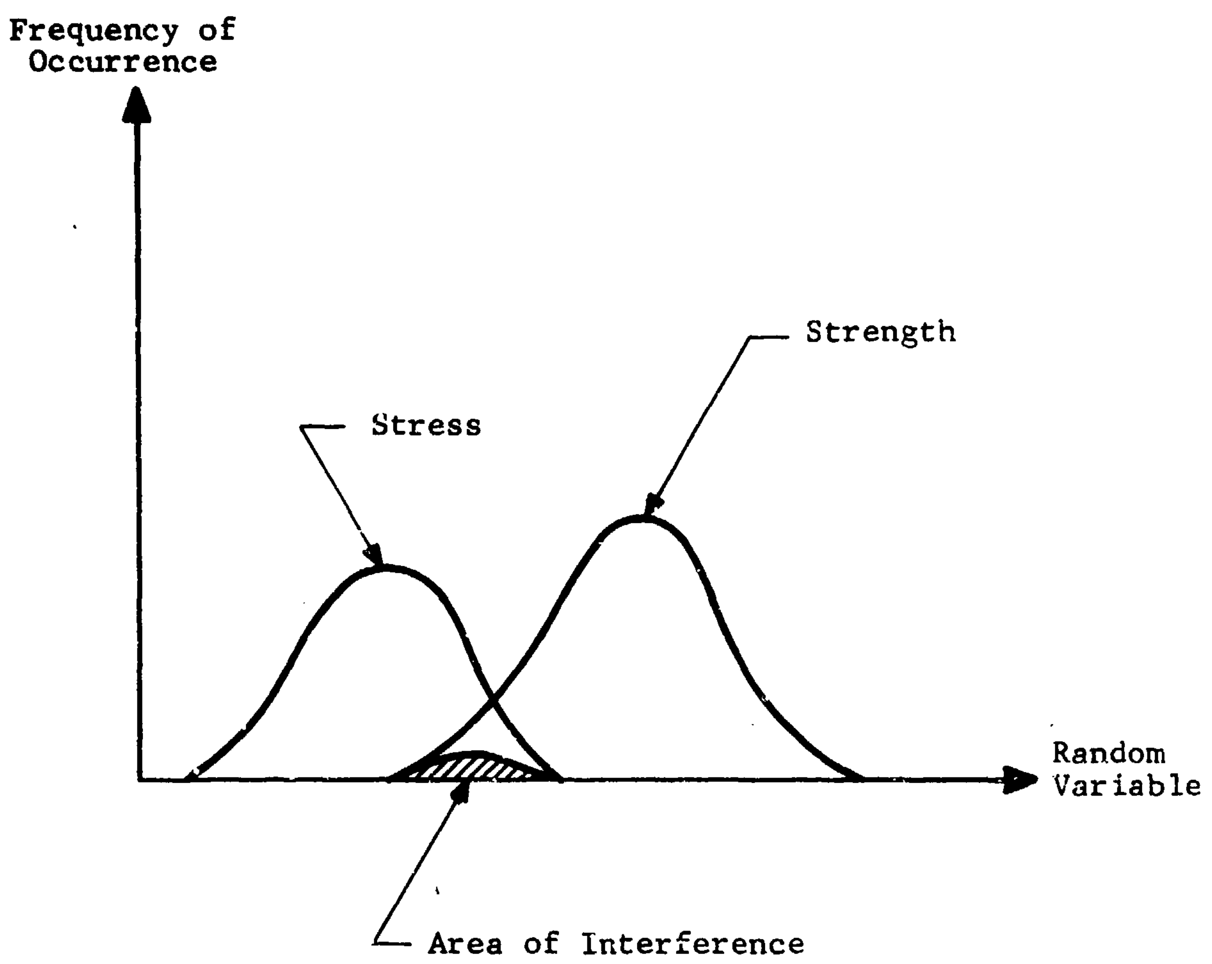


Figure 3-6. Typical Stress—Strength Interaction Diagram

calculation speed, numerical accuracy, ideal repeatability with variable inputs and graphical output—should receive consideration as part of the design effort. Refs. 3 and 18 enlist the service of the computer for the solution of mechanical design problems. Here methods are described for arriving at optimal solutions to design problems through the use of a consistent set of computational techniques. The class of problems treated is formulated concisely in terms of design and state variables that occur in mechanical design. A steepest-decent approach is developed for mechanical system design.

3-17 TYPICAL BREECH COMPONENT ILLUSTRATIVE DESIGN CALCULATIONS

The analyses described in pars. 3-11 through 3-15 are illustrated in this paragraph. Example calculations are provided for kinematic and

Downloaded from http://www.everyspec.com

kinetic analyses of a breech operating crank (pars. 3-17.1 and 3-17.2), dynamic analysis of breech recoil parameters (par. 3-17.3), stress analysis of open and closed breech rings (pars. 3-17.4 and 3-17.5), stress analysis of sliding block (par. 3-17.6), stress analysis of an interrupted-thread block (par. 3-17.7), stress analysis of block thread (par. 3-17.8), and constant failure rate reliability analysis (par. 3-17.9).

3-17.1 KINEMATIC ANALYSIS OF BREECH OPERATING CRANK

An example of kinematic analysis is the determination of the motion of the breech operating crank in the 75 mm. T83 Gun. Motions only during the counterrecoil of the gun will be considered. A description of the action of the mechanism follows.

During counterrecoil (Fig. 3-7), the gun moves forward and the cam follower on the breech operating crank strikes the breech operating cam, which is fixed to the gun cradle. As the gun moves toward the battery position, the operating cam forces the operating crank to rotate downward.

Fig. 3-8 schematically shows the breech operating crank in three positions during the counterrecoil:

1. Follower at the point of initial contact with the cam.
2. Follower at the point where the cam changes from a straight to a curved profile.
3. Follower at an arbitrary point on the curved portion of the cam.

Due to the discontinuity in the curvature of the cam, i.e., a straight line section and a curved section of constant radius, two equations are required to express the rotation of the operating crank with respect to time during counterrecoil. These are Eqs. 3-6 and 3-11.

From Fig. 3-8 (and where symbols are defined) when the follower is between positions 1 and 2,

$$d_c = R_b \sin\theta_1 + R_b \cos(\theta_T - \theta), \text{ in.} \quad (3\text{-}3)$$

Downloaded from http://www.everyspec.com

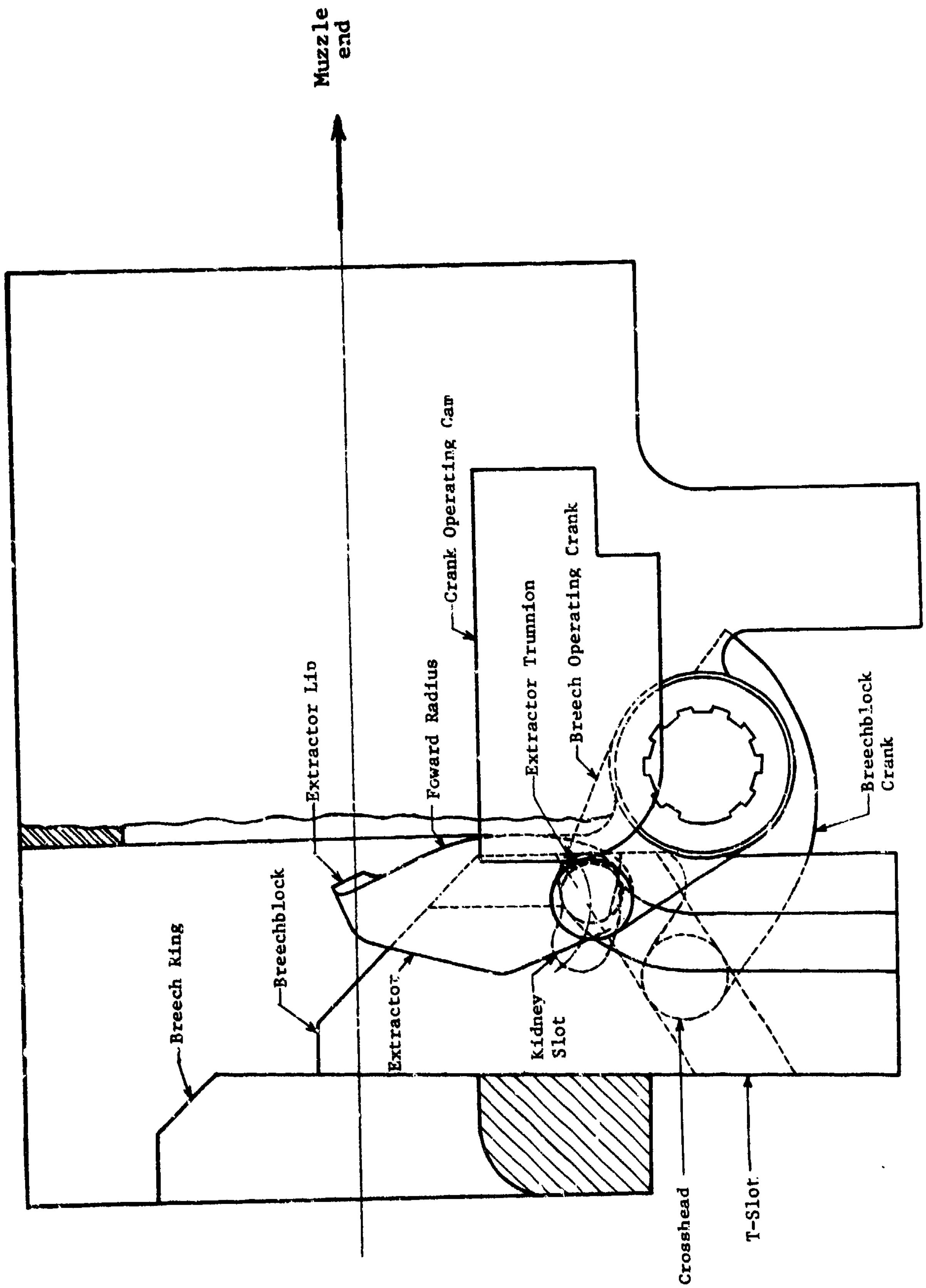
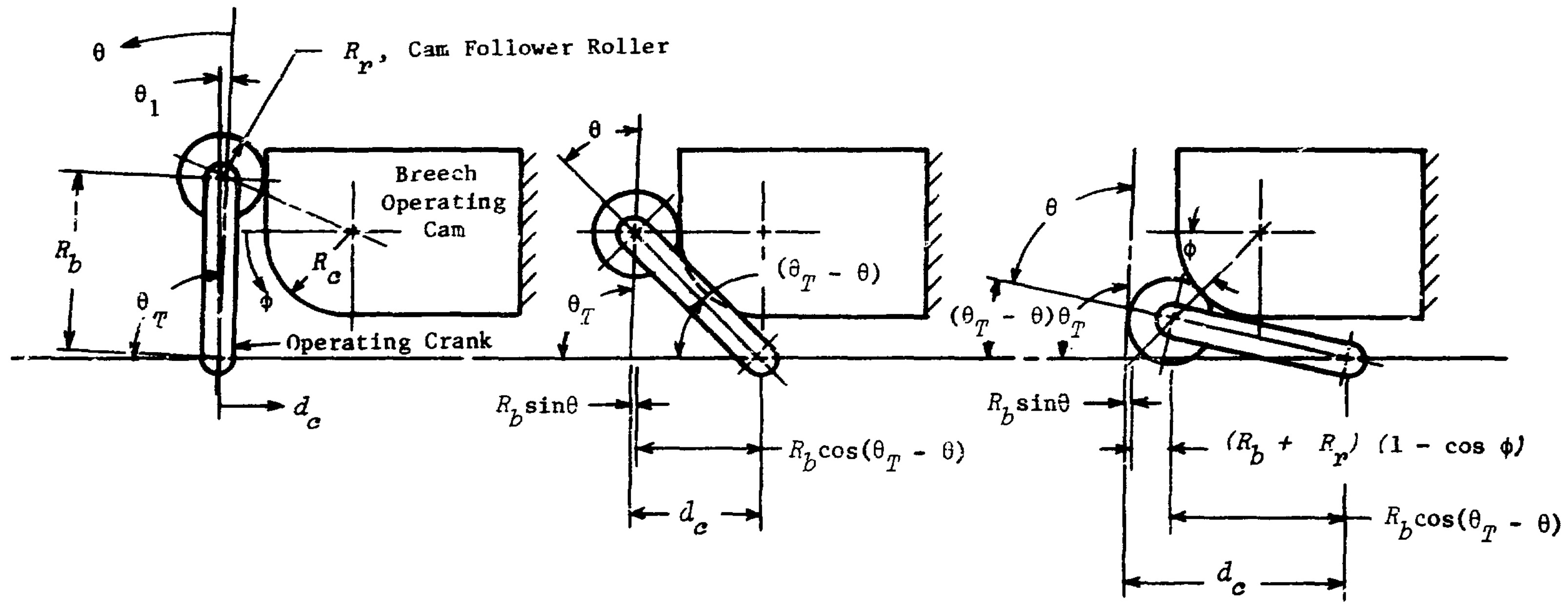


Figure 3-7. Breech Operating Linkage

Downloaded from http://www.everyspec.com



Position 1

Cam follower in position of initial contact with cam

Position 2

Cam follower at tangent point of cam straight and curved surfaces

Position 3

Cam follower at an arbitrary position on curved portion of cam

R_r = cam follower roller radius, in.

R_c = operating cam radius, in.

R_b = operating crank arm radius, in.

θ = instantaneous crank angle, deg ($0 \le \theta \le \theta_T$)

d_c = displacement of breech operating cam from point of initial contact with follower, in.

θ_T = total angular rotation of crank, deg

θ_1 = initial crank angle, deg ($\theta_1 = \theta_T - 90°$)

ϕ = angular position of cam follower on curved portion of cam surface

Figure 3-8. Breech Operating Geometry

Downloaded from http://www.everyspec.com

but

$$\theta_T = 90° + \theta_1, \text{ deg} \tag{3-4}$$

therefore

$$d_c = R_b \sin\theta_1 + R_b \sin(\theta - \theta_1), \text{ in.} \tag{3-5}$$

or

$$\theta = \text{Sin}^{-1}\left(\frac{d_c - R_b \sin\theta_1}{R_b}\right) + \theta_1, \text{ deg.} \tag{3-6}$$

Differentiating Eq. 3-5 with respect to time

$$\dot{\theta} = \dot{d}_c \Big/ [R_b \cos(\theta - \theta_1)] \tag{3-7}$$

and

$$\ddot{\theta} = \frac{\ddot{d} + R_b \dot{\theta}^2 \sin(\theta - \theta_1)}{R_b \cos(\theta - \theta_1)} \tag{3-8}$$

Similarly from Fig. 3-8, when the follower is between positions 2 and 3,

$$d_c = R_b \sin\theta_1 + R_b \cos(\theta_T - \theta) + (R_c + R_r)(1 - \cos\phi), \text{ in.} \tag{3-9}$$

where

$$\cos\phi = \frac{\sqrt{(R_c + R_r)^2 - [(R_c + R_r) - R_b \cos(\theta - \theta_1)]^2}}{R_c + R_r} \tag{3-10}$$

therefore

$$\begin{aligned} d_c = {} & R_b \sin\theta_1 + R_b \sin(\theta - \theta_1) + (R_c + R_r) \\ & - \sqrt{(R_c + R_r)^2 - [(R_c + R_r) - R_b \cos(\theta - \theta_1)]^2}, \text{ in.} \end{aligned} \tag{3-11}$$

from which θ can be factored. Differentiating Eq. 3-11 with respect to time

$$\begin{aligned} \dot{d}_c = {} & R_b \dot{\theta} \cos(\theta - \theta_1) - 0.5 \left\{ (R_c + R_r)^2 - [(R_c + R_r) - R_b \cos(\theta - \theta_1)]^2 \right\}^{-1/2} \\ & \times 2[(R_c + R_r) - R_b \cos(\theta - \theta_1)] R_b \dot{\theta} \sin(\theta - \theta_1) \end{aligned} \tag{3-12}$$

from which $\dot{\theta}$ can be factored; and

$$\begin{aligned} \ddot{d}_c = {} & R_b \ddot{\theta} \cos(\theta - \theta_1) - R_b \dot{\theta}^2 \sin(\theta - \theta_1) \\ & - 0.5 \left\{ (R_c + R_r)^2 - [(R_c + R_r) - R_b \cos(\theta - \theta_1)]^2 \right\}^{-1/2} \\ & \times \left\{ 2[(R_c + R_r) - R_b \cos(\theta - \theta_1)] \right. \\ & \left. \times \left[R_b \ddot{\theta} \sin(\theta - \theta_1) + R_b \dot{\theta}^2 \cos(\theta - \theta_1) + 2R_b^2 \dot{\theta}^2 \sin^2(\theta - \theta_1) \right] \right\} \\ & + 4\left[(R_c + R_r) - R_b \cos(\theta - \theta_1) \right]^2 [R_b \dot{\theta} \sin(\theta - \theta_1)]^2 \\ & \times \left\{ 0.25(R_c + R_r)^2 - [(R_c + R_r) - R_b \cos(\theta - \theta_1)]^2 \right\}^{-3/2} \end{aligned} \tag{3-13}$$

Downloaded from http://www.everyspec.com

from which $\ddot{\theta}$ can be factored.

3-17.2 KINETIC ANALYSIS OF BREECH OPERATING CRANK

A kinetic analysis is concerned with the forces required to produce a given motion, in this instance, the motion of the breechblock. The breech operating crank and the breechblock crank rotate simultaneously (being splined to the same shaft) and displace the breechblock downward by means of the T-slot roller motion in the inclined T-slot in the breechblock (Fig. 3-9).

Therefore, the equation relating angular rotation θ of the cranks to linear displacement x of the breechblock is

$$x = \frac{R - r_4}{\cos\alpha_b} - \frac{R\cos\theta - r_4}{\cos\alpha_b}$$

or

$$x = \frac{R(1-\cos\theta)}{\cos\alpha_b} \quad (3\text{-}14)$$

Differentiating with respect to time yields

$$\dot{x} = \frac{R}{\cos\alpha_b}(\dot{\theta}\sin\theta) \quad (3\text{-}15)$$

$$\ddot{x} = \frac{R}{\cos\alpha_b}(\ddot{\theta}\sin\theta + \dot{\theta}^2\cos\theta). \quad (3\text{-}16)$$

By taking the sum of the moments about the center of the operating shaft and neglecting friction (Fig. 3-10), the following torque equation is obtained:

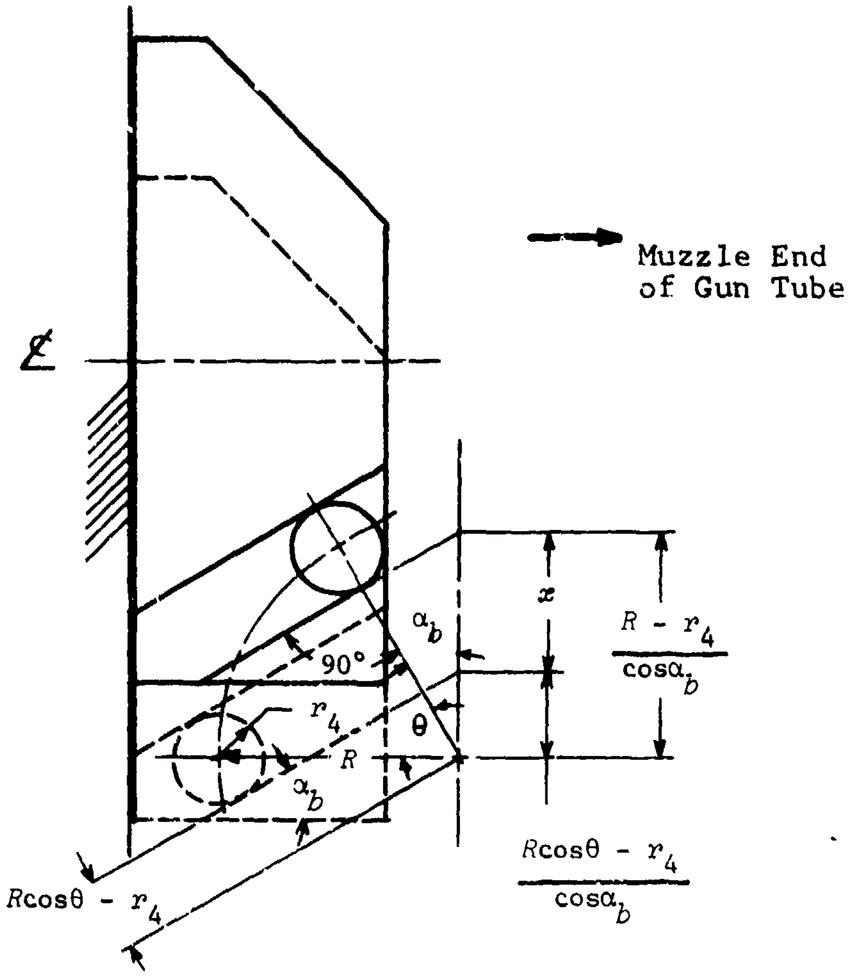
$$M_4 = M_b\ddot{x}\frac{R\sin\theta}{\cos\alpha_b} + kh_s(\theta + \theta_c) \quad (3\text{-}17)$$

where M_4 is the torque on the breech operating crank shaft and substituting the expression for $\ddot{x}$ from Eq. 3-16 into Eq. 3-17

$$M_4 = M_b\frac{R\sin\theta}{\cos\alpha_b}\left[\frac{R}{\cos\alpha_b}(\ddot{\theta}\sin\theta + \dot{\theta}^2\cos\theta)\right] + kh_s(\theta + \theta_c), \text{ lb·in.} \quad (3\text{-}18)$$

The criterion for separation of the breech operating crank from the cam is the condition that M_4 in Eq. 3-18 becomes zero. This can be found by using Eqs. 3-7 and 3-8, and Eqs. 3-12 and 3-13 for the values of $\dot{\theta}$ and $\ddot{\theta}$. For the 75 mm,

Downloaded from http://www.everyspec.com



R = radius of breechblock crank, in.

r_4 = T-slot roller radius, in.

x = breechblock displacement, in.

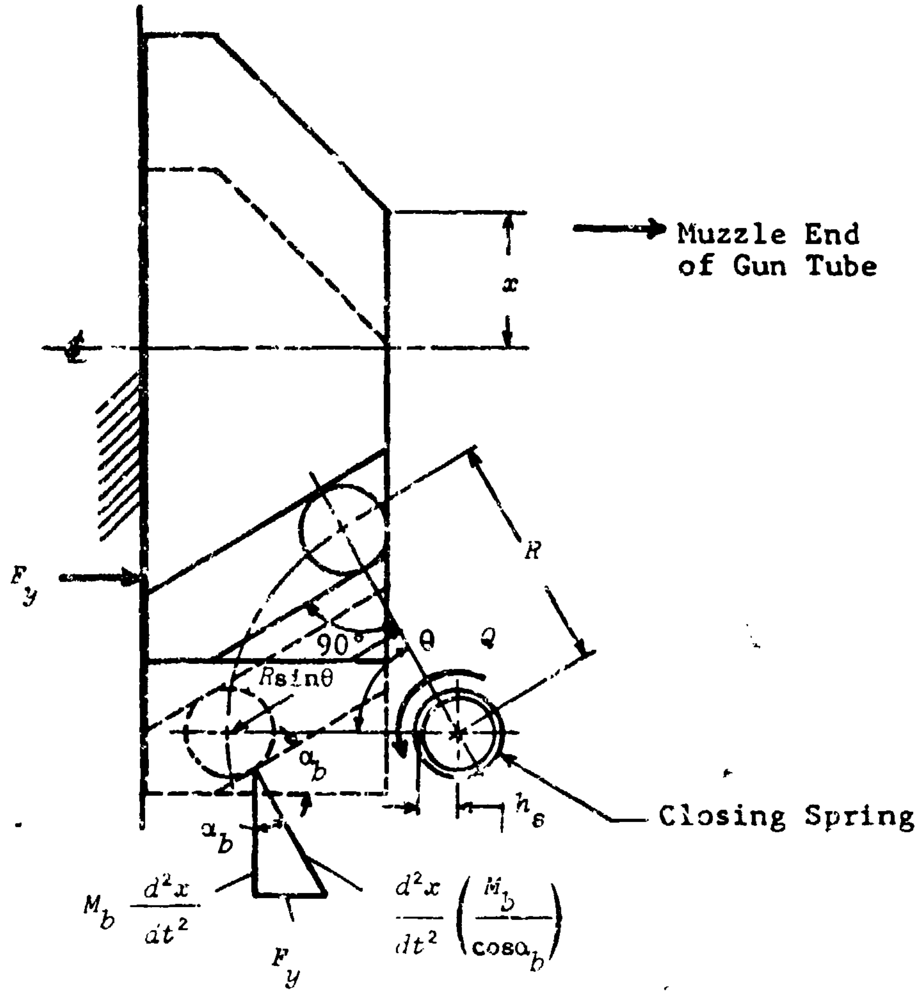
α_b = fixed angle between the horizontal and the T-slot in breechblock, deg

θ = instantaneous crank angle, deg

Figure 3-9. Breechblock Motion

T83 Gun, the curve for torque versus angular rotation is shown in Fig. 3-11. As indicated in the figure when θ is approximately 64.5 deg, M_4 becomes zero and the breech operating crank separates from the cam. The remaining portion of the curve, shown by a dotted line, is hypothetical since the follower is no longer in contact with the cam surface.

Downloaded from http://www.everyspec.com



M_s = spring force lever arm distance, in.

k = spring constant for closing spring, lb/deg

M_b = mass of breechblock and components, lb·s^2/in.

Q = momentum at shot ejection, lb·s

R = radius of breechblock crank, in.

x = breechblock displacement, in.

α_b = fixed angle between the horizontal and the T-slot in the breechblock, deg

θ = instantaneous crank angle, deg

θ_c = initial angular preload on closure spring, deg

Figure 3-10. Forces Acting on Crank

Downloaded from http://www.everyspec.com

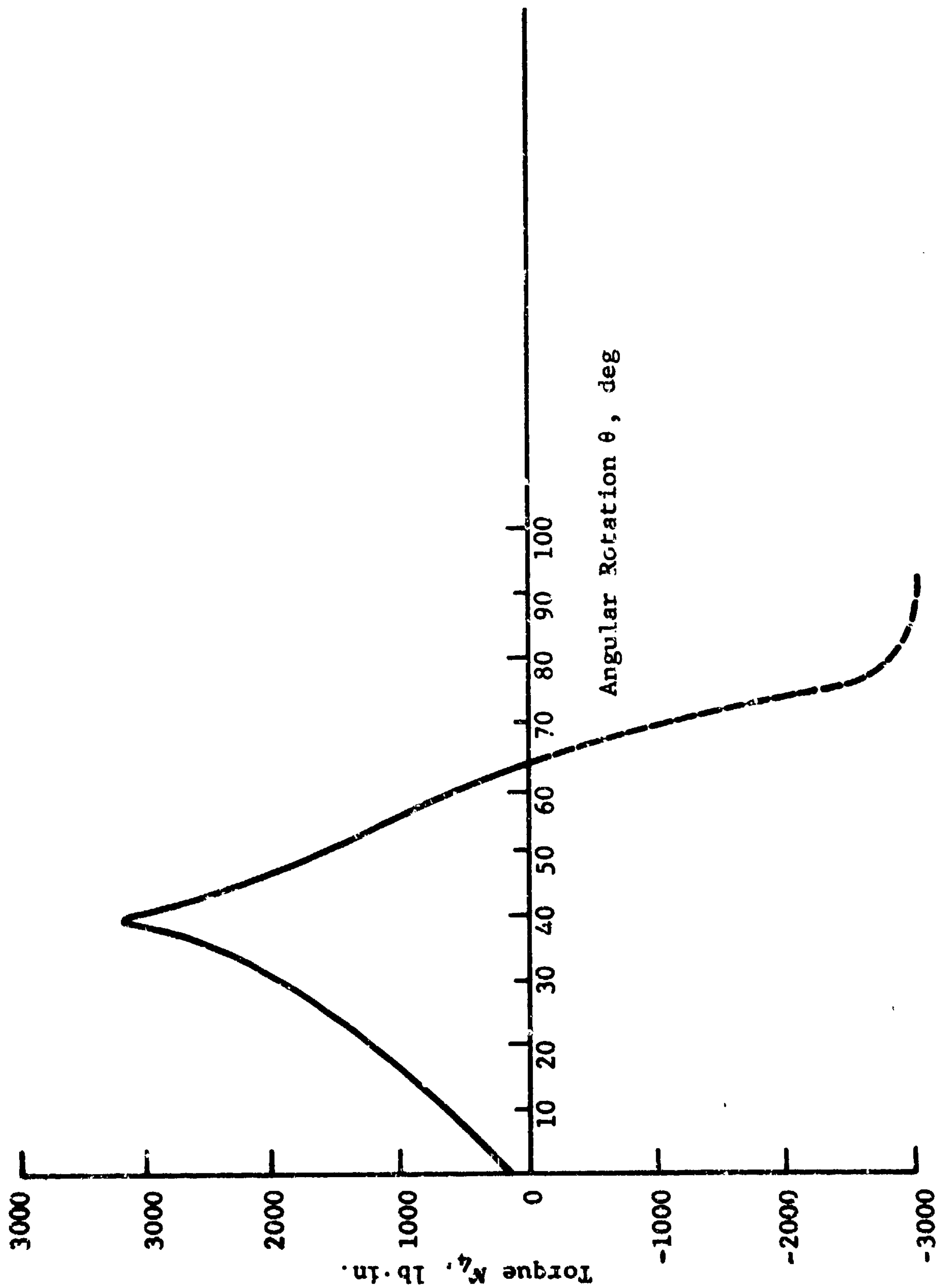


Figure 3-11. Torque Applied to Breechblock Crank

Downloaded from http://www.everyspec.com

3-17.3 DYNAMIC ANALYSIS OF BREECH RECOIL PARAMETERS

In large caliber weapons the breechblock is a portion of the recoiling mass. Therefore the block, firing mechanism, extractors, and actuating mechanism are exposed to high levels of acceleration during recoil. The dynamic shock loads imposed therefore must be considered in the design. Furthermore, the acceleration levels can be determined only from the dynamics of recoil, an example of which follows.

The dynamics of recoil presents a study in the conservation of momentum and energy. From mechanics we have the expressions for the conservation of momentum at shot ejection

$$Q = m_p v_p + m_g v_g, \text{ lb·s} \qquad (3\text{-}19)$$

and

$$Q = m_r v_f, \text{ lb·s} \qquad (3\text{-}20)$$

where

Q = momentum at shot ejection, lb·s
m_p = projectile mass, lb·s²/ft
m_g = propellant mass, lb·s²/ft
m_r = recoiling mass, lb·s²/ft
v_p = projectile velocity, ft/s
v_g = propellant gas velocity, ft/s
v_f = free recoil velocity, ft/s.

This conservation of momentum principle is directly applicable to the recoil activity of guns where one equation represents the momentum of the recoiling mass, and the other represents the total momentum of the projectile and propellant gases moving in the opposite direction.

Instantaneously as the gun is fired and the projectile starts moving, the propellant gas force accelerates the recoiling mass rearward. This motion is resisted by the inertia of the recoiling mass, gun-slide friction, and the recoil mechanism. The force produced by the recoil mechanism is derived from both the recoil brake and the recuperator. Acceleration of the recoiling mass occurs during the time of travel while the projectile is in the bore in addition to the time of pressure decay after the projectile leaves the muzzle.

The momentum imparted to the weapon is found easily from the products of the projectile and propellant mass with their respective velocities at shot ejection. The conservation of momentum equation can then be used to calculate the free recoil velocity v_f of the recoiling mass

$$v_f = \frac{Q}{m_r} = \frac{Qg}{W_r}, \text{ ft/s} \qquad (3\text{-}21)$$

where

W_r = recoiling parts weight, lb
g = acceleration due to gravity, ft/s².

As an example, if the recoil momentum, at maximum charge, for a 105 mm howitzer is 1950 lb·s with the recoiling parts weighing 1150 lb then

$$v_f = \frac{(1950)(32.2)}{1150} = 54.6 \text{ ft/s}.$$

The energy of free recoil energy E_f can now be found from the equation

$$E_f = \frac{W_r v_f^2}{2g}, \text{ ft·lb}. \qquad (3\text{-}22)$$

Evaluating, yields

$$E_f = \frac{1150 \times (54.6)^2}{2 \times 32.2} = 52{,}235 \text{ ft·lb}.$$

This free recoil energy is expended in several ways, namely:

1. A small amount is stored in deflecting the structure and ordinarily may be safely ignored.
2. Some is absorbed by the gun-slide friction.
3. A sufficient amount is stored in the recuperator to return the gun to the in-battery position.
4. The greatest portion is dissipated by the recoil mechanism.
5. The short recoil breech actuator absorbs some recoil energy through torsion of the breech closing spring.

This energy, divided by the length of recoil (stroke), gives the average resistance necessary to stop the recoiling mass.

To this resistance must be added the static force component $W_r \sin\psi$ —ψ is the angle of the

Downloaded from http://www.everyspec.com

elevation and W_r is the weight of the recoiling parts—of the recoiling parts weight. Therefore, the first approximation of the total resistance F_r to recoil is

$$F_r = \frac{E_f}{S} + W_r \sin\psi, \text{ lb} \qquad (3\text{-}23)$$

where

S = recoil stroke, ft
ψ = elevation angle, deg
F_r = resisting force, lb.

The forces acting on a recoiling mass are shown in Fig. 3-12. The differential equation of motion is obtained by summing these forces. Thus:

$$m_r\left(\frac{d^2x}{dt^2}\right) = F_g + W_r \sin\psi - F_r \qquad (3\text{-}24)$$

where

F_g = propellant gas force, lb
$\frac{d^2x}{dt^2}$ = instantaneous acceleration, ft/s².

The propellant gas force must be inserted as a function of time as shown in par. 2-21. The solution of this equation, usually obtained by numerical integration, will yield the acceleration, velocity, and displacement history of the recoiling parts.

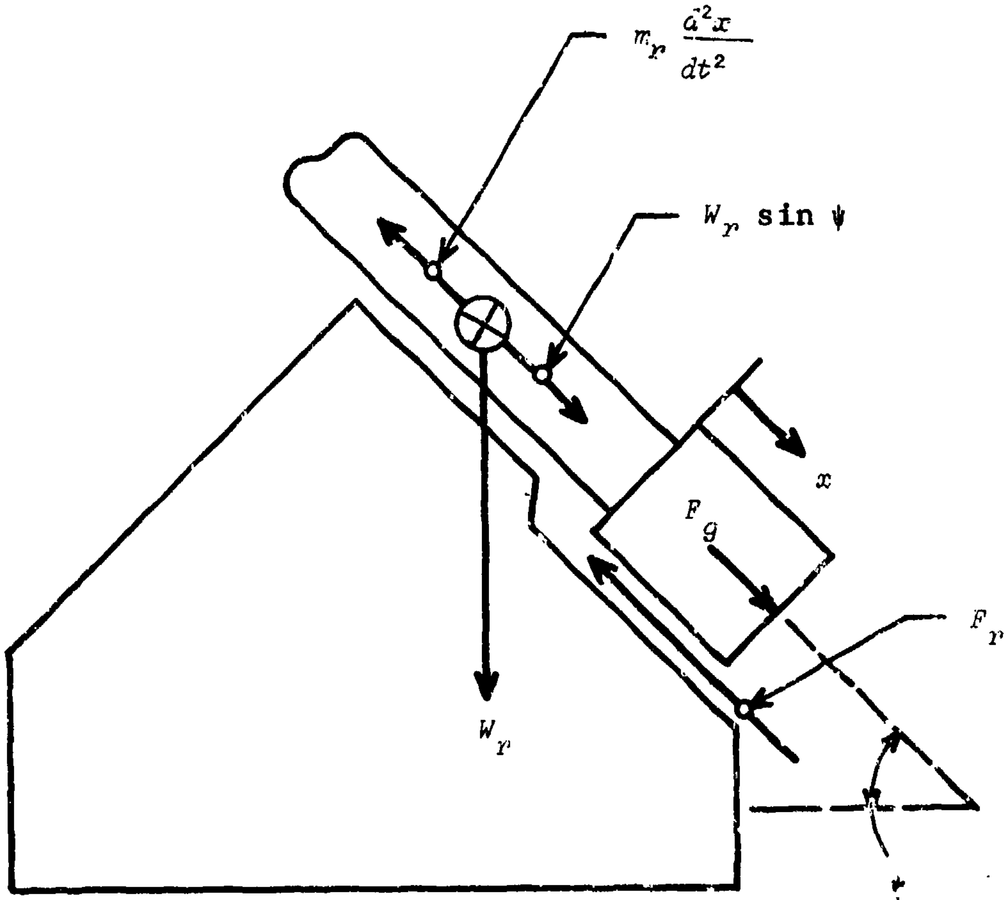


Figure 3-12. Recoil Force Diagram

Downloaded from http://www.everyspec.com

3-17.4 STRESS ANALYSIS OF OPEN BREECH RING

Many large artillery weapons employ a sliding-wedge type breechblock for use with cartridge case ammunition. The breechblock is normally rectangular in section and slides across the breech end of the gun within grooves in the breech ring. The grooves are at near right angles to the axis of the gun and are arranged so that the breechblock, as it slides into firing position, is wedged against the base of the cartridge case.

The breech ring is usually of rectangular section, with two slotted jaws between which the breechblock slides. For the smaller guns, these are separated, as shown in Fig. 3-13(A), and the ring is called an "open breech ring".

A complete analysis of the stresses acting on a breech ring should include not only the static and dynamic external loads, but also any internal residual stresses resulting from forming and machining processes, as well as inertial loads resultant from the ring kinematics. It should be noted also that one or more modes of failure are possible—such as static yielding, fatigue failure, surface spalling or pitting, or impact fracture.

A simple and usually adequate approach to the analysis involves the calculation of nominal stresses which are then modified by applying correction factors obtained from laboratory models. Also of interest are the deflection and rotation of the jaws during the firing period.

When a gun is fired, pressure from the gases is exerted on the breechblock and transmitted to the breech ring. For the purpose of this stress analysis, it is assumed that the load is evenly distributed between the jaws (Fig. 3-14) and distributed uniformly along a line through the center of the bearing surface. Also, the centerline of the jaws does not usually coincide with the centerline of load application, as illustrated by the eccentricity y in Fig. 3-14.

The total load $2P_1$ applied to the breechblock and transmitted to the breech ring is

$$2P_1 = P_c A_c, \text{ lb} \qquad (3\text{-}25)$$

where

P_1 = load per jaw, lb
P_c = chamber pressure, psi
A_c = breech chamber area, in.^{2}

The dimensions associated with Fig. 3-14 are defined

d_1 = maximum jaw thickness, in.
d_2 = minimum jaw thickness, in.
L_1 = moment arm for P_1, in.
L_2 = moment arm for P_2, in.
h_1 = jaw height, in.
h_3 = minimum distance of thrust surface from rear face of breech, in.
y = distance between bore axis and mid-height of breech rings, in.
$2P_1$ = total load, lb
a_1 = P_1 moment arm for section d_1, in.
a_2 = P_1 moment arm for section d_2, in.
P_2 = horizontal load (where $p_2 = \alpha P_1$ for small α) when the seat angle α is present, lb
α = seat angle, rad
δ_H = horizontal deflection of block center, in.
δ_V = vertical deflection of reaction loading, centerline remaining fixed, in.
θ_A = angular deflection of jaws about point A, rad.

The load applied to each jaw is thus P_1, and the direct tensile stress S_1, in the smallest section of each jaw, is

$$S_1 = P_1/(h_1 d_2), \text{ psi.} \qquad (3\text{-}26)$$

The bending moment M_2 tending to push each jaw outward is

$$M_2 = P_1 a_2, \text{ lb·in.} \qquad (3\text{-}27)$$

which results in an outward bending stress component S_2 of

$$S_2 = \frac{M_2 d_2}{2I_2} \qquad (3\text{-}28)$$

where the moment of inertia I_2 is

$$I_2 = \frac{h_1 d_2^3}{12}, \text{ in.}^4 \qquad (3\text{-}29)$$

Downloaded from http://www.everyspec.com

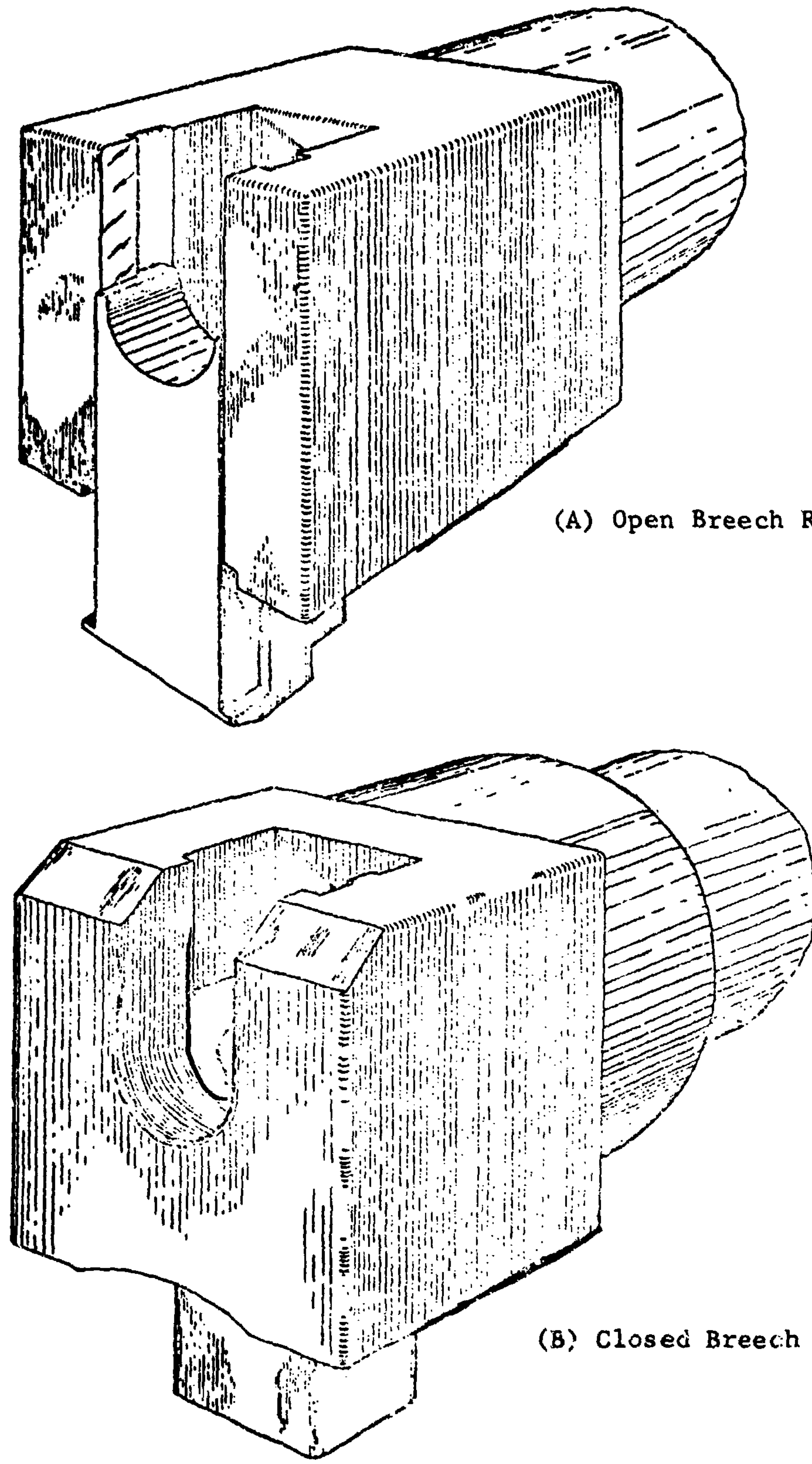


Figure 3-13. Typical Sliding-Block Breech Rings

Downloaded from http://www.everyspec.com

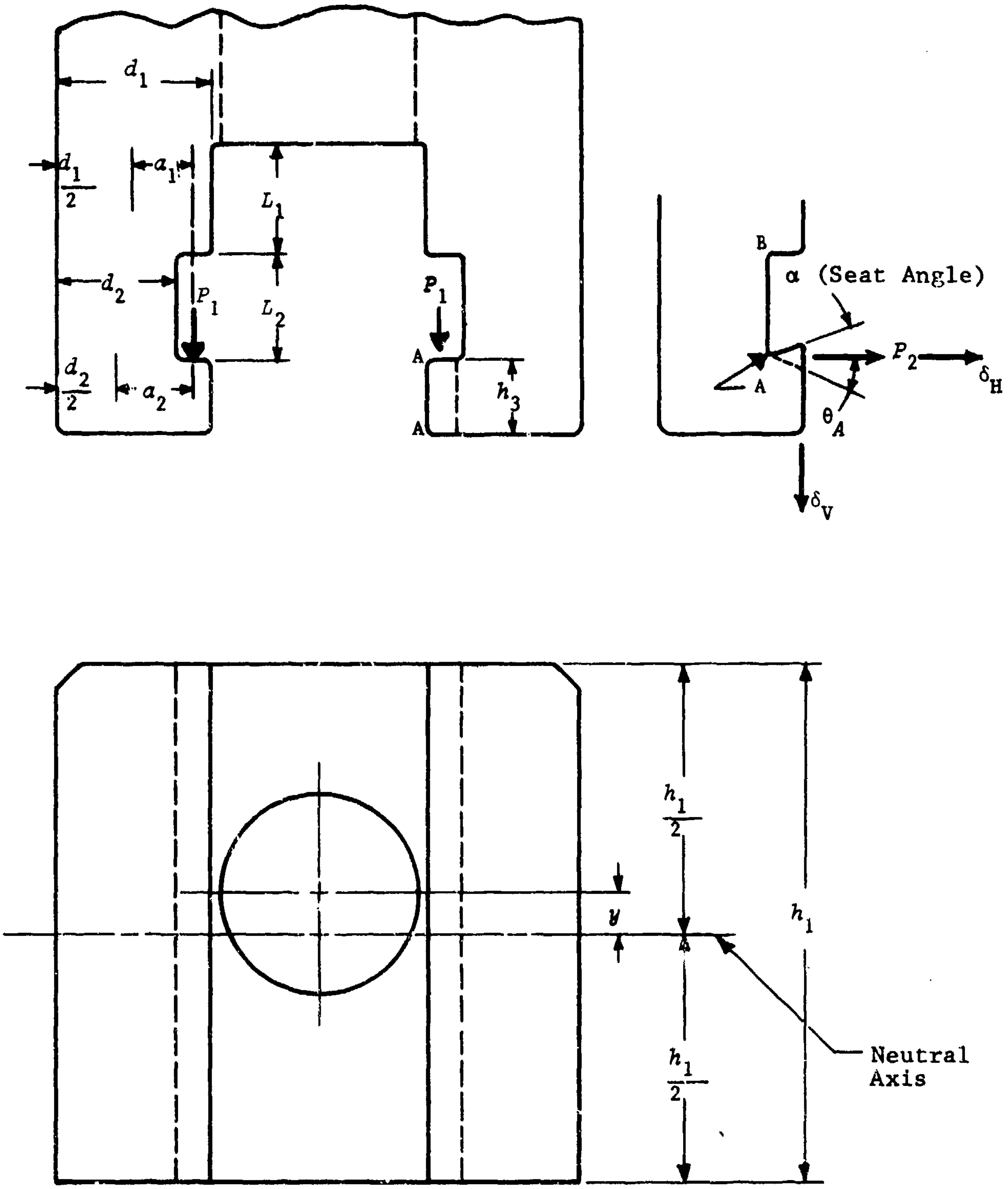


Figure 3-14. Open Breech Ring

Downloaded from http://www.everyspec.com

The eccentric bending moment M_3 caused by the eccentricity y is

$$M_3 = P_1 y, \text{ lb•in.} \tag{3-30}$$

and the maximum eccentric bending stress S_3 in each jaw is

$$S_3 = \frac{M_3 h_1}{2I_4}, \text{ psi} \tag{3-31}$$

where the moment of inertia I_4 is

$$I_4 = \frac{d_2 h_1^3}{12}, \text{ in}^4 \tag{3-32}$$

The maximum tensile stress S_{max} developed in the narrow section of each jaw is the sum of the three components

$$\left.\begin{aligned} S_{max} &= S_1 + S_2 + S_3 \\ &= \frac{P_1}{h_1 d_2} + \frac{M_2 d_2}{2I_2} + \frac{M_3 h_1}{2I_4}, \text{ psi} \\ \text{or} \\ S_{max} &= \frac{P_1}{h_1 d_2}\left(1 + \frac{6a_2}{d_2} + \frac{6y}{h_1}\right), \text{ psi.} \end{aligned}\right\} \tag{3-33}$$

S_{max} should always be below the yield stress of the material, and in fact should include a stress concentration factor to account for stress risers such as changes in cross-sectional area and intensification around fillet areas.

The shear stress S_s acting at Section A-A (Fig. 3-14) is given by

$$S_s = \frac{P_1}{h_1 h_3}, \text{ psi} \tag{3-34}$$

and generally should not exceed a value of one-third of the tensile yield stress of the material.

Often, a seat angle α is used on the jaw bearing surface resulting in a horizontal load P_3 on the jaws, where

$$P_3 = P_1 \tan\alpha \approx P_1\alpha \text{ for small values of } \alpha. \tag{3-35}$$

This horizontal load reduces the outward bending moment on the jaws and thus provides a slight safety factor on the maximum tensile stress in the jaw.

Fillet stresses at points A and B are found by multiplying the nominal stress components by stress concentration factors K_B and K_T for

Downloaded from http://www.everyspec.com

bending and tension, respectively. These factors are given in terms of the fillet radius R_f and the beam width d as shown in Fig. 3-15. The maximum fillet stresses at points A and B, respectively, are given by

$$S_A = K_B \frac{P_1 a_2 \left(\frac{d_2}{2}\right)}{I_2} + K_T \left[\frac{P_1}{h_1 d_2} + \frac{P_1 \left(y \frac{h_1}{2} \right)}{I_3} \right], \text{psi} \quad (3\text{-}36)$$

$$S_B = K_B \frac{(P_1 a_2 - P L_2) \frac{d_2}{2}}{I_2} + K_T \left[\frac{P_1}{h_1 d_2} + \frac{P_1 \left(y \frac{h_1}{2} \right)}{I_3} \right], \text{psi.} \quad (3\text{-}37)$$

Also of interest in the breech ring analysis are the deflections under load of the load bearing surface. The horizontal deflection δ_H and the vertical deflection δ_V, as shown in Fig. 3-14, are, respectively:

$$\delta_H = \frac{1}{E} \left[\frac{(P_1 a_1) L_1^2}{2 I_1} - \frac{(P_1 a_2) L_2^2}{2 I_2} - \frac{(P_1 a_1) L_1 L_2}{I_1} \right] + \frac{1}{E} \left[\frac{(P_2 L_2) L_1^2}{2 I_1} + \frac{P_2 L_1^3}{3 I_1} + \frac{(P_2 L_1^2) L_2}{2 I_1} + \frac{(P_2 L_2^2) L_1}{I_1} + \frac{P_2 L_2^3}{3 I_2} \right], \text{in.} \quad (3\text{-}38)$$

$$\delta_V = \frac{P_1 L_1}{E h_1 d_1} + \frac{P_2 L_2}{E h_1 d_2} + \frac{1}{E} \left(\frac{P_1 a_1 L_1}{I_1} + \frac{P_1 a_2 L_2}{I_2} \right) [a_1 - (a_2 - a_1)] - \frac{1}{E} \left(\frac{P_2 L_1^2}{2 I_1} + \frac{P_2 L_2^2}{2 I_2} \right) [a_1 - (a_2 - a_1)], \text{in.} \quad (3\text{-}39)$$

where

$$I_i = \frac{h_1 d_i^3}{12}, \text{in}^4 \quad (3\text{-}40)$$

E = modulus of elasticity, psi.

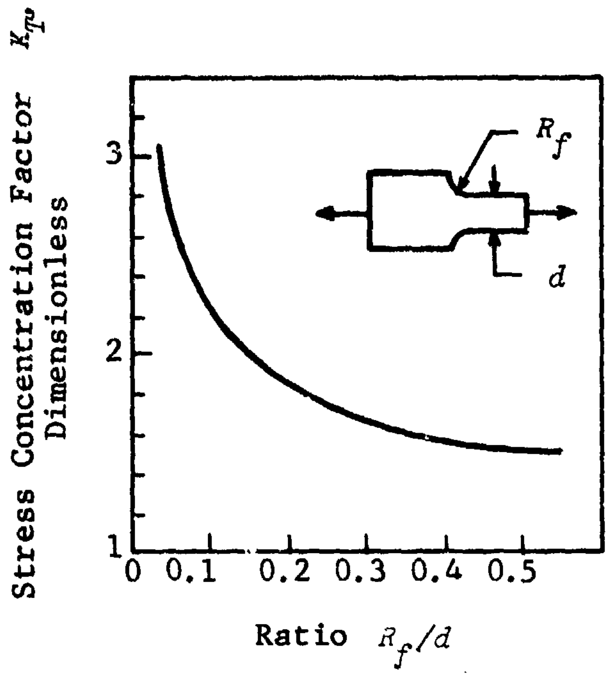
The deflection of the jaws or rotation θ_A of the load bearing surface about point A is given by

$$\theta_A = \frac{1}{E} \left(\frac{P_1 a_1 L_1}{I_1} + \frac{P_1 a_2 L_2}{I_2} - \frac{P_2 L_1^2}{2 I_1} - \frac{P_2 L_2^2}{2 I_2} \right), \text{rad.} \quad (3\text{-}41)$$

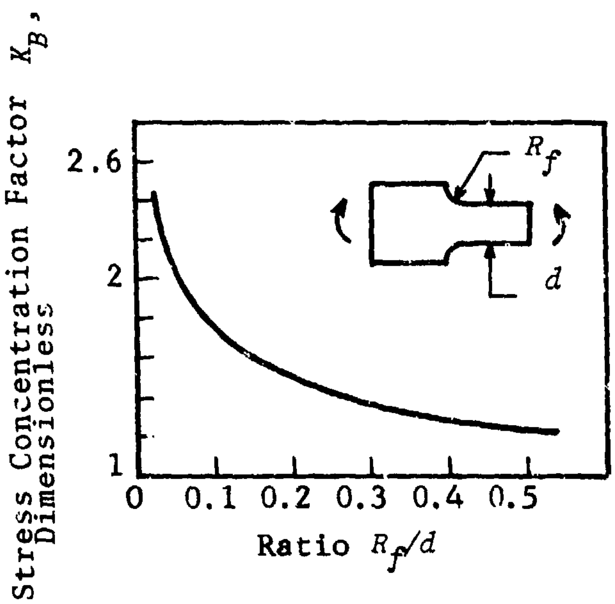
3-17.5 STRESS ANALYSIS OF CLOSED BREECH RING

A closed breech ring is similar to an open breech ring except that a tie bar is used across

Downloaded from http://www.everyspec.com



(A) Tension



(B) Bending

Figure 3-15. Stress Concentration Factors in Fillets for Tension and Bending

Downloaded from http://www.everyspec.com

the jaws (Fig. 3-13(B)) to prevent them from deflecting outward when subjected to the firing load. The closed breech ring can be idealized as shown in Fig. 3-16. The tie bar is considered as a simple beam that connects the jaws and limits horizontal expansion.

The external load per jaw P_1 is taken as half the firing load. The internal horizontal force P_2 and moment M_1 are found by first computing the following coefficients:

$$K_{11} = \left(\frac{L_1}{I_1} + \frac{L_3}{I_2} + \frac{L_4}{2I_3}\right), \text{ in.}^{-3} \tag{3-42}$$

$$K_{12} = -\left(\frac{L_1^2}{2I_1} + \frac{L_3^2}{2I_2}\right), \text{ in.}^{-2} \tag{3-43}$$

$$K_{13} = \left[\frac{a_2(L_4 - 2a_2)}{2I_3} - \frac{a_2(a_1 - a_2)}{I_1}\right], \text{ in.}^{-2} \tag{3-44}$$

$$K_{21} = -\left(\frac{L_1^2}{2I_1} + \frac{L_3^2}{2I_2} + \frac{L_1L_3}{I_1}\right), \text{ in.}^{-2} \tag{3-45}$$

$$K_{22} = \left(\frac{3L_3L_1^2}{2I_1} + \frac{L_1^3}{3I_2} + \frac{L_3^3}{3I_2} + \frac{L_4}{2h_2d_3}\right), \text{ in.}^{-1} \tag{3-46}$$

$$K_{23} = \left[\frac{(a_1 - a_2)L_1^2}{2I_1} + \frac{(a_1 - a_2)L_1L_3}{I_1}\right], \text{ in.}^{-1} \tag{3-47}$$

where the lengths L_i are defined in Fig. 3-16 and,

$$I_i = \frac{h_i d_i^3}{12}, \text{ in.}^4 \; (i = 1,2)$$

$$I_3 = \frac{h_3 d_3^3}{12}, \text{ in.}^4$$

The internal force P_2 and moment M_1 are then given by

$$P_2 = \left(\frac{K_{11}K_{23} - K_{13}K_{21}}{K_{11}K_{22} - K_{12}K_{21}}\right)P_1, \text{ lb} \tag{3-48}$$

$$M_1 = \left(\frac{K_{13}K_{22} - K_{12}K_{23}}{K_{11}K_{22} - K_{12}K_{21}}\right)P_1, \text{ lb}\cdot\text{in.} \tag{3-49}$$

By using P_2 and M_1, the maximum tensile stress S_E at point E in the figure, the narrow section of the jaw, is given by

$$S_E = \frac{P_1}{h_1 d_2} + \frac{P_1 y h_1}{2I_4} + \frac{M_1 d_2}{2I_2} + \frac{P_2 d_3 d_2}{4I_2}, \text{ psi.} \tag{3-50}$$

Downloaded from http://www.everyspec.com

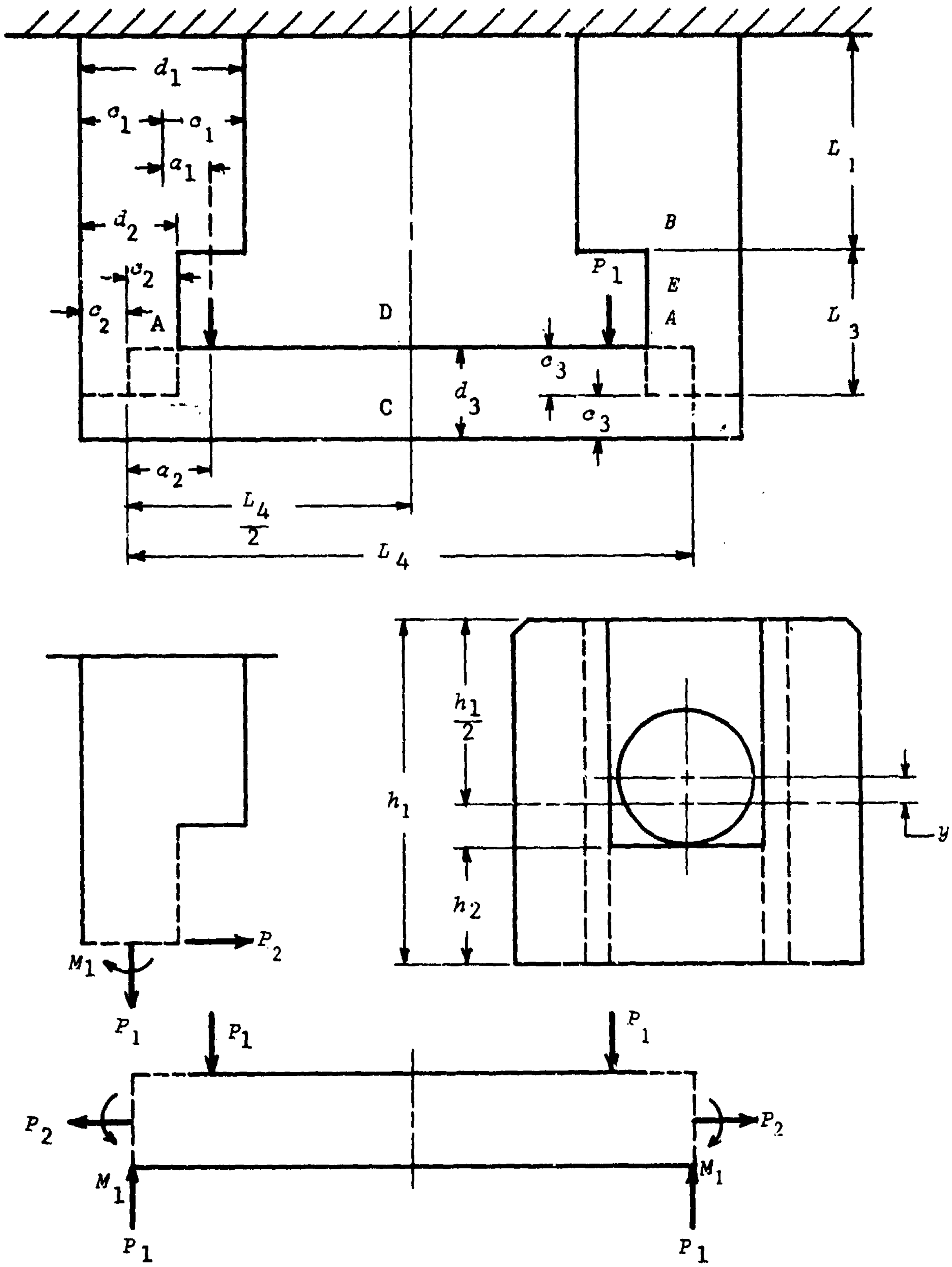


Figure 3-16. Closed Breech Ring

Downloaded from http://www.everyspec.com

The maximum stresses S_A, S_B, S_C, and S_D at the points denoted by the subscripts (Fig. 3-16) are given by

$$S_A = K_T\left(\frac{P_1}{h_1 d_2} + \frac{P_1 y h_1}{2I_4}\right) + K_B\left(\frac{M_1 d_2}{2I_2} - \frac{P_2 d_3 d_2}{4I_2}\right), \text{ psi} \quad (3\text{-}51)$$

$$S_B = K_T\left(\frac{P_1}{h_1 d_2} + \frac{P_1 y h_1}{2I_4}\right) + K_B\left(\frac{M_1 d_2}{2d_2} - \frac{P_2 L_3 d_2}{2I_2}\right), \text{ psi} \quad (3\text{-}52)$$

$$S_C = \frac{P_2}{h_2 d_3} + \frac{P_1 a_2 d_3}{2I_3} - \frac{M_1 d_3}{2I_3}, \text{ psi} \quad (3\text{-}53)$$

$$S_D = \frac{P_2}{h_2 d_3} - \frac{P_1 a_2 d_3}{2I_3} + \frac{M_1 d_3}{2I_3}, \text{ psi.} \quad (3\text{-}54)$$

3-17.6 STRESS ANALYSIS OF SLIDING BLOCK

The breechblock in a gun is in direct contact with the cartridge case and must transfer the firing load to the breech ring. The firing load is distributed uniformly over an area covered by the maximum area of the cartridge case, which is a circle of diameter D_c (rear chamber diameter). For the purpose of analysis, the breechblock is assumed to behave as a simply supported beam but, because of the irregular cuts needed to accommodate the firing and actuating mechanisms, the neutral axis of the block may not lie at the center. These irregular cuts also give rise to stress concentrations.

Consider the breechblock as shown in Fig. 3-17. The stresses S_G, S_H, and S_I at the points depicted by the subscripts each have three components:

1. Tension due to the horizontal load P_2
2. Bending tension/compression from the moment of the horizontal force P_2 about the neutral axis
3. Bending tension/compression from the moment of the vertical force P_1 about the centerline of the block.

The stresses at points, H, G, and I are given by

$$S_G = K_T\left(\frac{P_2}{h_I d_4}\right) + K_B\left(\frac{P_2 a_4 b_1}{I_4}\right) + K_B\left(\frac{P_1 L_6 b_1}{2I_4}\right), \text{ psi} \quad (3\text{-}55)$$

Downloaded from http://www.everyspec.com

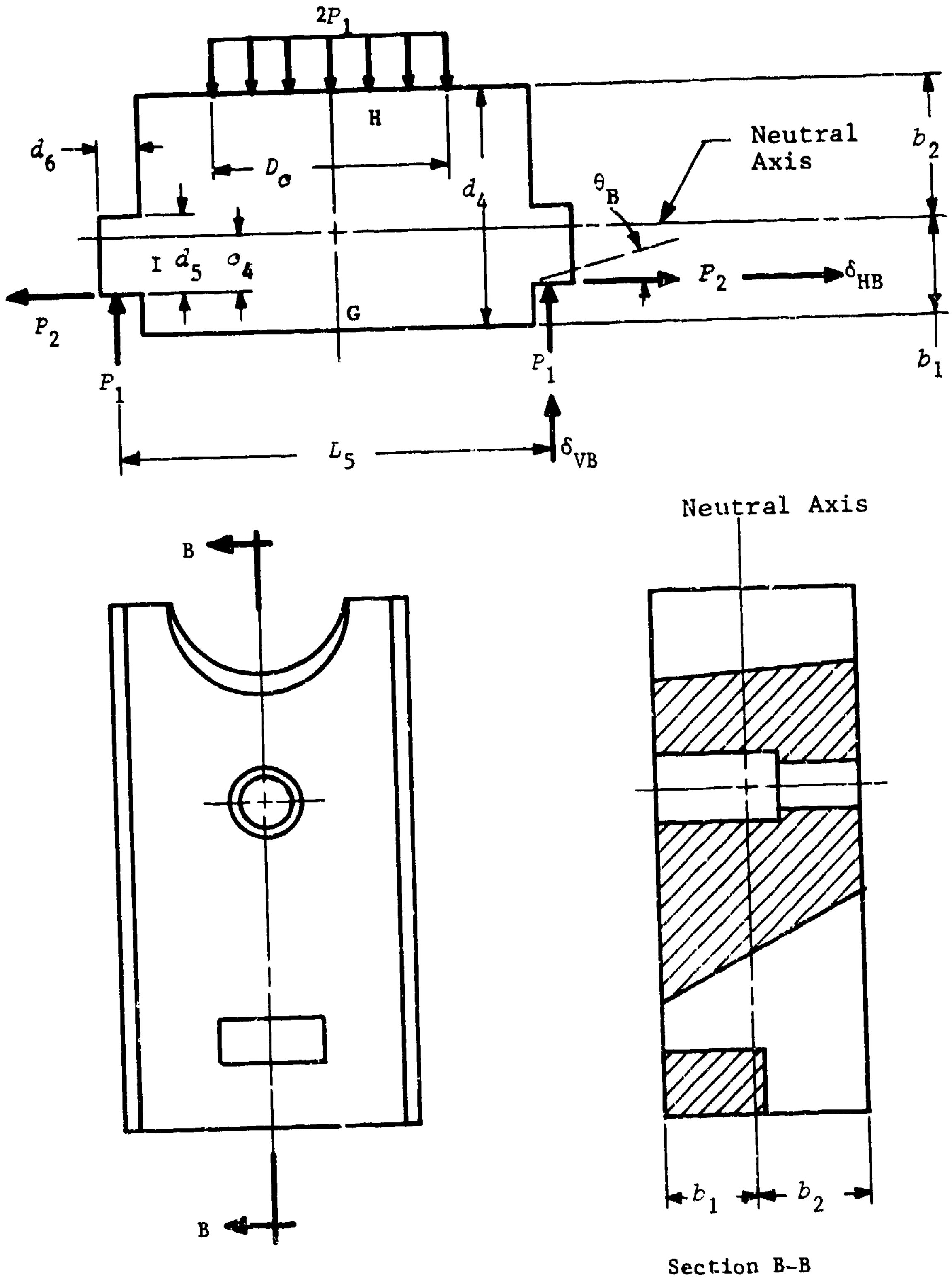


Figure 3-17. Typical Breechblock Section

Downloaded from http://www.everyspec.com

$$S_H = K_T\left(\frac{P_2}{h_t d_4}\right) - K_B\left(\frac{P_2 a_4 b_2}{I_4}\right) - K_B\left(\frac{P_1 L_6 b_2}{2I_4}\right) \quad (3\text{-}56)$$

$$S_I = K_T\left(\frac{P_2}{h_t d_6}\right) + K_B\left(\frac{P_2 d_6^2}{4I_6}\right) + K_B\left(\frac{P_1 d_6 d_6}{4I_6}\right), \text{ psi} \quad (3\text{-}57)$$

where K_T and K_B are stress concentration factors for tension and bending, respectively, h_t is the effective height of the section considered, and

$$I_t = \frac{h_t d_t^3}{12}, \text{ in}^4 \quad (3\text{-}58)$$

The stress concentration factors K_T and K_B may be read from Fig. 3-15, or may be taken as follows:

1. With holes through G and H

$$K_T = K_B = 3.$$

2. With radius R_I at I

$$K_T = K_B = 0.8/R_I.$$

The equations for the horizontal deflection δ_{HB}, vertical deflection δ_{VB}, and angular deflection θ_B of the load bearing surfaces which contact the jaws of the breech ring are

$$\delta_{HB} = \frac{1}{E}\left(\frac{P_1 a_4 L_6^2}{12I_4} + \frac{P_2 a_4^2 L_6}{2I_4} + \frac{P_2 L_6}{2h_4 d_4}\right), \text{ in.} \quad (3\text{-}59)$$

$$\delta_{VB} = \frac{1}{E}\left(\frac{5P_1 L_6^3}{12I_4} + \frac{P_2 a_4 L_6^2}{8I_4}\right), \text{ in.} \quad (3\text{-}60)$$

$$\theta_B = \frac{1}{E}\left(\frac{P_1 L_6^2}{12I_4} + \frac{P_2 a_4 L_6}{2I_4}\right), \text{ rad.} \quad (3\text{-}61)$$

3-17.7 STRESS ANALYSIS OF AN INTERRUPTED-THREAD BLOCK

The exact determination of stresses in circular breechblocks with interrupted threads, such as on the 155 mm howitzer, is extremely difficult from the analytical viewpoint because of the complex geometries and boundary conditions. To visualize how the breechblock is loaded, consider the sectional view shown in Fig. 3-18. The chamber pressure is transmitted by the spindle to the obturator pad which in turn loads the breechblock. Since the breechblock is threaded

Downloaded from http://www.everyspec.com

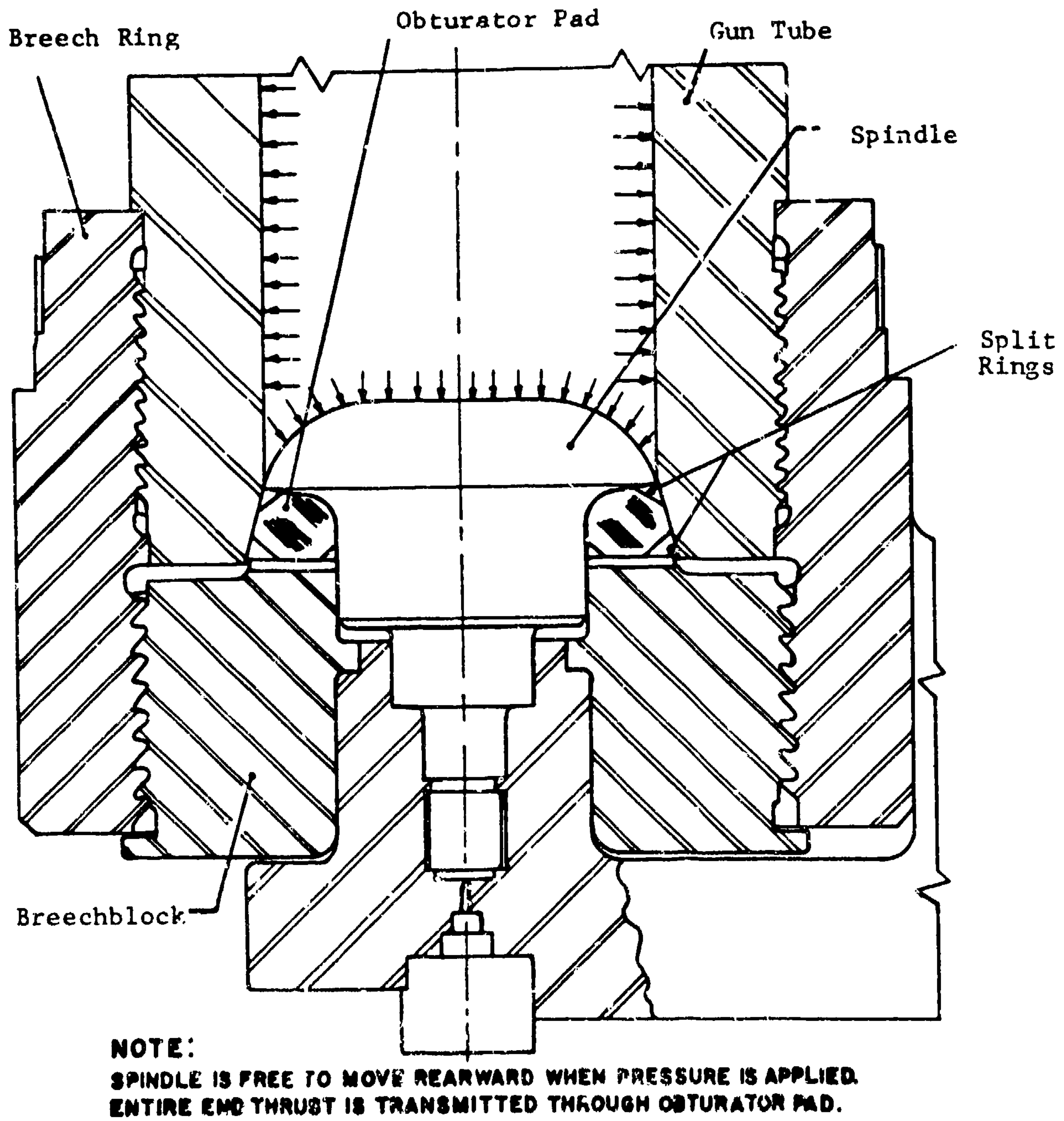


Figure 3-18. Breech Loading Configuration

into the breech ring by means of an interrupted-type thread, the end force due to the chamber pressure is transmitted as essentially a shearing force distributed over the outer circumference of the block in the four thread-sector areas. However, if certain reasonable assumptions are made with respect to these boundary conditions and geometries, useful predictions can be made.

Downloaded from http://www.everyspec.com

For the purpose of analysis, the following assumptions are made:

1. The block is loaded by a uniform pressure acting through the obturator pad.

2. This pressure acts only over the surface area of the breechblock in direct contact with the obturator pad.

3. The block is simply supported on its external boundary, and this support is considered to extend around the entire circumference of the block.

4. The total force that must be resisted by the breechblock must equal the force generated by the internal chamber pressure acting over the area of the breech chamber.

5. The block is treated as a thick circular plate and a solution, originally obtained by Timpé, of the stress state as a funtion of pressure intensity on the loaded boundary is employed.

The geometry of the block is shown in Fig. 3-20 along with the idealized description of pressure on the upper boundaries (Fig. 3-19). The problem for which Weigle (Ref. 30) obtained a Timpé solution is shown in Fig. 3-20 with the appropriate loading conditions for his treatment of the problem. It is seen immediately that the practical problem and the idealized problem as shown are similar geometrically, but the load conditions differ in that a discontinuous type of loading function exists for the actual case of the 155-mm breechblock. For the purpose of analysis, a modified pressure intensity must be determined which matches the loading conditions as originally investigated by Timpé.

In order to utilize the solution for the idealized problem and obtain meaningful results for the practical problem, a continuous loading function must be determined to replace the discontinuous loading function that actually exists. Initially, the total end thrust (force) must be determined by considering the breech chamber area and the operating pressure. Thus, the end thrust P_e may be calculated from the relationship

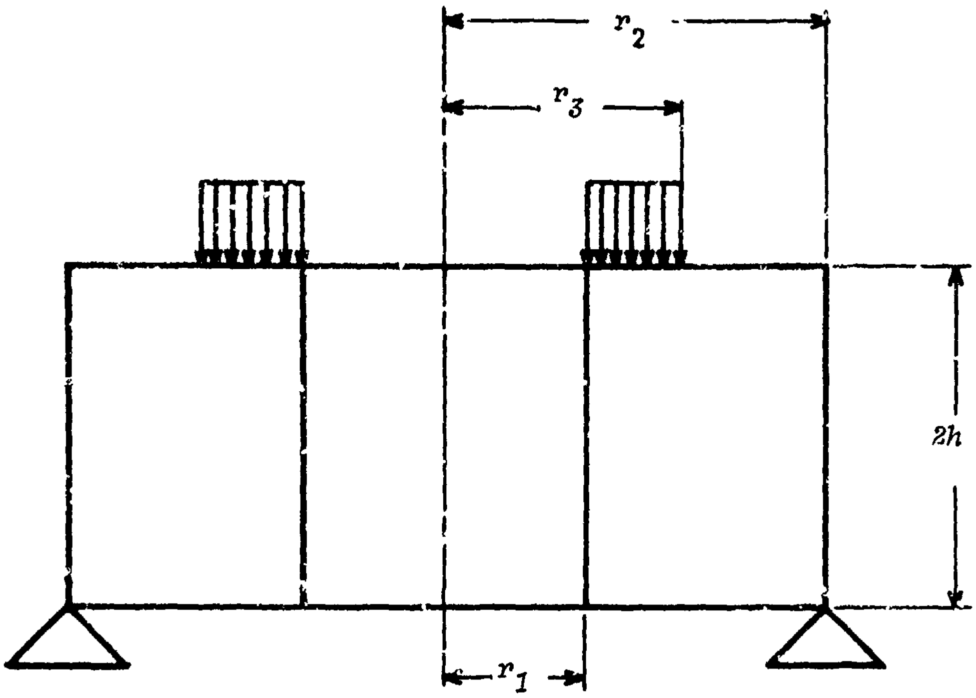


Figure 3-19. Idealized Breechblock Geometry and Loading Conditions

Downloaded from http://www.everyspec.com

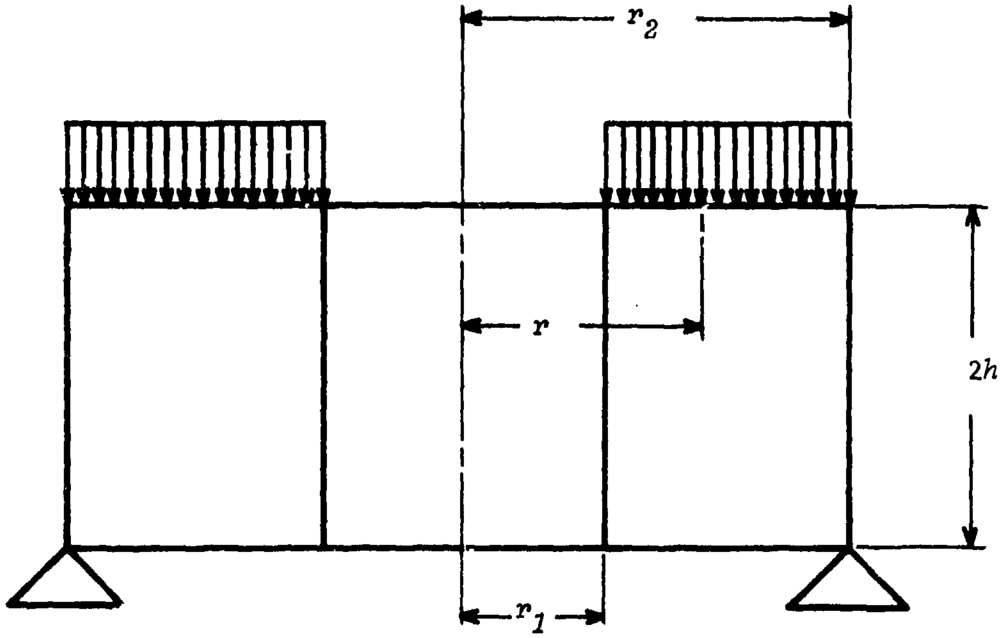


Figure 3-20. Thick-Plate Geometry and Loading Conditions for Timpé Solution

$$P_e = A_c P_c, \text{ lb} \quad (3\text{-}62)$$

where

A_c = breech chamber area, in.^{2}

P_c = chamber pressure, psi.

Consider now that the total end thrust is distributed uniformly over the entire surface area of the breechblock. The resulting pressure-loading q^* on the breechblock can be calculated from Eq. 3-63:

$$q^* = \frac{P_e}{\pi(r_2^2 - r_1^2)}, \text{ psi} \quad (3\text{-}63)$$

where

r_1 = inner radius of breechblock, in.

r_2 = external radius of breechblock, in.

Note that q^* will be significantly lower than the actual pressure intensity occurring on the contact area between the obturator pad and breechblock.

A modified pressure intensity q can be found by considering the ratio of the area of the breechblock to the surface area in contact with the obturator pad and applying this ratio to modify the pressure intensity q^* in the following manner:

$$q = \frac{q^*}{12}\left(\frac{r_2^2 - r_1^2}{r_3^2 - r_1^2} + 1\right), \text{ psi} \quad (3\text{-}64)$$

where

r_3 = radius defining limits of breechblock loading function, in.

It should be realized that the preceding relationship is entirely arbitrary, but produces satisfactory results. With the modified pressure intensity q determined, it is then possible to calculate the dimensionless radial stress σ_r and dimensionless tangential stress σ_θ by use of the following relationships:

Downloaded from http://www.everyspec.com

$$\sigma_r = -3\left\{\left[(3-\nu)(\rho^2-\beta^2-1)+(3+\nu)(\beta^2/\rho^2)-4(1-\nu)[\beta^2/(\beta^2-1)](\ln\beta)(1/\rho^2)\right.\right.$$
$$\left.+4(1+\nu)[\beta^2\ln(\beta/\rho)-n(1/\rho)\right](\beta^2-1)^{-1}$$
$$\left.-(8/15)[(2-\nu)(\eta^2/\rho^2)-(2-\nu)\eta^2]\right\}(32\eta^2)^{-1}, \text{ dimensionless} \quad (3\text{-}65)$$

$$\sigma_\theta = -3\left\{-(3+\nu)(\beta^2+\beta^2/\rho^2)-(5\nu-1)+(1+3\nu)\rho^2\right.$$
$$+4(1+\nu)[\beta^2/(\beta^2-1)](\ln\beta)(1/\rho^2)+4(1+\nu)[\beta^2\ln(\beta/\rho)-\ln(1/\rho)](\beta^2-1)^{-1}$$
$$\left.+(8/15)[(2-\nu)(\eta^2/\rho^2)-(2+\nu)\eta^2]\right\}(32\eta^2)^{-1}, \text{ dimensionless} \quad (3\text{-}66)$$

where

η = h/r_1 = ratio of half thickness to inner radius, dimensionless
ρ = r/r_1 = dimensionless radius
β = r_2/r_1 = ratio of external radius to inner radius, dimensionless
σ_r = S_r/q = dimensionless radial stress
σ_θ = S_θ/q = dimensionless tangential stress
ν = Poisson's ratio, dimensionless
h = half thickness, in.
S_r = radial stress, psi
S_θ = tangential stress, psi.

Eqs. 3-65 and 3-66 are valid for the lower boundary; i.e., rear face of the breechblock. It is on this surface that the maximum tensile type stresses will occur for the loading conditions specified. Furthermore, the maximum tangential stress occurs when $r = r_1$, although the stress may be evaluated for any given radius r. The stress computed should be compared to the material yield strength after proper consideration of stress intensification and strength reduction factors.

3-17.8 BLOCK-THREAD STRESS ANALYSIS

The analysis of thread stresses varies according to thread type and weapon classification but, in artillery design, an evaluation of direct shear stress is usually sufficient.

During firing of a gun, the total force carried by the threads of a sectored block must equal the propellent gas force F_g where

Downloaded from http://www.everyspec.com

$$F_s = P_c\pi\left(\frac{D_c^2}{4}\right), \text{ lb.} \quad (3\text{-}67)$$

Considering the sector-thread shown in Fig. 3-21, the total shear area A_s is given by

$$A_s = n\pi\left(\frac{D_1}{3} + \frac{D_2}{3}\right)(p - C), \text{ in}^2 \quad (3\text{-}68)$$

where

D_1 and D_2 = pitch diameters of threaded sectors, in.
C = tooth clearance, in.
n = number of threads engaged
p = thread pitch, in.

The average shear stress τ_{ave} is then

$$\tau_{ave} = \frac{F_s}{A_s} = \frac{3P_cD_c^2}{4n(D_1 + D_2)(p - C)}, \text{ psi.} \quad (3\text{-}69)$$

Note that this is the "average" shear stress. Investigative studies indicate that the tooth nearest the load may carry as much as 140% of the average load. Therefore it is recommended that the teeth be designed to carry a maximum shear stress τ_{max} of $1.4\tau_{ave}$. A reasonable factor also should be included when comparing τ_{max} to the material shear strength.

3-17.9 RELIABILITY ANALYSIS OF BREECHBLOCK CRANK

As an example of one type of reliability analysis, the constant-failure rate approach will be used to determine the Mean Time Between Failure $\bar{\theta}$ for the breechblock crank shown in Fig. 3-7.

From Eq. 3-2, it can be seen that

$$\bar{\theta} = -T/\ln P_s, \text{ h} \quad (3\text{-}70)$$

where

T = period of operation, h
P_s = probability of survival.

However, hours of operation are not an appropriate measure for the operation of a system such as a breech mechanism. A more reasonable measure is the number of rounds fired, hours of operation being more suited for equipment which operates continuously.

Therefore, Eq. 3-70 can be restated in terms of rounds fired as:

$$\bar{\theta} = -N/\ln P_s, \text{ rounds} \quad (3\text{-}71)$$

where

N = number of rounds fired during operation

N, rounds fired during operation, is a projection made by the designer at the time of the

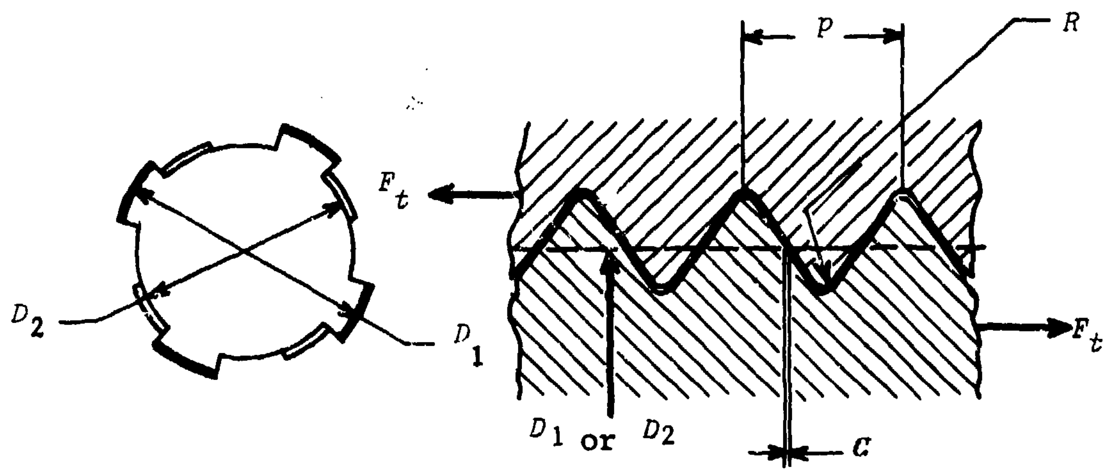


Figure 3-21. Sector Thread

Downloaded from http://www.everyspec.com

analysis. Thus P_s, the probability of survivability, is the only unknown in the equations and must be determined in order to calculate $\bar{\theta}$.

In order to determine P_s, it is necessary to make calculations concerning the failure of the crank. For this purpose, the failure mode for the breechblock crank is postulated to be a material overstress due to bending. The existence of this potential overstress will be dependent on the geometry of the crank, the bending load applied, and the characteristics of the material used. As stated in par. 3-15, the fundamental assumption underlying the field of reliability analysis is that the pertinent variables determining the performance of a mechanical system are not single-valued functions. Rather they are subject to a certain degree of uncontrollable variation.

The probabilistic distributions of these variations can be described mathematically by a number of general classes of distributions—i.e., Weibull, normal, gamma, beta, etc. For the purposes of the example, a normal distribution will be used; it is a good fit to the types of distributions actually found and lends itself conveniently to calculations.

The characteristics of any normal distribution are completely defined by two parameters—the mean (average) μ of the distribution and the standard deviation σ of the distribution. By convention, these two parameters are represented as (μ, σ). This convention will be used throughout the discussion that follows.

The probability of survival P_s will be determined through the use of Fig. 3-22. Inspection of the figure shows that three ratios must be calculated and used as inputs to the process:

$$\text{FS} = \frac{\mu_T}{\mu_S} \tag{3-72}$$

$$(\text{ratio})_S = \frac{\sigma_S}{\mu_S} \tag{3-73}$$

$$(\text{ratio})_T = \frac{\sigma_T}{\mu_T} \tag{3-74}$$

where

μ_T = mean of material strength distribution, psi

μ_S = mean of stress distribution, psi

σ_T = standard deviation of strength distribution

σ_S = standard deviation of stress distribution.

The mean and standard deviation of strength distributions for some commonly used materials can be found in Ref. 29. The characteristics of the stress distribution must be calculated, starting from the familiar bending stress equation

$$S_b = \frac{M}{Z}, \text{psi} \tag{3-75}$$

where

S_b = maximum bending stress, psi

M = applied bending moment, lb·in.

Z = section modulus, in.^{3}

The distributional characteristics of M, the applied moment, can be obtained either through testing or analytical estimation. If estimation is used, the designer should bear in mind that this is a crucial factor in the reliability calculation, and special care must be taken to ensure that the estimation is as accurate as possible.

The distributional characteristics of the section modulus Z can be calculated from the distributions of piece-part dimensions. Assume the cross section of the crank to be rectangular, as shown in Fig. 3-23; then the classical (nonprobablistic) equation for the section modulus is

$$Z = \frac{wh_4^2}{6}, \text{in.}^3 \tag{3-76}$$

where the symbols are defined in Fig. 3-23.

However, in order to be of utility in a reliability analysis, it is necessary to determine the distributional characteristics of the section modulus variable. The mean μ_Z of the distribution for the section modulus Z is rather straightforward

$$\mu_Z = \frac{\mu_w \mu_{h_4}^2}{6}, \text{in.}^3 \tag{3-77}$$

Downloaded from http://www.everyspec.com

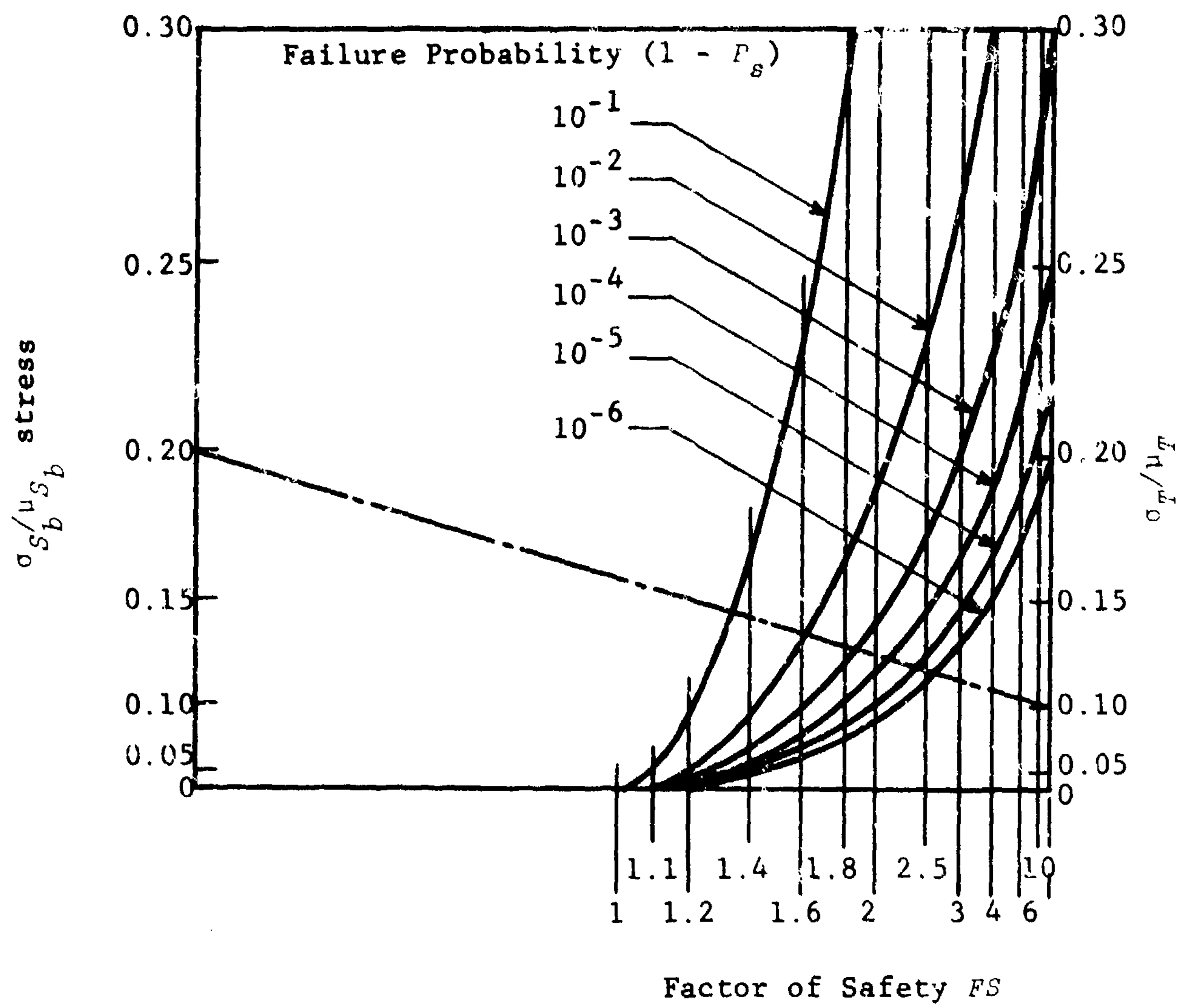


Figure 3-22. Safety Factor Related to a Probability of Failure

where

μ_w = mean of the w dimension distribution. (This is normally the nominal dimension.)

$\mu_{h_4^2}$ = mean of the h_4^2 distribution.

Determination of the mean of the h_4^2 distribution in Eq. 3-77 deserves further discussion. The value of this variable is not simply the square of the mean of the h_4 distribution. By consulting a test on reliability or statistics, such as Ref. 4 or Ref. 12, one can find rules to be followed in determining the characteristics of the normal distribution which results from mathematical combinations of two other normal distributions, based on the distributional characteristics of the component variables. From these rules, it can be found that

$$\mu_{h_4^2} = (\mu_{h_4})^2 + \sigma_{h_4}^2, \text{ in}^2 \qquad (3\text{-}78)$$

Substituting this quantity $\mu_{h_4^2}$ into Eq. 3-77, and again applying the rules for binary combinations of normal variables

Downloaded from http://www.everyspec.com

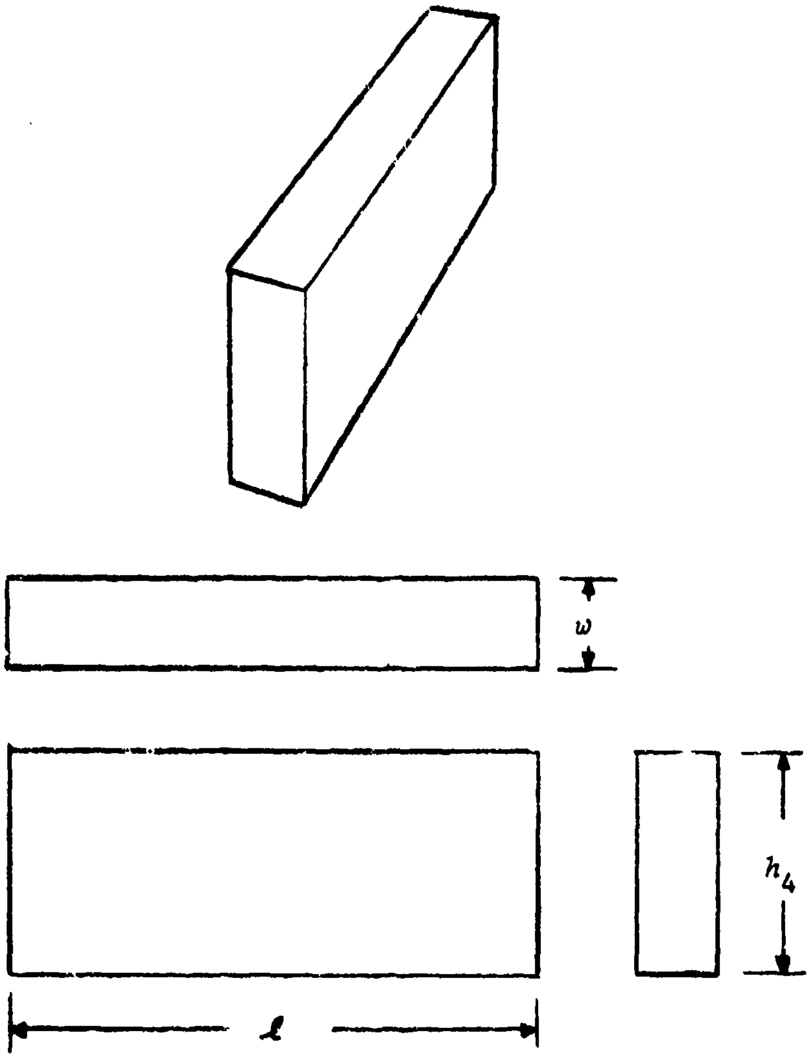


Figure 3-23. Breechblock Crank (Illustrative Geometry)

$$\mu_Z = \frac{\mu_w(\mu_{h_4^2} + \sigma_{h_4^2})}{6}, \text{ in.}^3 \quad (3\text{-}79)$$

By applying similar rules for the determination of the standard deviation, we obtain

$$\sigma_Z = \left[\mu_w^2(\sigma_{h_4^2})^2 + (\mu_{h_4^2})^2\sigma_w^2 + \sigma_w^2(\sigma_{h_4^2})^2\right]^{1/2} \quad (3\text{-}80)$$

where

$$\sigma_{h_4^2} = \sqrt{4(\mu_{h_4})^2(\sigma_{h_4})^2 + 2(\sigma_{h_4})^4}, \text{ in.}^2 \quad (3\text{-}81)$$

μ_w = mean of distribution of w, in.

$\mu_{h_4^2}$ = mean of distribution of h_4^2 as defined in Eq. 3-78, in.

$\sigma_{h_4^2}$ = standard deviation of distribution of h_4^2, in.

σ_w = standard deviation of distribution of w, in.

The standard deviation of the dimensional variables h_4 and w is usually taken to be one-half the value of the two-sided tolerances. For example, if a given dimension were $A \pm a$, the standard deviation would be estimated as $a/2$.

Downloaded from http://www.everyspec.com

Having determined the distributional characteristics of Z, it is now possible to calculate the characteristics of the bending stress S_b. By using the combination rules applying to division:

$$\mu_{S_b} = \frac{\mu_{M_4}}{\mu_Z}, \text{ psi} \tag{3-82}$$

$$\sigma_{S_b} = \frac{1}{\mu_Z}\left[\frac{(\mu_{M_4})^2\sigma_Z^2 + \mu_Z^2(\sigma_{M_4})^2}{\mu_Z^2 + \sigma_Z^2}\right]^{1/2}, \text{ psi.} \tag{3-83}$$

The necessary parameters having been determined, it is now a simple procedure to use Fig. 3-22. First calculate the three indices for the graph, $\frac{\mu_T}{\mu_{S_b}}$, $\frac{\sigma_{S_b}}{\mu_{S_b}}$, and $\frac{\sigma_T}{\mu_T}$. Next construct a line connecting the points on the vertical axes corresponding to the calculated values, as shown on Fig. 3-22. At the point where this constructed line intersects the vertical FS-line, interpolate between the curved $(1 - P_s)$ lines to determine $(1 - P_s)$ for this design. For the example shown on Fig. 3-22, with $\frac{\sigma_T}{\mu_T} = 0.10$ and $\frac{\sigma_{S_b}}{\mu_{S_b}} = 0.20$, if $FS = 1.8$, $(1 - P_s)$ is approximately 10^{-3}. Solving for P_s, we obtain the probability of survival as 0.999.

By using the value of P_s determined as shown, and substituting into Eq. 3-71, it is now possible to determine $\bar{\theta}$, the Mean Time Between Failure for the breechblock crank. If $P_s = 0.999$, and N is assumed to be 10,000 rounds,

$$\begin{aligned}\bar{\theta} &= -10{,}000/\ln(0.999)\\ &= -10{,}000/(-0.001)\\ &= 9{,}994{,}999 \text{ rounds.}\end{aligned}$$

Components, subsystems, and materials which have demonstrated field reliability should be used whenever possible. This will increase the probability that these items will be reliable in the new design. Designs which are "at a limit of experience" should only be used when this is necessary to achieve a specific requirement. New systems or components should be subjected to accelerated life and environmental tests whenever possible as part of the design development and reliability demonstration.

SECTION IV. PROTOTYPE TESTING

3-18 GENERAL CONSIDERATIONS

Testing is a major element of an overall design procedure for breech mechanisms. Prototype testing is an investigative process, simulating a desired operational environment. It is employed to challenge the fundamental design characteristics of the breech mechanism such as strength, operational interface, and function. Prototype testing is performed to identify design deficiencies requiring redesign (Ref. 19).

Successive iterations of the design/test cycle should produce models of improved behavior whose characteristics or potential characteristics will meet or exceed the required criteria or specifications of model performance. Instances occur, however, where performance criteria may not be satisfied for a model design due to spatial, mechanistic, and material constraints; program redirection is then required.

The planning of tests is one of the most significant aspects of prototype development after the initial concept is evolved. Test plans elect or define the problem area for investigation, select the model configuration, describe the operational and environmental exposure, and determine the required instrumentation system (Refs. 20 and 21).

Further discussion of breech mechanism testing is given in Chapter 4.

3-19 MODELS

Upon completion of the test plan, the area of investigation and the breech model characteristics will be defined. The model configuration will vary from fairly simple pressure vessels, to detailed plastic models for photoelastic verification or determination of stresses, through

Downloaded from http://www.everyspec.com

wooden mock-ups for machine function or human response to full-scale models for firing and operational tests (Refs. 22 to 24).

The mock-up is used to illustrate concept and demonstrate handling. Another function of the mock-up is to provide a three-dimensional visualization of design for the purpose of verifying or allocating spatial assignments. The mock-up is used extensively for problems related to human engineering factors.

Dependent upon the purpose they serve, mock-ups will vary in operational detail from no relative motion to a complete mechanistic replication of the handling functions. Breechblock design and closure, chamber design, automatic versus manual design features, loader-rammer interaction, manufacturing techniques, and external configuration are some of the purposes which may best be illustrated by a system mock-up.

Another series of models which are available to the designer is constructed to determine, verify, or upgrade operational and structural characteristics of new design features. The models are constructed to transmit both static and dynamic loads through model materials that physically respond in a manner that is relatable to candidate design materials. The degree of simulation is quantified in terms of response so that engineering credence is maintained when test data are translated to design requirements.

The nonfiring prototype models are test devices employed to investigate load distribution (especially stress concentrations) and fatigue life, and may be used to evaluate operator loads. The models usually simulate a specific function such as breech closure or sealing, or a design characteristic such as strength and ease of loading. A different model may be required for operator loads which would simulate the dimensional and inertial characteristics of the breechblock and bushing interface. The spatial constraints of the carriage and auxiliary equipment could then be constructed as a mock-up where dimensional authenticity is needed but only nominal structural response is required (Refs. 22, 23, and 24).

The breech prototype firing model is constructed to verify the operational design premise and evaluate long-term trend effects. The breech subsystem usually is incorporated in a functional firing model of the weapon system. Some variance may occur in weapon model completeness for features which are not required during actual firing—such as roadability and automatic loading.

The model is used to verify load distribution, handling, and to determine long-term effects from questionable stress concentrations, new material processing, and manufacturing techniques.

3-20 PERFORMANCE SIMULATION TESTS

Two test machine systems exist for actuating artillery and breech subsystems which may be considered for use in lieu of designing special purpose equipment or using firing tests. One, the gymnasticator, provides a good simulation of the recoil cycle without the necessity of firing projectiles and may be employed to test or evaluate breech unlocking, opening, ramming, loading, etc. These devices are located principally at Rock Island Arsenal. Additional information for design or availability can be obtained from the US Army Armament Research and Development Command, Dover, NJ (Ref. 26).

Another is the cannon breech mechanism testing machine. Two of these were designed and developed by Watervliet Arsenal for use with the 175 mm M113/M113E1 Gun and 8 in. Howitzer, M2A1E1. The system is capable of reproducing the pressure-time signature of most gun firing pressures up to 75,000 psi. The system requires a capped stub tube to close the tube end of the breech and seal off the firing mechanism cavity. Provision also must be made to obturate the breech to prevent initial oil leakage. Cyclical studies for fatigue or life estimates can be conducted with this equipment. Additional information is available at the Benet R&E Laboratories, Watervliet Arsenal, Watervliet, NY (Refs. 27 and 28).

Downloaded from http://www.everyspec.com

REFERENCES

1. AR 1000-1, *Basic Policies for Systems Acquisition by the Department of the Army.*
2. S. Timoshenko and D. H. Young, *Elements of Strength of Materials*, D. Van Nostrand Company, Inc., Princeton, NJ, 1962.
3. DARCOM-P 706-193, Engineering Design Handbook, *Computer Aided Design of Mechanical Systems, Part Two.*
4. Lloyd and Lipow, *Reliability, Management, Methods, and Mathematics*, Prentice-Hall, Inc., Englewood Cliffs, NJ, 1962.
5. AMCP 706-196, Engineering Design Handbook, *Development Guide for Reliability, Part Two, Design for Reliability.*
6. AMCP 706-197, Engineering Design Handbook, *Development Guide for Reliability, Part Three, Reliability Prediction.*
7. AMCP 706-198, Engineering Design Handbook, *Development Guide for Reliability, Part Four, Reliability Measurement.*
8. AMCP 706-200, Engineering Design Handbook, *Development Guide for Reliability, Part Six, Mathematical Appendix and Glossary.*
9. *Reliability Engineering*, ARINC Research Corporation, Prentice-Hall, Inc., Englewood Cliffs, NJ, 1964.
10. C. Lipson, *Engineering Applications of Reliability*, University of Michigan, Ann Arbor, MI, 1963.
11. E. Pieruschka, *Principles of Reliability*, Prentice-Hall, Inc., Englewood Cliffs, NJ, 1963.
12. E. Barlow and F. Proschan, *Mathematical Theory of Reliability*, John Wiley and Sons, New York, NY, 1965.
13. "A Manual of Reliability", *Product Engineering Special Report*, Morgan Grampian, Inc., New York, NY, 16 May 1960.
14. D. N. Chorafas, *Statistical Processes and Reliability Engineering*, D. Van Nostrand Company, Inc., Princeton, NJ, 1960.
15. E. A. Felsted, "Product Reliability", *Ordnance*, (November-December 1971).
16. R. P. Haviland, "Reliability in Guided Missiles", *Jet Propulsion*, July 1971.
17. C. Lipson, *Interference Theory from the Viewpoint of Safety Factor*, University of Michigan, Ann Arbor, MI, 1967.
18. AMCP 706-192, Engineering Design Handbook, *Computer Aided Design of Mechanical Systems.*
19. AR 70-10, *Test and Evaluation During Development and Acquisition of Materiel.*
20. Col. F. King, "Product Assurance Symposium Technical Report (Acquisition Guidelines on Test and Evaluation, USAMC)", *American Ordnance Association*, 1972.
21. F. B. Pollard and J. H. Arnold, Jr., *Aerospace Ordnance Handbook* (12 Test and Evaluation), Prentice-Hall, Inc., Englewood Cliffs, NJ, 1966.
22. J. W. Dally and W. F. Riley, *Experimental Stress Analysis*, McGraw-Hill, Inc., New York, NY, 1965.
23. A. J. Durelli and V. J. Parks, *Moire Analysis of Strain*, Prentice-Hall, Inc., Englewood Cliffs, NJ, 1970.
24. Design of Breech Mechanism, *A Symposium Ordnance Project* R1-100L, Franklin Institute, Philadelphia, PA, 1969.
25. Harris and Crede, *Shock and Vibration Handbook*, McGraw-Hill, Inc., New York, NY, 1961.
26. *Future Artillery Test Requirements by the Test Facilities Committee*, ART-469, USAWECOM, R&D Directorate, Artillery System Laboratory, Rock Island, IL, August 1969.
27. *The Design and Construction of a Cannon Breech Mechanism Testing Machine*, WVT-QA-6902, Watervliet Arsenal, Watervliet, NY, 1969.
28. *Determination of the Fatigue Life for the Breech Mechanism Assembly for the Cannon, 175 mm Gun, M113 and M113A1*, WVT-7108, Watervliet Arsenal, Watervliet, NY, 1971.

Downloaded from http://www.everyspec.com

REFERENCES (cont'd)

29. E. B. Haugen and D. H. Mutti, *Statistical Metals Manual*, University of Arizona Tucson, AZ, 1973.

30. R. E. Weigle, "Dynamic and Static Analysis of Strains in Breechblock Components of Large-Caliber Weapons", Proceedings of the Society for Experimental Stress Analysis 21 (1964).

BIBLIOGRAPHY

AR 70-38, *Research, Development, Test, and Evaluation of Materiel for Extreme Climatic Conditions*.

MIL-STD-810, *Environmental Test Methods*.

MTP 3-2-807, *Materials Testing—Nondestructive Examination*, AD-717 372.

MTP 3-2-809, *Strain Measurement—Brittle Lacquer Method*, AD-717 374.

MTP 4-2-805, *Projectile Velocity Measurements*, AD-872 645.

MIL-STD-831, *Preparation of Test Reports*.

MTP 3-2-500, *Weapon Characteristics*, 1971, AD-726 909.

MTP 3-2-509, *Artillery Cannon*, 1970, AD-718 833.

MTP 3-3-510, *Weapons Functioning*, 1969, AD-867 236.

FSTC-HT-23-928-68, *Preparation of Artillery Weapons for Firing*, Translated (USSR), 1962, AD-688 058.

T. G. Beckwith and N. G. Buck, *Mechanical Measurements*, Addison Wesley Publishing Co., Inc., Reading, MA, October 1961.

ISA Transducer Compendium (Instrument Society of America) IFI/Plenum Data Corp., subsidiary of Plenum Publishing Corp., 227 West 17th Street, NY, 1969.

MTP 3-2-810, *Weapon Pressure Instrumentation*, 1966, AD-717 376.

C. C. Perry and H. R. Lissner, *Strain Gage Primer*, McGraw-Hill, Inc., New York, NY, 1962.

MTP 3-1-006, *Strain Measurement—Instrumental*, AD-876 179.

G. A. Jones, *High Speed Photography*, John Wiley and Sons, New York, NY, 1952.

MTP 2-2-800, *Center of Gravity*, AD-717 506.

MTP 3-2-800, *Inspection and Measurement of Cannon*, AD-718 709.

Downloaded from http://www.everyspec.com

CHAPTER 4
DEVELOPMENT CRITERIA AND PROCEDURES
SECTION I. DEVELOPMENT EVALUATION PROGRAM

4-1 GENERAL CONSIDERATIONS

The path of development of ordnance equipment from prototype to final product and serial manufacture is long and complex. A number of the activities that take place during this phase relate directly or indirectly to breech design. The failure of the weapon system in certain of these activities may necessitate redesign of the breech and, therefore, an understanding of the complete development procedure will benefit the designer. The objective of this chapter is to provide the designer with an overview of the complete process.

The procedure from initial design specifications to acceptance of initial serial manufacture is characterized by a number of specified design testing phases. In addition, internal development testing is conducted as required.

4-1.1 TESTING

For breech mechanisms, as for all mechanical systems, physical testing is an essential part of a development program. While the test programs have the obvious result of demonstrating successes and pinpointing failures, a coordinated test program has a second, less obvious role within the development cycle, which should be made clear at the outset of this discussion.

The development cycle can be viewed as a series of actions which are targeted to pass a series of test milestones. As a direct result of this fact, test reports are a perfect vehicle for amassing complete documentation of the development process. Test reports are generated which contain a statement of the test objectives, a complete description of the item being tested (by including drawings, material specifications, etc.), and a description of the tests which were performed. Thus the test report could serve not only to detail any successes or failures but also to establish a body of information which can be used as a reference source by the design team currently involved in the development of the breech mechanism, as well as by future groups who use the reports for data bank information.

The types of tests to be conducted — as well as the distribution of responsibility for the various tests among design, evaluation, and user agencies — will change from weapon system to weapon system. Details of the specific types of tests, as well as guidelines for their application, are found in AR 70-10 (Ref. 1) and will not be discussed in this handbook.

4-1.2 EXTERNAL INFLUENCES

The breech mechanism, being a subsystem of a larger weapon system, cannot be designed independently of the other subsystems. While it is far beyond the scope of this handbook to consider all possible influences on the breech mechanism design which may come into play, there are two areas which have enough effect that they cannot be ignored.

The first of these areas of influence is the type of ammunition to be used in the weapon system. For conventional ammunition, the breech development can proceed through standard progression. However, development for the use of ammunition which is substantially different from prior models (as with the introduction of missile launching capability on the 152 mm gun/launcher) will require, well in advance of a formal test prototype, the design and fabrication of a breech mechanism which will incorporate the new features mandated by the predictions for the

Downloaded from http://www.everyspec.com

new ammunition. It is conceivable that this action will be required even before ammunition parameters have been fully established and may serve as inputs to the ammunition design. This is a clear departure from the usual progression of development and places an additional burden on the design team. However, it presents an opportunity to obtain early test results on the applicable components.

A second external source of potential change is the gun tube. Should the tests of the tube dictate a change in the tube design, which in turn changes the breech ring configuration, a change to the breech mechanism design is a likely result. The existence of this possibility should be taken into consideration when establishing design and testing schedules.

4-1.3 SIMULATION TESTING

Simulation testing is a capability which has come into use for testing gun systems within the recent past. The two major advantages of simulation testing are the reduced time and expense incurred in achieving the required number of test-fire cycles, as compared with conventional prototype testing.

At the present time, there are two types of simulation testing which are used on breech mechanisms. The first of these is a propellant-charge simulator which can duplicate the time-pressure loading characteristics of the proposed ammunition (Ref. 2). The test is used to assess the strength and fatigue adequacy of a proposed design.

The second type of simulation often used is one which repeatedly and automatically opens and closes the breech mechanism (referred to as gymnastication). This simulation can be used to determine the acceptability of the performance of the mechanism as it degrades due to wear of the component parts. For more information concerning the specifics of these tests, the reader is referred to par. 3-20.

For almost any testing approach, the premium paid for strong advantages in some areas is the existence of shortcomings in other areas. Simulation testing is no exception to this rule, and some of them are discussed in the paragraphs that follow. The points discussed are not intended to be an exhaustive list; indeed, they are intended primarily to make the designer aware that there are shortcomings in the simulation approach and to give him a starting point from which he can begin his own evaluation of the benefits of simulation. Consideration of these possible shortcomings should be incorporated into the test plan.

The principal shortcomings lie in the propellant charge simulation. As mentioned previously, this simulation duplicates the time-pressure signature of the proposed propellant charge and is used to test the strength/fatigue characteristics of the breech mechanism. However, due to the way in which the pressure loading is applied, this test does not simulate the recoil-counterrecoil accelerations experienced by the breech mechanism in service. Further, this test does nothing to simulate the temperature or chemical environment encountered during service. It is fully possible to simulate each of these effects in the laboratory environment. However, it is extremely difficult to apply them concurrently. This fact should be taken into consideration during the planning and evaluation stages of testing.

Breech mechanism gymnastication testing also has one major shortcoming — i.e., the method of application, as was the case with ammunition simulation. When the mechanism is tested on the gymnasticator, the loads and motions applied are those which the designer considers "proper". Unfortunately, these limits do not necessarily correspond to the use profile to which the mechanism may eventually be subjected.

As a result of the preceding comments on simulation testing shortcomings, one point should by now be clear to the reader; simulation testing can be used to supplement, but not to supplant, firing tests. Due to their time and cost advantages, simulation tests should still be considered a valuable part of the overall test schedule. However, actual firing tests should still

Downloaded from http://www.everyspec.com

be considered as a final check on the results and conclusions gained from the simulation tests.

4-1.4 ENGINEERING TEST/EXPANDED SERVICE TEST (DT-2)

When the weapon has been redesigned and debugged using data obtained during Development Suitability Tests (DT-1), Refs. 2-5, an average of from 1 to 20 engineering prototypes are fabricated with materials, manufacturing procedures, and tolerances as close as possible to those to be used in final manufacture. These prototypes are used to develop data on solutions to the problems detected during DT-1 and to ensure that no new problems have developed. Usually one or two prototypes are used for internal firing and laboratory testing by the manufacturer. The remaining weapons are used in field tests which are conducted at test sites located at Aberdeen Proving Ground, MD; Yuma Proving Ground, AZ; Panama Canal Zone; and Alaska.

4-1.5 INITIAL PRODUCTION TESTS (DT-3)

Sample weapons from the initial production run are used for Government field testing. These tests are necessary to ensure that the production weapons function satisfactorily and that no new problem areas have been introduced by manufacturing technique modifications (from prototype to production manufacture). Normally, no additional internal testing by the manufacturer is required during this phase unless deficiencies are detected. For a more detailed discussion, the reader is referred to Refs. 2-5.

4-2 PROTOTYPE DESIGN DEFICIENCIES

Most of the design-related problems associated with a new breech mechanism will be detected during the testing described in par. 4-1. It is extremely important that such difficulties be detected as early as possible in the development cycle since correction becomes increasingly costly and time-consuming as development progresses. Such problems may, in addition, necessitate redesign or modification of other components in the weapon system. The paragraphs that follow summarize some of the problems that may be encountered. Due to the complexity of the breech mechanism, an individual treatment of the potential problems is beyond the scope of this handbook. However, by highlighting some of these problems, it is hoped that any design team will see the necessity for careful analysis of a proposed design in order to anticipate and eliminate potential problems at as early a stage in the development cycle as possible.

4-2.1 MECHANISM MALFUNCTIONS

Mechanism malfunctions include premature failure or unusual wear of the breechblock, breech ring, latches, operating lever assemblies, counterbalance mechanisms, extractor mechanism, firing mechanisms, breech closure threads, and sliding surfaces. Component failure includes breakage, cracks, excessive strain (deformation) causing poor or unreliable functioning or seizure, galling or pitting of moving parts, weakening of springs, excessive leakage, formation of burrs, pitting, excessive rusting, and corrosion or wear resulting in unsafe or unacceptable operation. In most cases, minor modifications such as change of material, surface finish, heat-treatment, and fillet radii will eliminate many of these problems. In other cases, minor or even major redesign is necessary.

4-2.2 DESIGN DEFICIENCIES

Design deficiencies relate to the inability of the breech system to perform satisfactorily when all components are operating as designed. These deficiencies include improper interaction with other system components such as recoil or loading mechanisms; the poor design or placement of operating handles or levers that cause awkward, unnatural, or excessive force by the weapon operators; insufficient space to load, unload, or operate the weapon; poor access to primer loading parts that require removal of gloves in

Downloaded from http://www.everyspec.com

cold weather; difficulty in operating the weapon at extremes of elevation or azimuth; other malfunction or failure of components when subjected to unusual stresses during firing or transport; and failure to protect components from the environment because of ineffective shields or covers, poor design, or allowing pockets, corners or exposed threads to accumulate water, dirt, dust, mud, or firing residue during storage, transport, or operation.

The effectiveness of design trade-off (e.g., the necessity of protecting the obturator pad and rings during loading as opposed to the desirability of having them exposed for easy visual inspection and maintenance) also will be determined during the testing phases and will provide additional feedback to the designer for use in redesign and debugging.

4-2.3 MAINTENANCE

The designer should strive to eliminate maintenance altogether by using sealed bearings or bearings requiring no lubrication, lubricated and sealed gears and chains, etc. If these are not possible, modular subassemblies, which can be easily and rapidly replaced in the field using available or, preferably, no tools, are recommended.

4-3 DEVELOPMENTAL REDESIGN PHASES

Responsibility lies with the design agency for correcting the design and implementing the changes shown to be necessary by the test phases. It is, however, important to consider the effects such changes will have on other parts of the weapon system; e.g., the crew, development and testing, production scheduling, and the cost of the program. Changes that affect the responsibilities of other members of the project team should be documented and transmitted to those individuals as soon as possible. If changes are significant enough to alter project scheduling or cost, the design agency must make appropriate recommendations to the contracting officer and project manager who have the responsibility for authorizing contract changes.

During this phase, other design refinements not included in the prototype weapon must be implemented. These may include provisions for lifting points for assembly/disassembly during maintenance, and complete implementation of the human factors analysis. The weapon analysis should be completed and the required manufacturing processes, material specifications, quality assurance requirements, and initial production planning reviewed. This is, of course, a team effort and it is of vital importance that all team members be kept informed of developments affecting their roles and be given an opportunity to contribute to decisions. Formal design reviews that provide documentation and control on a systemized basis are recommended to maintain optimal program coordination and progress. This subject is covered more completely in Ref. 6.

4-4 ACCEPTANCE: ENGINEERING/SERVICE TESTS

All testing, whether of the programmed (DT) or special purpose type, comprises three distinct phases:

1. Before-fire checks and preparations
2. Firing tests
3. After-fire checks.

Beyond this general breakdown, the programs are tailored to the specific requirements of the data sought. To illustrate, a representative test program will be described for a test series used to proof the 105 mm, M68 Cannon used on the M60A1 Tank.

Fig. 4-1 shows a work flowchart used to proof the first three units manufactured under a new production contract. Subsequent production units are tested using an abbreviated version of the proof tests (Fig. 4-2). The breech mechanism portions of these proof-test procedures follow.

Downloaded from http://www.everyspec.com

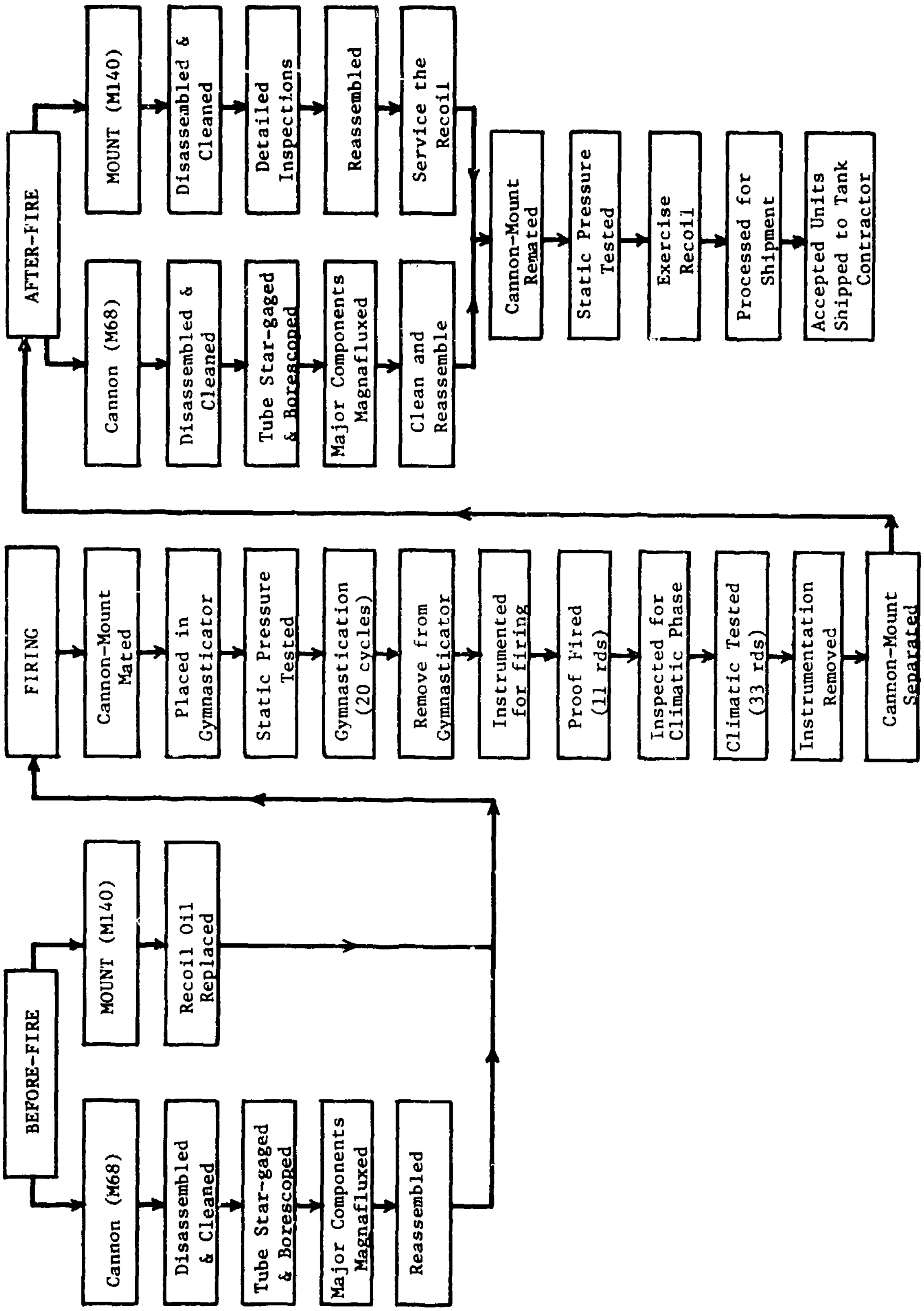


Figure 4-1. Work Flowchart (First of Contract)

Downloaded from http://www.everyspec.com

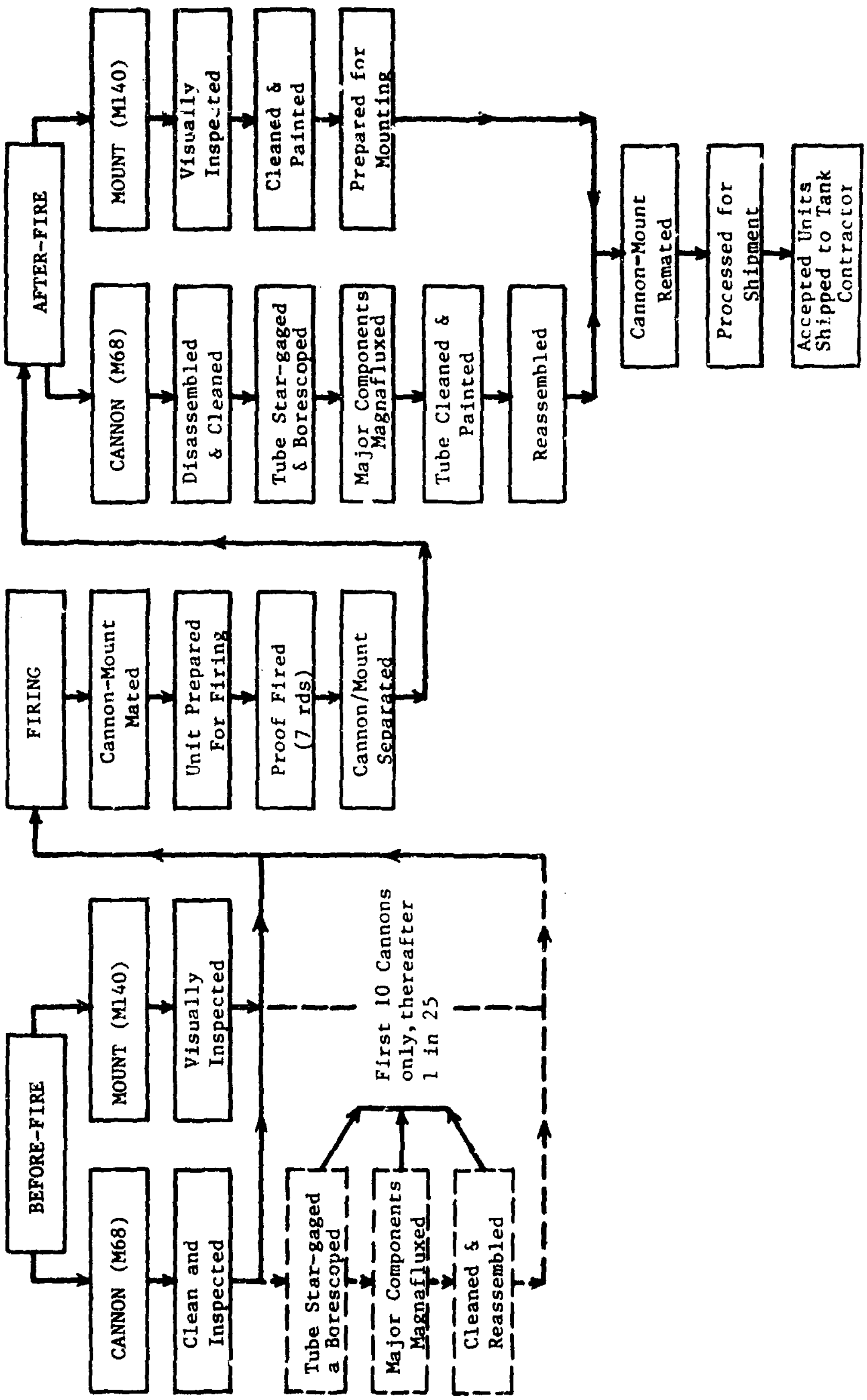


Figure 4-2. Work Flowchart (Subsequent Production)

Downloaded from http://www.everyspec.com

4-4.1 PROOF-TEST PROCEDURES

4-4.1.1 Before-Fire Checks and Preparations

The cannon is completely disassembled and cleaned. All components are examined for quality of workmanship to determine if they are free of defects (chips, burrs, scratches, stains on finished surfaces, or dimensions out of tolerance) due to improper fabrication, machining, or handling.

All major components (tube, breech ring, breechblock, and bore evacuator) are subjected to a magnetic particle inspection as prescribed in specification MIL-M-11472.

Acceptable components are reassembled and lubricated. The breech mechanism assembly is checked for proper operation of the breechblock. A continuity check is made of the electric firing circuit.

After gymnastication tests of the mount, the complete unit is mounted on the testing facility and instrumented in preparation for the proof-firing phase of the test.

4-4.1.2 Proof-Firing Tests

The proof-firing phase consists of firing the weapon at local ambient temperature conditions in accordance with the order of firing shown in Table 4-1.

TABLE 4-1
FIRING SCHEDULE

Round No.	Type	Rated Maximum Pressure of Gun,%	Gun Elevation, deg
1	M486	50	0
2	M489	Standard	0
3	M486	100	0
4	M486	115	0
5	M486	115	10
6	M486	100	10
7	M486	115	20
8	M486	100	35
9	M486	115	35
10	M486	115	35
11	M489	Standard	0

The following data are recorded on all rounds:

a. Oil pressure versus time (recoil cylinder, CEC gage)
b. Travel versus time (gun, potentiometer assembly)
c. Recoil length (gun, mechanical marker)
d. Recoil cycle time (gun, electric timer)
e. Peak chamber pressures (115% rmp* rounds only, M11 gage)
f. Muzzle velocities (chronograph)
g. Case ejection velocities (gun at 0 deg elevation) measured for standard, 100% rmp and 115% rmp only.

*rmp = rapid maximum pressure of gun

4-4.1.3 After-Proof Checks and Preparations

After the proof-firing phase, the cannon is disassembled, cleaned, and inspected in the same manner as that used in the before-fire check. Acceptable components are reassembled and prepared for the climatic phase of testing. It is essential that proper lubricants be used sparingly in this stage of preparations. All components of the firing mechanism and cam hinge pin should be left dry (not lubricated).

4-4.2 CLIMATIC TEST FIRING

4-4.2.1 Emplacement of Weapon

The weapon is emplaced in a temperature-conditioning facility (cold room), and all necessary instrumentation is installed and checked. The recoil system is serviced and the breech mechanism assembly is checked for proper functioning.

4-4.2.2 Firing Schedule

The weapon is fired; 11 rounds each at temperatures of +70°F, +125°F, and -65°F. The order of firing is the same as that listed in Table 4-1; however, cold room limitations might necessitate readjustment of the gun elevations. In this event, the test director should fire the weapon at the lowest and highest gun elevations possible. The weapon shall be conditioned a minimum of 48 h at each temperature before the firing tests are begun.

4-4.2.3 After-Fire Checks and Preparations (Climatic Testing)

After climatic testing, all instrumentation is removed, and the cannon and mount are

Downloaded from http://www.everyspec.com

separated. The cannon is completely disassembled and cleaned. The tube is star-gaged and borescoped, then subjected to a magnetic particle examination along with the breech ring, breechblock, and bore evacuator.

All other components of the breech mechanism assembly (i.e., extractors, drivers, firing mechanism parts) are inspected visually for evidence of damage, excessive wear, or peening of friction surfaces. After the inspections, acceptable components are cleaned, relubricated, reassembled, and processed for shipment.

4-4.3 ACCEPTANCE

4-4.3.1 Proof Markings

Proof accepted mounts and cannon are marked as proof accepted (PA) or tagged as proof rejected. The PA markings are stamped to the right of the serial numbers on the tube (muzzle end), breech ring, and mount nameplate.

4-4.3.2 Acceptance Criteria

All parts should be free of cracks, fractures, tears, and other defects after proof and climatic test firings as evidenced by both visual borescope and magnetic particle examination. The breech mechanism should operate without evidence of interference, erratic movement, or malfunction whether operated manually or semiautomatically.

4-4.4 ENDURANCE — LIFE TESTS

Because of the relatively high cost of field firing (costs range from approximately $125 per round for conventional ammunition up to $1,700 for the special development round in 1978 dollars), weapons are seldom tested to destruction under field conditions. After field firing tests are conducted to establish various life factors, the life of the weapon is usually established by subjecting the entire weapon or various components to cyclic testing using hydraulic firing simulators and breech mechanism gymnasticators.

The cost of using a drophammer of accumulator type hydraulic firing simulator would typically range from $4.00 to $6.00 per simulated firing (1978 dollars). The correlation between simulated and field firing test data for endurance and life testing has generally proved to be quite good.

4-5 PERFORMANCE EVALUATION

With favorable test results, the weapon design is finalized and production planning begins. With unfavorable results, redesign and/or changes in manufacturing processes or materials are necessary. Weapon acceptance, however, does not end the design process. Normally, a weapon is redesigned throughout its useful life in light of field failures, new or more efficient manufacturing processes, new materials, or changing use requirements.

The main criterion for weapon performance evaluation is its usefulness in the field. This includes — in addition to its ability to meet functional requirements — its reliability, availability, maintainability, and durability (RAMD). Functional performance — i.e., the ability of the weapon to deliver the required number of rounds per minute to the required point on the range under specified climatic and terrain conditions, etc. — can be verified in a relatively short time period by field testing. Conversely, verification of RAMD is not so simple and direct. Reliability and availability are considered sufficiently in Chapter 3 and Ref. 6. Although maintainability and durability are discussed in Chapter 3, additional material is provided in pars. 4-5.1 and 4-5.2 that follow. The *Quality Assurance Reliability Handbook*, Ref. 7, may be used as reference.

4-5.1 MAINTAINABILITY

Breech mechanism maintenance is essentially a mechanical problem. The advent of electrically powered breech mechanisms (Figs. 1-5 and 2-36) has made the problem somewhat more complex. As breech mechanisms become more sophisticated, the task of correctly maintaining and repairing them becomes increasingly challenging. In order to ensure that procedures are

Downloaded from http://www.everyspec.com

carried out correctly, the following maintainability guidelines should be followed in establishing maintenance procedures:

1. Maintenance operations should be kept as simple as possible, yielding simple instructional material.

2. Arithmetic calculations to be performed by the maintenance personnel should be kept to an absolute minimum.

3. No additional reference sources for performance of any task should be required.

4. Data processing (collection, reporting, transferring, etc.) should be kept to an absolute minimum.

Unless these guidelines are followed, the probability of an increased error rate is always present when the operations are performed at the weapon site along with other duties. Designing maintainability into the equipment is the only way to improve maintenance other than devising cumbersome, detailed "cookbook" type manuals that anticipate each action required by the technician. It is essential that all systems, particularly those that must be maintained under conditions of combat and unfavorable climatic conditions, be made as simple as possible Special tools and skill requirements must be kept to an absolute minimum. If a simple, easily repairable system cannot be designed, a modular system that can be replaced rapidly, or discarded or sent to a rear area for specialized maintenance should be used.

Military maintenance is usually stratified into levels that correspond to the skill of the personnel and the degree of difficulty of the task. Such stratification is necessary because of the demands for tactical development of the equipment and it is also a solution to the problem of efficiently using maintenance personnel of varying skill levels. Periodic checkouts of electronic equipment, for example, require a great deal of time but not a high degree of skill. Such tasks can be assigned to the less skilled person, releasing those with greater skills for more difficult repair jobs. The Department of the Army has grouped all maintenance into four categories: organization, direct support, general support, and depot. Equipment design must take into account the actual level of skill available at each maintenance level. Table 4-2 shows the categories and levels of maintenance in a theater of operations (Ref. 8).

Organizational maintenance describes maintenance normally authorized for and performed by the organization using the equipment. This maintenance includes functions and repairs within the capabilities of the unit personnel, skills, tools, and test equipment. Organizational level personnel usually are fully occupied with operating and using the weapon system and have little time for detailed maintenance and diagnostic checkouts. Usually, personnel associated most closely with weapon operation have few assigned maintenance operations. Consequently, maintenance at this level normally is restricted to periodic performance checks, cleaning and lubrication of the system, minor adjustments, and removal and replacement of some components. Personnel at this level usually do not repair the removed components. Rather, they forward them to the next higher level, provided the unserviceable component is to be repaired. Mobility requirements limit the amount of tools, test equipment, and repair parts available at the organizational level. The designer should consider these factors — especially the limited skills of available personnel and lack of maintenance equipment — in designing the breech mechanism.

Direct support maintenance generally is authorized and performed by designated maintenance activities in direct support of using organizations. This category is limited to the repair of end items or unserviceable assemblies in support of user organizations on a return-to-user basis. Material that is not authorized for repair by the using organization is repaired, if possible, by the direct-support unit that also furnishes maintenance supplies and services. Direct-support units are designed to provide close support to combat troops and facilitate tactical operations.

Downloaded from http://www.everyspec.com

Table 4-2
CATEGORIES OF MAINTENANCE IN A THEATER OF OPERATIONS

Category	Organizational Maintenance		Direct Support Maintenance	General Support Maintenance	Depot Maintenance
Done Where	Wherever the Equipment is	In Unit	In Mobile and/or Semi-Fixed Shops		In Base Depot Shop
Done by Whom	Operator	Using Unit	Division/Corps/Army		Theater Commander Zone and/or Z/I
On Whose Equipment	Own Equipment		Other Unit's Equipment		
Basis	Repair and Keep it		Repair and Return to User or Lower Support Activity		Repair for Stock
Type of Work Done	Inspection Servicing Adjustment Minor Repairs and Modification		Inspection Complicated Adjustment Major Repairs and Modifications Major Replacement Overload from Lower Echelons		Inspection Most Complicated Adjustments Repairs and Replacement Including Complete Overhaul and Rebuild Overload from Lower Echelons

Although these units have larger supplies of repair parts and maintenance equipment than the using organization, their mobility requirement limits the range of equipment and supplies and, therefore, the type of repairs that can be undertaken.

Direct-support maintenance personnel generally are more skilled and better equipped than personnel at the organizational maintenance level. Accordingly, they are charged with performing more detailed maintenance. At this level, failed components and equipment are repaired by replacing parts and subassemblies. These specially trained units support the using organization directly and make up an important part of major combat units. Usually, they are of company and detachment size with the capability of being organized into battalion and groups in a specific situation.

General support maintenance is authorized and performed by designated organizations in support of the Army supply system. Normally, general support maintenance organizations repair or overhaul materiel to required maintenance standards in a ready-to-issue condition based on applicable supported Army area supply requirements. This level of maintenance is performed by units organized as semifixed or permanent shops. They serve all the lower maintenance levels within a given geographical area. General support units include companies and detachments specializing in general supply, ammunition supply, maintenance by commodities, and other services. These units perform work for direct-support companies but rarely deal directly with the equipment user. Their primary function is to repair items that cannot be repaired by direct-support units. Such units must possess some

Downloaded from http://www.everyspec.com

mobility so that they can remain within convenient working distance of the direct-support units but rapid movement is not imperative. Some mobility is sacrificed so that they can have adequate time and facilities to perform their mission. A high degree of specialization and competence can be expected at this level. Personnel usually are trained extensively to become experts in specific components.

Depot maintenance, or thorough overhaul of economically repairable materiel, augments the procurement program. Depot maintenance organizations are nonmobile with equipment of extreme bulk and complexity. The high volume operation possible in these shops lends itself to effective use of assembly line techniques. This, in turn, permits the use of relatively unskilled workers in most positions, with a concentration of highly skilled specialists in key positions. Depot maintenance shops are located in areas remote from the theaters of operation and may perform services for several theaters. Operation of these installations by troops is not necessary; the bulk of the work may be done by the local labor market under military supervision.

Maintenance activities relating to or part of development programs must be examined during in-process reviews (Ref. 9). This constitutes a review of a materiel development project conducted at critical points of the development cycle to evaluate project status, effect coordination, and facilitate proper and timely decisions to assure ultimate acceptability for use by the Army. In-process reviews offer the various activities or agencies involved in the project the opportunity to analyze the subsystem from their respective viewpoints. Trade-offs can be evaluated and problem areas investigated. The following checklist indicates the major maintainability related areas that are considered during in-process reviews:

1. Evaluate access features of maintenance tasks-lubrication points; surfaces to be cleaned and oiled.
2. Evaluate assembly-disassembly tasks (including field adjustment needs) — applicable to firing mechanism, obturator, and other parts requiring disassembly for cleaning. Field stripping considerations; foolproof assembly qualities of designs.
3. Evaluate simplicity of tasks — time expended, extent of special tools needed, and degree of personnel skills required.
4. Evaluate degree of ease, or difficulty, encountered in extreme climate maintenance of the breech system.
5. Evaluate measures to protect the system from the environment (e.g., control of dirt and mud catching features in mechanisms and equipment; provision of covers for adverse weather).
6. Evaluate safety design features.
7. Inspect critical dimensions, threads, fillets, etc.; conduct diagnostic inspections using magnaflux, ultrasonics, and X-ray.

4-5.2 DURABILITY

Durability is a special case of reliability (MIL STD-721). Durability is the probability that an item will successfully survive its projected life, overhaul point, or rebuild point (whichever is the more appropriate durability measure for the item) without a failure. A durability failure is considered to be a malfunction that precludes further operation of the item and is great enough in cost, safety, or time to retore, that the item must be replaced or rebuilt. Thus durability implicitly describes the ability of a system to withstand the rugged environment of field use, rough handling, and lack of or improper maintenance. Durability of a system, i.e., its ability to withstand abuse without failing or becoming inefficient, is a major component of reliability and also of availability. In breech mechanisms, redundancy plays an important role in durability. If the automatic breech activation system fails, a backup manual mode of operation is available to keep the weapon firing. Evaluation of tests results from service life and accelerated testing, along with input from in-process reviews, help pinpoint shortcomings in durability factors (e.g., fatigue, wear, corrosion, and deterioration of finishes and paints). However, the major input

Downloaded from http://www.everyspec.com

for determining system durability comes from actual field use. As mentioned in par. 4-5, continuous redesign of a weapon system usually continues throughout its useful life because of unanticipated field failures and other reasons. Unfortunately, there seems to be no fooiproof method of simulating or testing all the situations that a system will undergo in actual combat use.

SECTION II. DESIGN FINALIZATION

4-6 INCORPORATION OF DEVELOPMENTAL RESULTS

During the developmental testing stages, numerous deficiencies will be discovered that will necessitate design changes, improvements, additions, deletions, and reevaluations. In this section methodology to ensure the orderly transition from test prototype to production weapon will be described.

4-7 ORGANIZATIONAL DOCUMENTATION, THE TECHNICAL DATA PACKAGE

To ensure an orderly development process, the designer must maintain progress documentation. Such documentation includes maintaining up-to-date specifications, data files, log books, design review and progress reports, and detail and assembly drawings. The final output of development phase documentation is the technical data package (TDP). The TDP, which normally is developed over a period of approximately 18 months, becomes the vehicle by which the Army conveys requirements to the manufacturer. The TDP documentation contains all design disclosure data, specifications, quality assurance provisions, and acceptance criteria required for development, production, and acceptance of the item. It includes the data lists, parts lists, drawings, Government standards and specifications, industry standards and specifications, and end item final inspection requirements. The TDP provides the Government with an equitable basis for competitive bidding and industry with the official documentation needed for bidding, make-or-buy decisions, estimating, vendor item purchasing, speciality house procurement, and production engineering. It is the basis of Government acceptance or rejection.

4-7.1 PRODUCT SPECIFICATION

The product specification, the basic document of the TDP, contains general design criteria, performance requisites, and inspection procedures not covered by the engineering drawings.

4-7.2 DATA LIST

The data list is an inventory of the total content of the TDP (including those items incorporated by reference) and a record of revision status. All specifications and standards (military, federal, and industrial) and all standard hardware items are identified.

4-7.3 PARTS LIST

The parts list is indentured starting at the top part (the complete system) and gives the total physical content of the end item. A separate parts list is prepared for each assembly which does not contain a list of material on the drawing depicting it. A list of material appears in the drawing only when the item is an inseparable assembly or a detailed drawing. The parts list is associated with its assembly drawing by use of the same number. Because assembly drawings lack definitive specifications, item quantities, and connecting hardware information, the parts list serves to complete the data in a manageable and convenient form.

4-7.4 DRAWINGS

Drawings are the heart of the TDP since they alone can control and completely delineate shape, form, fit, function, and interchangeability

Downloaded from http://www.everyspec.com

requirements for full competitive procurement. Military design drawings are prepared in accordance with Ref. 10. All or part of the TDP received by the industrial user, bidder, or manufacturer may be in the form of 35 mm microfilm aperture cards (Ref. 11). This format reduces the storage and shipping bulk of the TDP (or portion thereof) by about 95%. The use of aperture cards enables the user to reproduce as many copies as he may require.

TDP drawings are engineering rather than production drawings. DOD Instruction 5010.12 states that "End product documentation is defined as a design disclosure package which is sufficient to permit a competent manufacturer to reproduce an item without recourse to the original design activity". An engineering drawing applicable to a part — when supplemented by the referenced specifications and standards — should include all dimensions, tolerances, notes, and other data necessary to describe fully the characteristics of the part after all manufacturing has been completed.

4-7.5 QUALITY ASSURANCE DATA

The quality assurance data included in the TDP consists of the supplementary quality assurance provisions (SQAP), the inspection equipment drawings, and the appropriate quality assurance pamphlets. The SQAP cannot contain elements not cross-referenced to the applicable design requirements on the parent document. The SQAP is an inspection instrument providing quality assurance check points.

Certain end items requiring closely toleranced and geometrically controlled machine surfaces are accepted by the Government inspectors after scrutiny in conjunction with use of a Government supplied gage, an item normally not commercially available. Since it is supplied to the producer, certain limitations and restrictions are enforced. For each Government gage, there is an associated quality assurance pamphlet detailing its operation and maintenance. More often, however, the production contractor is expected to supply his own gages and inspection equipment to meet specified detail or general requirements.

4-7.6 STANDARDS AND SPECIFICATIONS

Government standards and specifications include the pertinent Military Standards, Military Specifications, Federal Standards and Specifications, and applicable Government handbooks and documents. Appropriate industry standards and specifications, as well as those published by societies, associations, or committees are included in the TDP.

4-7.7 END ITEM FINAL INSPECTION REQUIREMENTS (EIFIR)

This section of the TDP is a controlling factor in the final Government acceptance of an end item. The EIFIR specifies a record requirement and a chronological sequence listing relative to quality characteristics which must be verified for functional performance and completeness by the producer. Defects and the resultant corrective actions are listed to establish a permanent record of the final inspection of the item. The EIFIR is used in conjunction with the quality assurance provisions section of the specification, the SQAP, and any special contract requirements affecting quality characteristics.

4-7.8 REVISION SYSTEM

If the need for TDP revision develops, it is imperative that care be exercised in so doing. For example, changes made to any drawing that affects the interchangeability of repair parts for an equipment in the supply system must reflect a change in the affected part number. All revisions made to drawings and parts lists necessitate follow-through revisions up-dating all drawings lists in which the revised drawing and parts lists are mentioned.

4-8 OPERATING AND MAINTENANCE MANUALS

In addition to the TDP, it is normally necessary to prepare operating and maintenance

Downloaded from http://www.everyspec.com

manuals. These documents must be written to allow personnel with a minimum of technical training to operate and repair the equipment with a minimum of supervision or special training. For complex systems, several maintenance manuals — one for each level of maintenance activity — are usually necessary. Operating and maintenance information on breech mechanisms normally is included in a larger manual covering the entire weapon.

4-9 STANDARDIZATION AND INTERCHANGEABILITY

Standardization as a practice refers to the establishment of engineering procedures targeted to achieve the greatest practical uniformity of design. As this practice applies to breech mechanism design, it essentially is the assessment of procedures, specifications, configurations (as in thread profiles), standard components, and tools in light of their records of prior successful achievement in use.

One significant advantage which can be gained through this practice of assessing standard items for possible use, is the existence of supporting production testing and gages as well as maintenance tools. By using standard items, it is possible to eliminate the time and expense which would be incurred through implementing a new design. Further, there will exist test results which can serve as additional input into the decision process.

It should be emphasized that standardization should be given no higher priority in the design process than any other of the goals established initially. Since the ultimate test for acceptance of a design will be a vigorous firing test, the data available through standardization should be considered as informational only.

Further, standardization should not be allowed to inhibit design improvement efforts. The advantages and disadvantages of innovation should be compared on an equal basis with those of standardization when deciding which philosophy will be incorporated into the final design effort.

One caution is in order concerning standardization. Items which are or have been standard will not necessarily remain standard for the life of the breech mechanism design being undertaken. In order to assure that any specified standard parts will be available when needed, the using agency should have a controlling voice in any future revision or obsolescence action taken by the supplier.

Interchangeability is defined as the capacity of any given part, unit, or material to be substituted for a like part, unit, or material. There are two basic types of interchangeability: (1) functional, in which the two items fulfill the same requirements for the operation of the larger systems, and (2) physical, which exists if the two items can be mounted or connected in the same configuration, but the proper functioning of the device cannot be restored. From an expediency viewpoint, as with repair under field conditions, functional interchangeability is an obviously preferable alternative and should be the objective of the design team wherever practical.

In units requiring frequent servicing and replacement of component parts because of wear or damage, every part should be completely interchangeable with every similar part in every unit. In units expected to function satisfactorily without replacement of parts, it may be uneconomical to insist that parts be strictly interchangeable. The parent unit itself should be interchangeable with all other similar units, but the parts of one parent unit need not be interchangeable with those of another.

Within the context of the breech mechanism design, interchangeability becomes fundamentally a consideration of the fit and alignment between mating parts. Proper fit and alignment are achieved through either of two processes: (1) prior design and control of all critical features of all mating parts, or (2) a finish machining of the mating parts at assembly to some final dimension. For purposes of comparison of these two approaches, consider the case in which a cam follower lever is to be mounted in a specified axial

Downloaded from http://www.everyspec.com

and angular position relative to its shaft. An example of this type configuration might be the automatic breech opening cam follower crank of a sliding-block breech mechanism.

Consider first the finish-machine-in-assembly approach. As shown in Fig. 4-3, the shaft and cam follower are joined by a dowel pin. In order to accomplish this the piece parts are first fitted together loosely by hand. They are held either in a fixture designed to establish proper orientation or installed into their actual working position in the gun. By use of the references provided by the fixture or gun, the parts are positioned correctly, clamped together to prevent relative motion, then drilled and reamed to size to accept the dowel. If the resultant assembly is not to be put into service immediately, the two mating parts must be stored in a manner which assures that they will be matched up at final assembly.

Now consider the (prior-design) approach. The piece parts used in this approach are shown in Fig. 4-4; critically controlled dimensions in both figures are designated by asterisks (*). A comparison of Figs. 4-3 and 4-4 immediately reveals that the prior-design piece parts are more complex than the final-fit parts. There are more machining operations involved for the manufacture of the prior-design parts and the manufacturing process must be more carefully controlled; each of the critical dimensions must be checked, and some of the checks may require the use of special fixtures to assure accuracy. However, once these checks have been made, each of the cam followers can be used with any of the shafts; there is no need to inventory matched sets of parts.

The comparison can be continued on to field application and maintenance. Should the finish machined assembly require repair in the field, it must either be replaced as part of an assembly, or the final fitting operations must be repeated for two nonmating parts. The prior-design parts, on the other hand, can be replaced singly, as they fail, and with less specialized equipment; in fact, in some cases it would be possible to cannibalize disabled equipment under combat conditions.

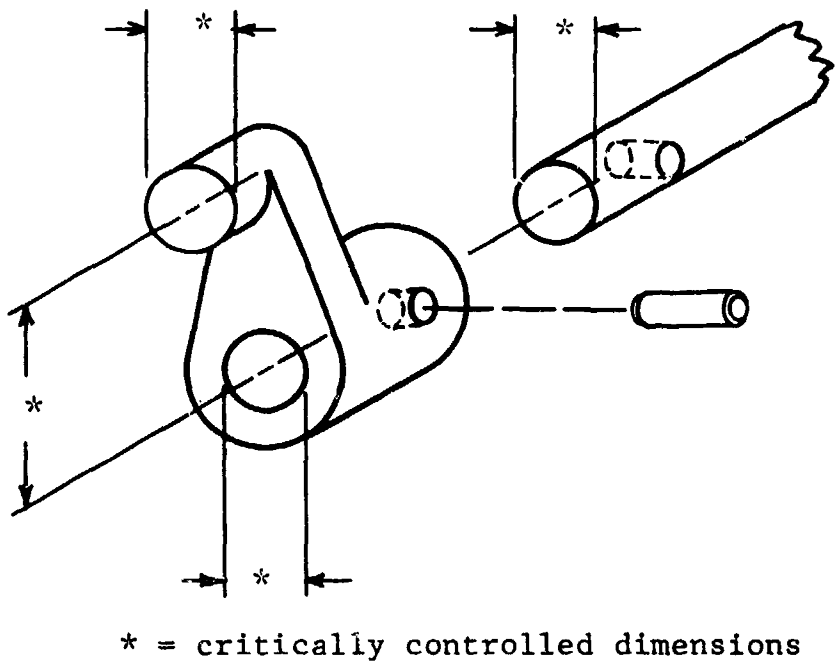
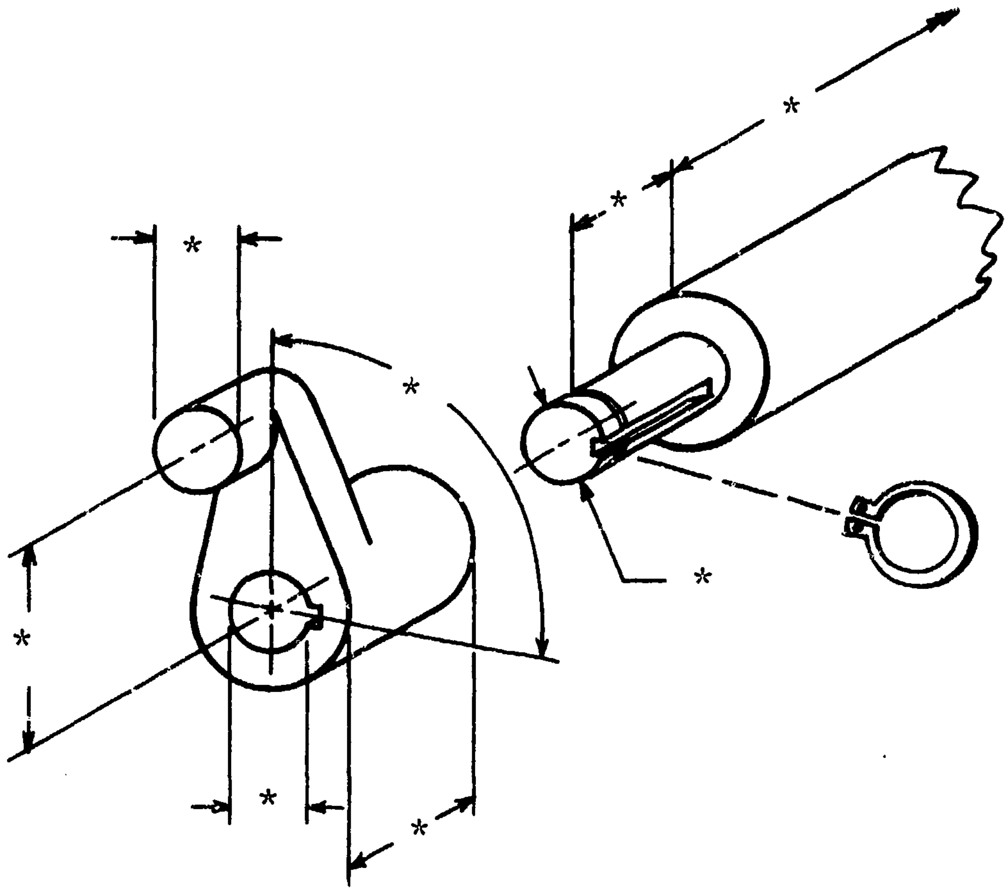


Figure 4-3. Finish-Machined Parts, Finish Machining in Final Assembly Approach for Interchangeability

Downloaded from http://www.everyspec.com



* = critically controlled dimension

Figure 4-4. Prior-Dimensioned Parts, Prior-Designed Approach for Interchangeability

While this discussion of the two manufacturing approaches has been centered on the cam follower example, the basic comparisons between the two approaches apply on a general basis. Finish machining has smaller manufacturing costs, in that fewer gages and inspection procedures are required, but inventory and maintenance costs are higher. The opposite is true for the prior-design approach, with the additional advantage of allowing cannibalization in the field.

The trade-offs between these two approaches must be assessed early in the program. In order to accomplish this task properly, it will be necessary for the design engineer to consult both a manufacturing specialist and a maintenance or maintainability expert in order to obtain a valid assessment of the implications of the alternative approaches. The further services of a cost specialist may be needed to determine accurately the comparative costs of the approaches projected over the life of the weapon.

Whichever of the two means for obtaining fit is chosen, there a requirement will exist to specify tolerances on the dimensions to which part are manufactured. The establishment of these tolerances is the responsibility of the design agency. Since they are a necessary part of any fabrication process, they should appear on drawings as early as the first prototype. Further, since tolerances are involved in the production process, the

Downloaded from http://www.everyspec.com

value of the tolerances will dictate the number and type of gages used for inspection, as well as the type of manufacturing equipment which will be used.

It should be apparent from the preceding discussions that dimensional tolerances play a key role in the successful implementation of a design. Too loosely applied tolerances can lead to poor performance of the weapon system. Applied too stringently, a weapon system can become so costly to produce and maintain that it may become impractical to introduce the weapon into the inventory. The reader is referred to Refs. 6 and 8 for a more detailed discussion of these trade-off considerations.

SECTION III. PRODUCTION PLANNING

4-10 MANUFACTURING ENGINEERING

As the weapon system enters its final development and preproduction stages, the breech mechanism designer's role changes to one of association and liaison with other engineering specialists. By this stage, all of the deficiencies in the functional design will have been worked out and the development emphasis shifted to producing the best possible system for the least possible time and money. During this period the in-process reviews will be conducted by a team that includes the breech designer; designers of other associated systems; production planners; manufacturing and process engineers; procurement, quality assurance, and gage personnel; and the project management team. Major objectives of the in-process reviews will be:

1. To maximize:
   a. Design simplicity
   b. Material and component standardization
   c. Potential industrial production capability
   d. Confirmation of design adequacy prior to production
   e. Process repeatability
   f. Product inspectability
   g. Industrial safety in production
   h. Competitive procurement.
2. To minimize:
   a. Procurement lead time
   b. Use of critical (strategic) materials
   c. Special production tooling
   d. Special test systems
   e. Use of critical processes
   f. Skill levels of production personnel
   g. Unit costs
   h. Design changes in production
   i. Use of limited availability items and processes
   j. Use of proprietary items without production right releases.

4-10.1 METHODS

The manufacturing processes used to produce breech mechanism components appear at first inspection to be quite conventional. Major components such as breech rings or breechblocks are made from high strength castings or forgings on large conventional metal working machines. Smaller components are similarly produced. Conventional as the machines and methods may appear, a substantial amount of development and modification has gone into the adaptation of these standard machine tools to the efficient production of complex breech mechanism components. Table 4-3 outlines the machining operations used in fabricating these components.

4-10.2 MATERIALS

Breechblocks and rings are typically made from 4140 or 4340 medium carbon steels hardened to R_C35 to 40. These materials are relatively hard to machine, particularly after hardening, and the breech mechanism designer may be tempted to look for other high strength substitutes that appear to be just as good

Downloaded from http://www.everyspec.com

TABLE 4-3
STANDARD MACHINING OPERATIONS

BORING	TURNING	DRILLING	MILLING	BROACHING
BORING MILL: Vertical Horizontal Precision ENGINE LATHES TURRET LATHES BAR MACHINES DRILL PRESSES MILLING MACHINES JIG BORER	LATHES: Engine Gap-Frame Facing Duplicating Tracer Turret SCREW MACHINE SWISS-AUTOMATIC	DRILL PRESS: Hand Feed Power Feed TURRET LATHE RADIAL DRILLING MACHINES DRILLING MACHINES: Multiple Spindle Turret Gang Horizontal	MILLING MACHINES: Knee & Column Ram Type Rotary Head PLANTER-MILLERS BED TYPE MILLERS	BROACHING MACHINES: Horizontal Vertical Pull-up Vertical Pull-down Vertical Single Ram Vertical Double Ram Chain Type Surface Rotary

SHAPING	PLANING	TREPANNING	TAPPING	GRINDING
SHAPERS: Horizontal Vertical SLOTTERS	PLANERS: Open-Side Double-Housing Convertible Milling Double Cut	DRILL PRESS: ENGINE LATHE TURRET LATHE	TAPPING MACHINES Single Spindle Multiple Spindle Gang TURRET LATHE DRILL PRESS	GRINDING MACHINES: Cylindrical Centerless Surface Chucking — Internal Centerless — Internal Special

functionally but easier to produce. Table 4-4 shows the general machinability for representative alloys. Maraging steels such as the 250 or 300 series may seem to be an ideal solution since these steels are extremely strong, tough, and are dimensionally very stable during hardening, thereby eliminating most of the after-hardening finish machining required on most materials. However, testing reveals that thick sections (in excess of 2 in. thick) tend to crack and are subject to early failure. Because of such experiences, the designer is cautioned to be very careful when contemplating a drastic deviation from normal materials. This is not to say that new materials and processes should not be used, but rather that care should be exercised to ensure proper testing of new materials and methods before they are committed to production.

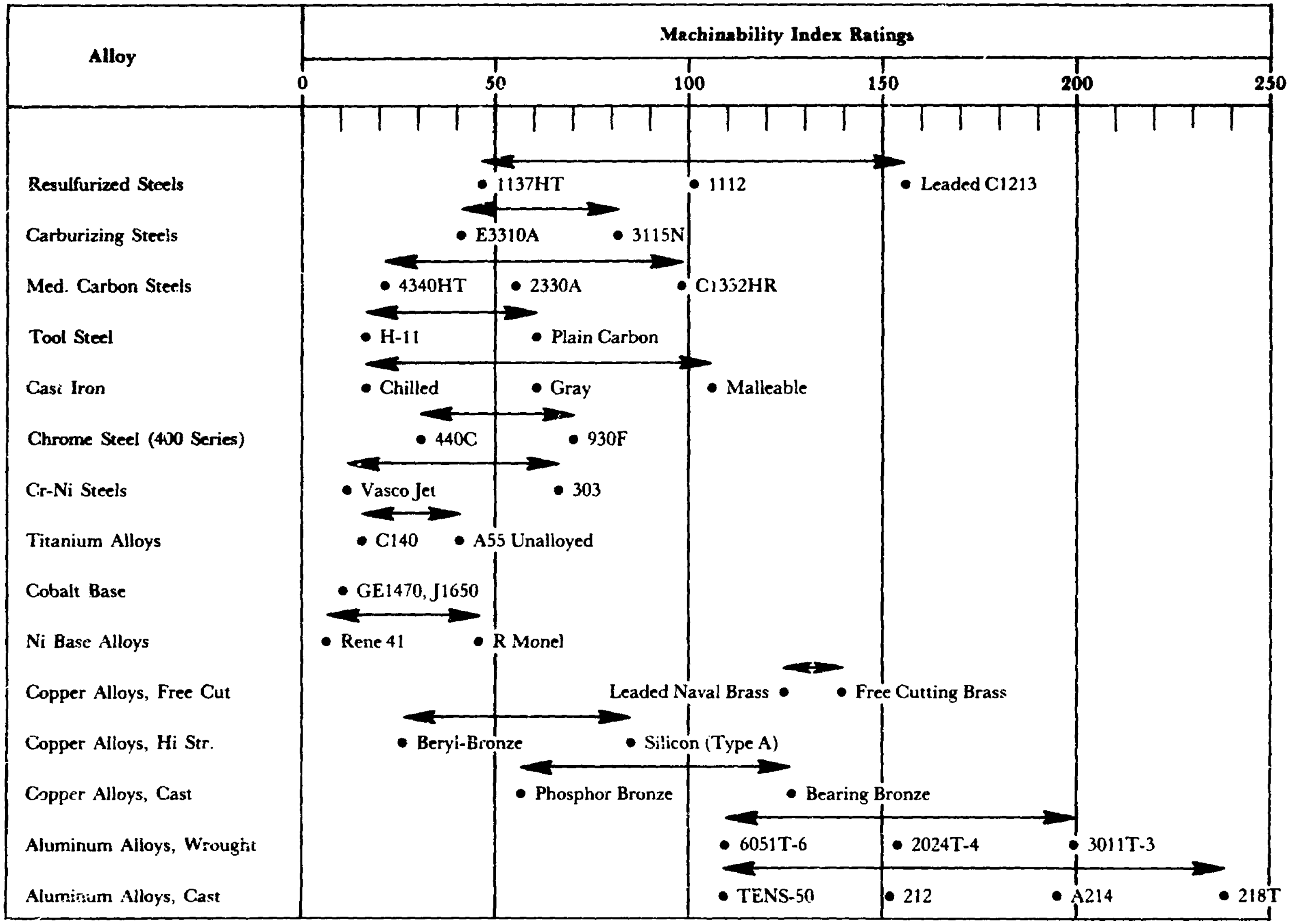
Materials that are difficult to machine, require special processing, or unusual handling should generally be avoided unless there are good reasons for their use. The use of materials that are in short supply or of uncertain availability should be avoided. This is particularly critical during wartime when normal supply channels may not be operating. (A listing of strategic materials may be found in Ref. 6.)

4-10.3 ECONOMICS

Concern for manufacturing costs is an increasingly important factor in weapon development contracts. Growing complexity, increased

Downloaded from http://www.everyspec.com

TABLE 4-4
COMPARISON OF MACHINABILITY INDEX RATINGS FOR SELECTED ALLOYS



Downloaded from http://www.everyspec.com

performance requirements, and a general rise in production costs have greatly increased the costs of procuring weapons. Electrically operated breech mechanisms such as the 152 mm gun launcher, for example, cost far more to produce than a more conventional breech and require close scrutiny to optimize production processes and minimize costs. The economics of producing any weapon component or system is a complex matter composed of numerous cost factors. It is the responsibility of the designer not only to design a workable breech mechanism but to minimize the cost of producing it. Fig. 4-5 reviews the costs associated with producing a typical piece part. Each of these costs is a function either directly or indirectly of the basic design of the part, the material used, the tolerances and finishes specified, and the gaging required.

An additional significant cost consideration that is often overlooked is the volume to be produced. A design that is optimal for prototype production is usually far from optimal for small-volume production and is most surely very uneconomical to mass produce. The design of the part, the material used, the machining and

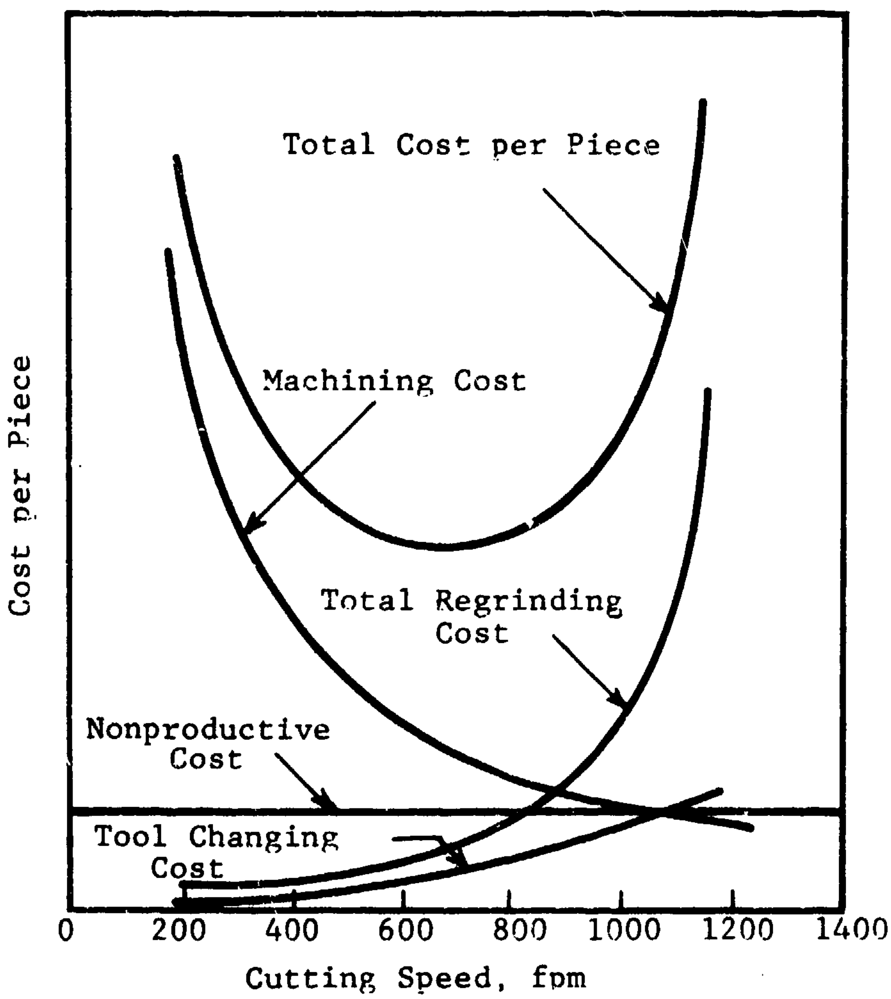


Figure 4-5. Total Cost per Piece—Sum of Tool Cost, Machining Cost, and Nonproductive Cost

Downloaded from http://www.everyspec.com

fabrication processes, and even the gaging and inspection are direct functions of the number of parts being produced. While the typical production lot size for breech mechanism components of the sizes considered in this handbook seldom exceed several hundred, it is still of prime importance to relate the projected production lot size to the design of the part. A detailed discussion of the applicability of basic processes to lot size can be found in Ref. 6.

Figs. 4-6 through 4-12 show the cost relationships of rigidly specified machining. They are

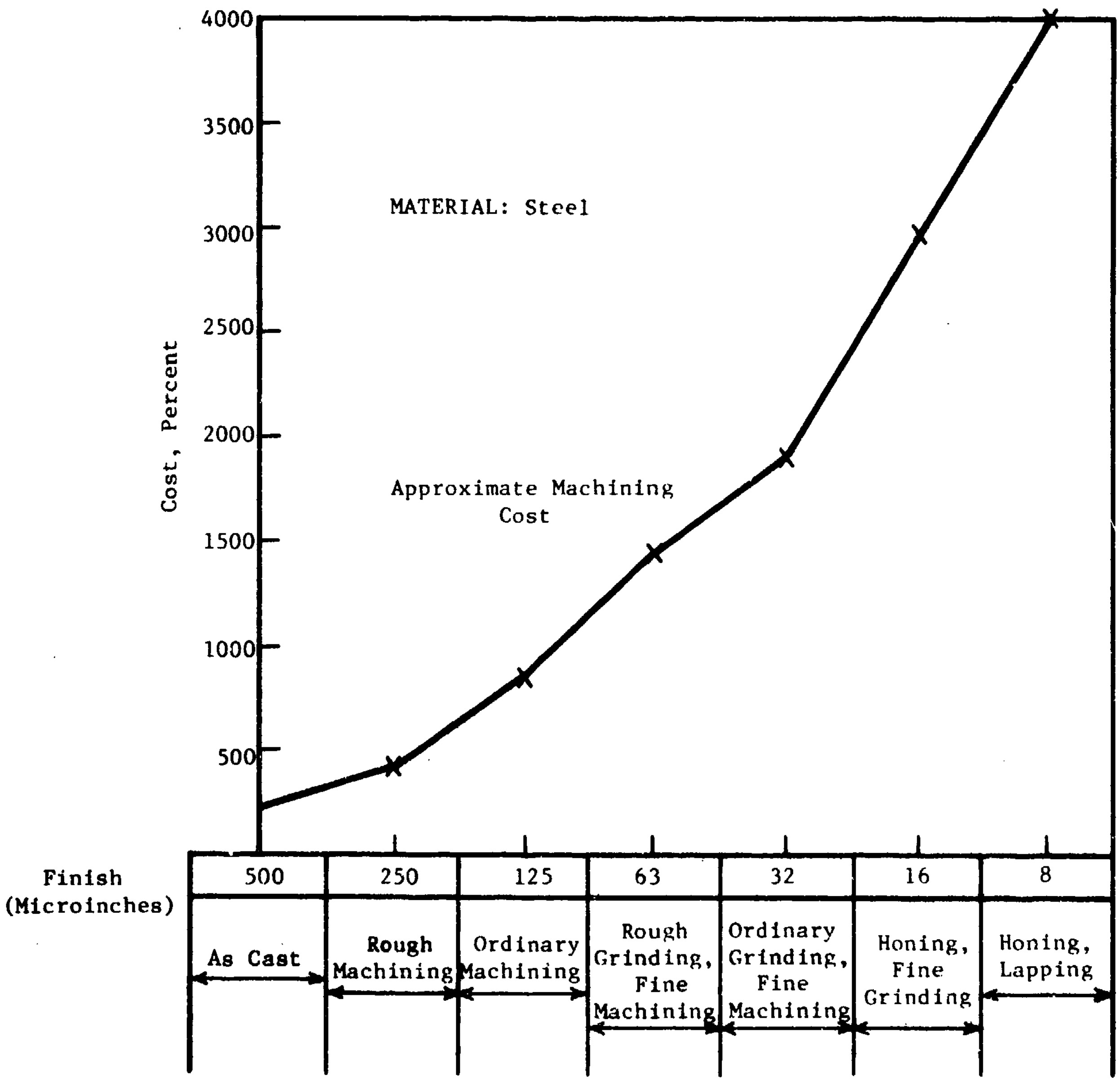


Figure 4-6. Machining Costs and Surface Finishes

Downloaded from http://www.everyspec.com

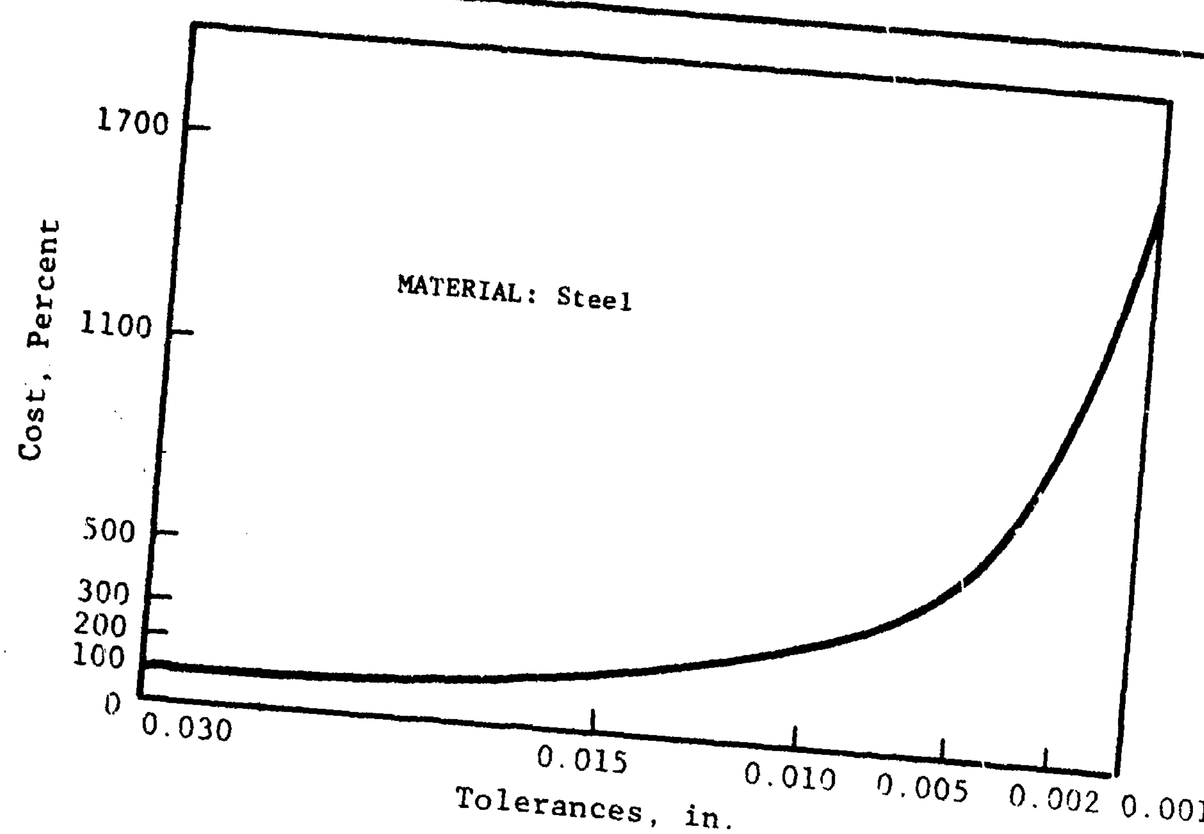


Figure 4-7. Relationship of Tolerance to Cost

presented to give the designer insight into the relationships between close tolerances and very fine finishes and costs.

4-11 MILITARY/INDUSTRIAL PROCUREMENT CONSIDERATIONS

4-11.1 PLANNING

While most of the purchased hardware and tooling required to fabricate breech mechanisms is essentially "off the shelf", it is important to involve procurement in the planning as early as possible. Quite often those items that are assumed to be readily available prove to be the hardest to acquire. The availability of tooling and machine tools can also influence the design of breech mechanism components. Information on the machine tools, tooling, and hardware available can be of great assistance to the designer, even during the early design stages. Under emergency conditions, consultation with procurement is even more important since needed hardware, machine tools, and tooling probably will be in short supply. Failure of the designer to make his requirement known at an early stage could cause considerable delay or shortages of components for the entire weapon system.

4-11.2 TOOL AND GAGE REQUIREMENTS

To design a breech mechanism or its component parts effectively, it is essential that the designer be familiar with the machine tools and tooling that make the parts and the gages, and techniques that are used to check the in-process and finished parts. The designer is referred to Ref. 12 for such information.

Downloaded from http://www.everyspec.com

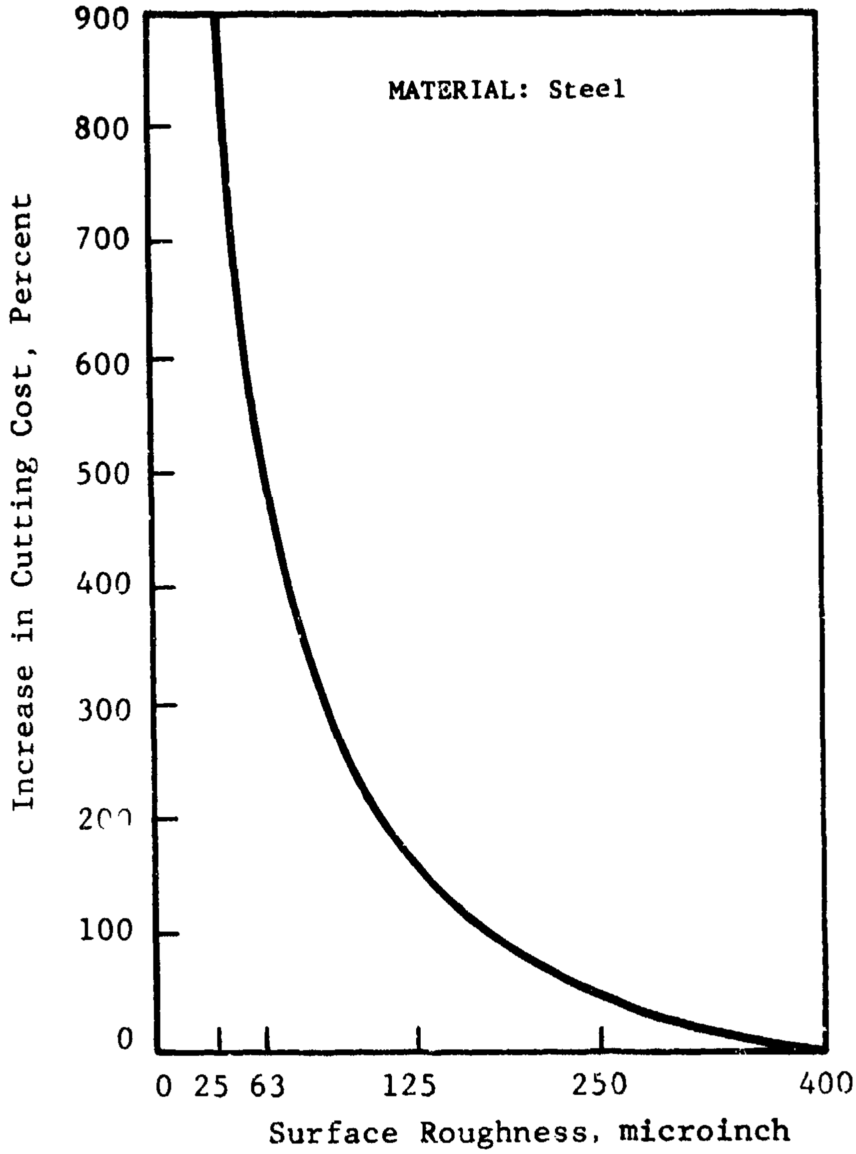


Figure 4-8. Quality Standards vs Cost

Downloaded from http://www.everyspec.com

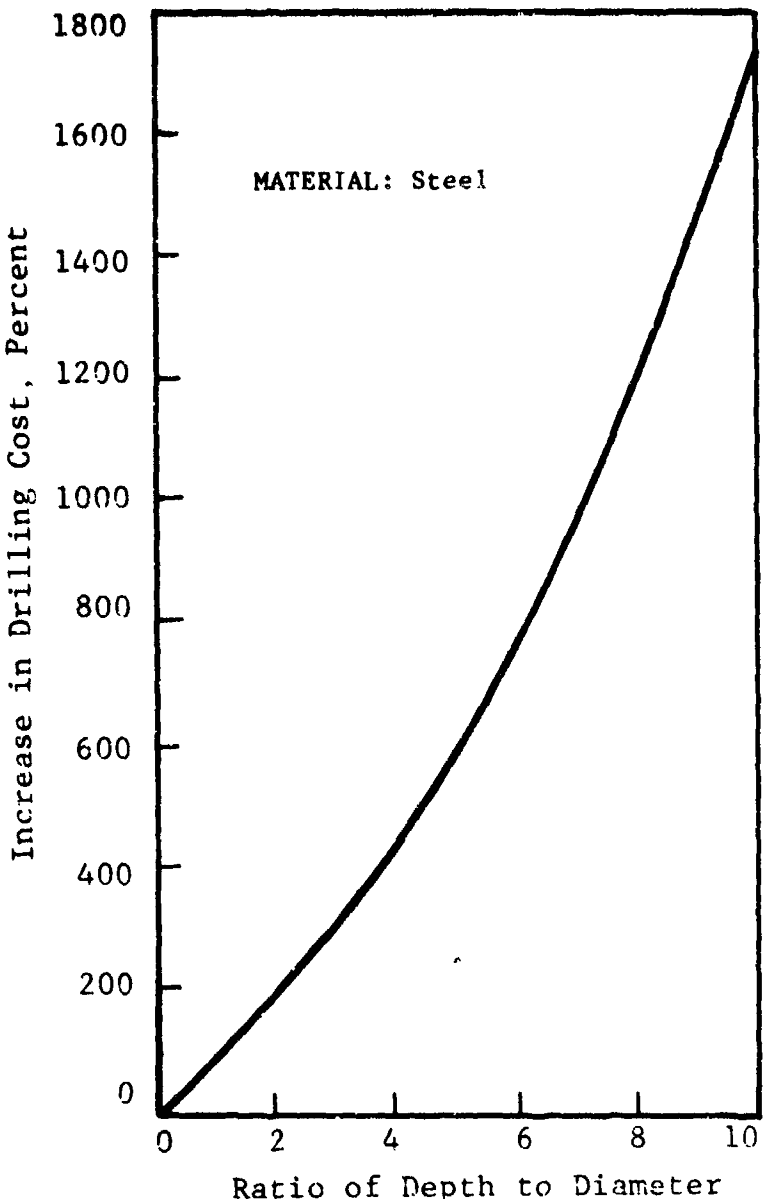


Figure 4-9. Depth-Cost Study of Drilled Holes

Downloaded from http://www.everyspec.com

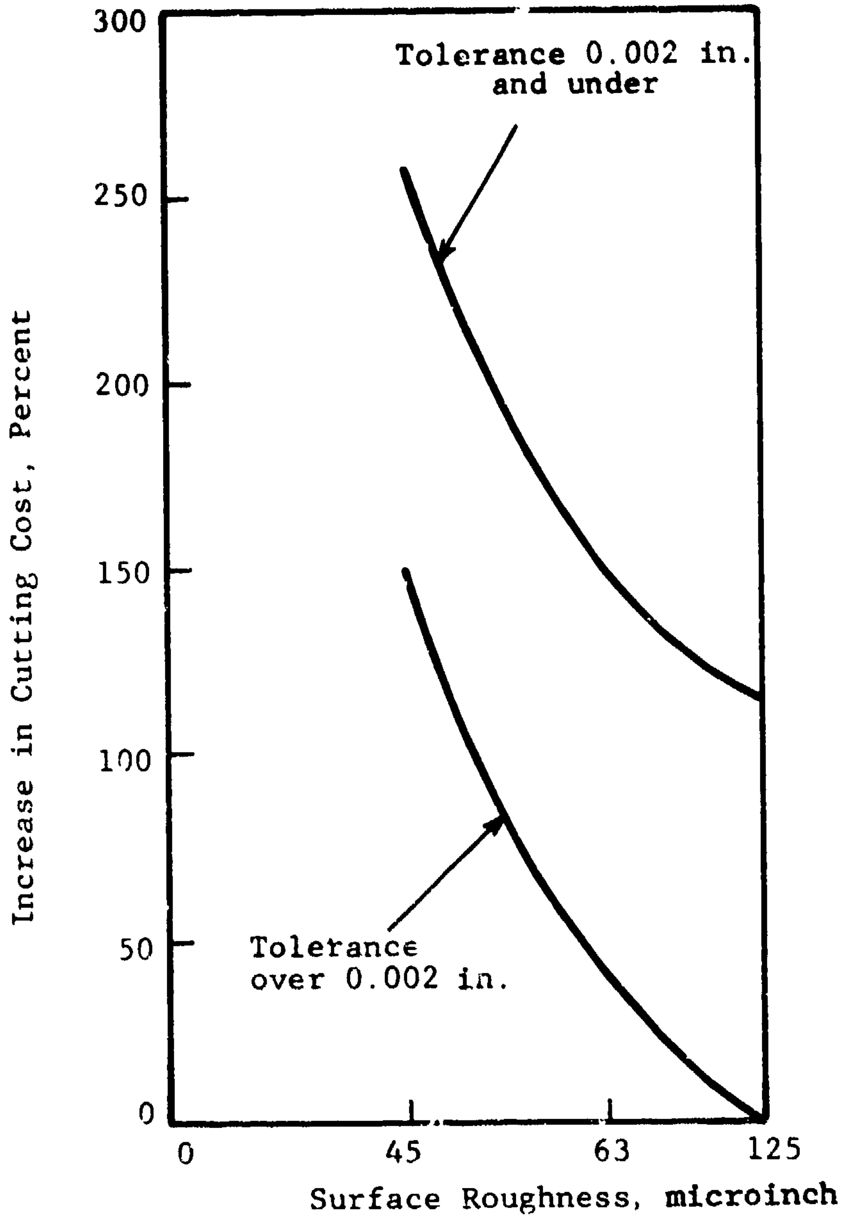


Figure 4-10. Cost Behavior in Face Milling

Downloaded from http://www.everyspec.com

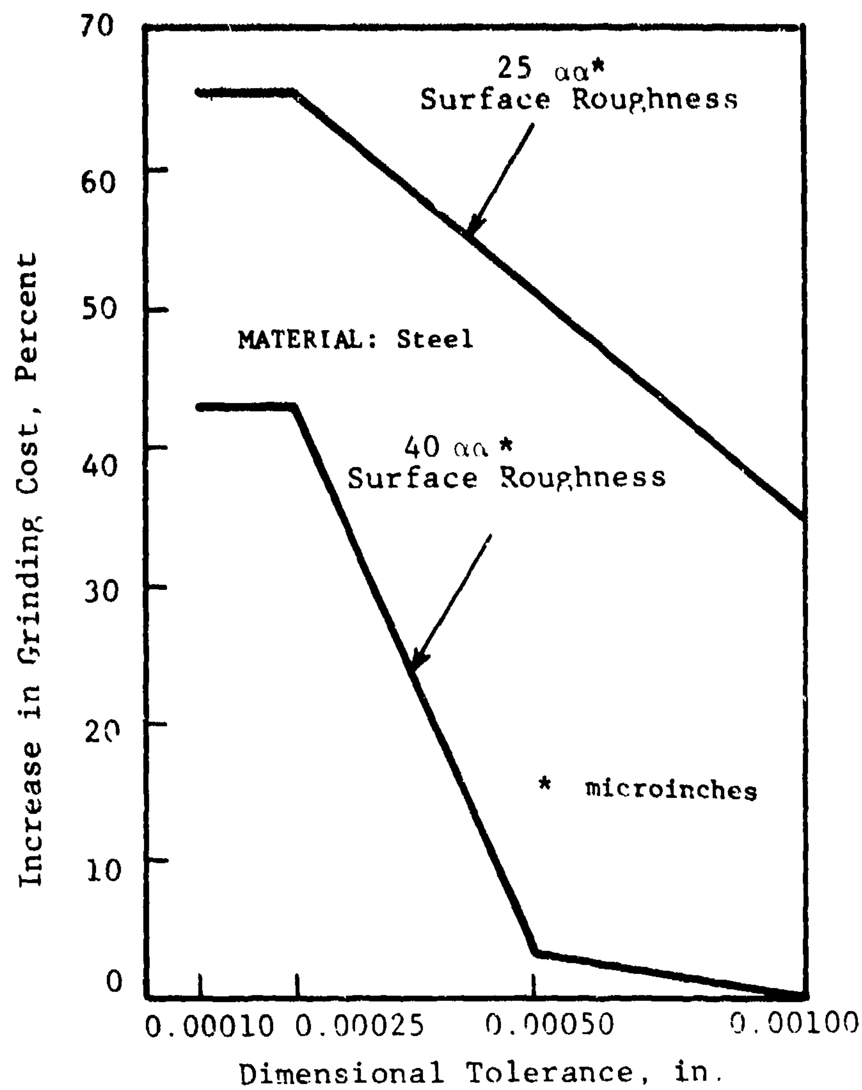


Figure 4-11. General Pattern of Grinding Costs

Downloaded from http://www.everyspec.com

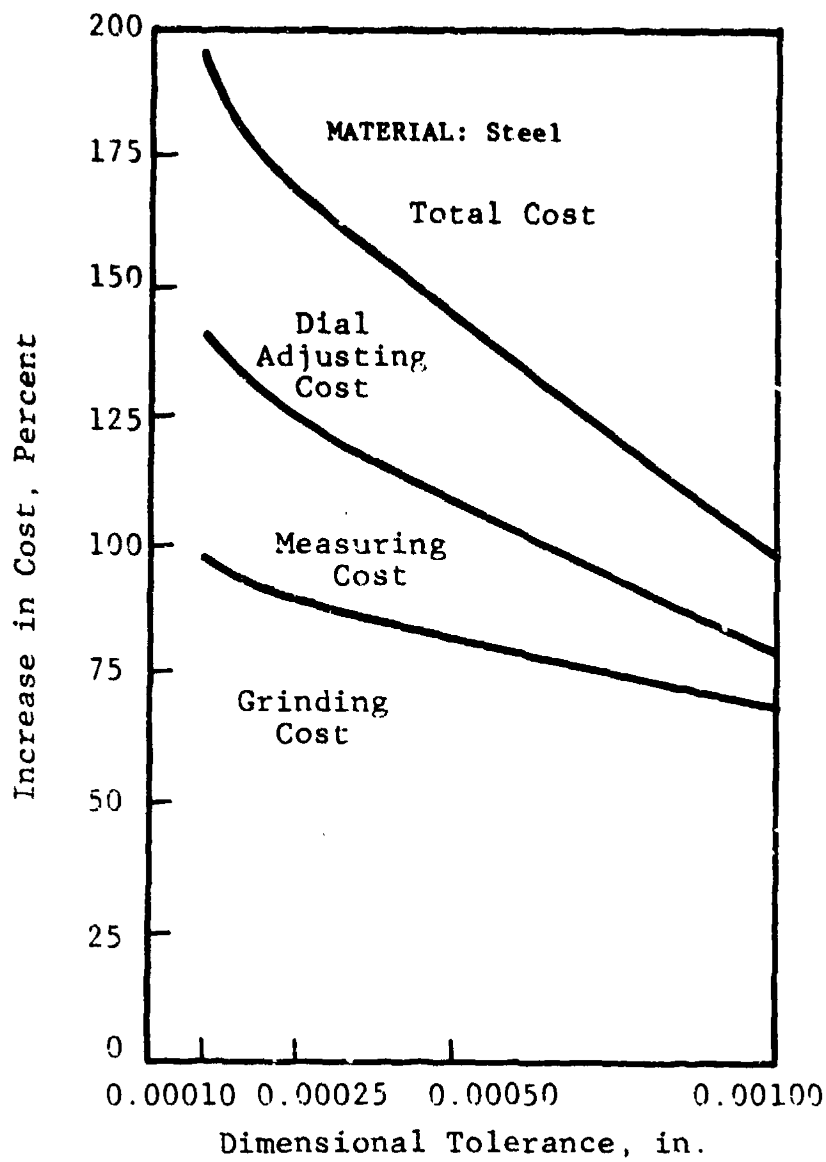


Figure 4-12. Machine and Operator Cost Effect

REFERENCES

1. AR 70-10, *Test and Evaluation During Research and Development of Materiel*.
2. C. W. Egan and J. P. Purtell, *Development of Repetitive Kiloton Thrusts of Milliseconds Duration for Simulating the Firing and Determining the Reliability of Heavy Weapon Components*, Watervliet Arsenal, Watervliet, NY, June 1972, AD-286 647.
3. DOD Directive 5000.1, *Major System Acquisitions*
4. AR 1000-1, *Basic Policies for Systems Acquisition by the Department of the Army*.

Downloaded from http://www.everyspec.com

REFERENCES (cont'd)

5. Letter of Instruction for Implementing the New Material Acquisition Guidelines, ACSFOR, 23 August 1972.
6. AMCP 706-100, Engineering Design Handbook, *Design Guidance for Producibility*.
7. AMCP 702-3, *Quality Assurance Reliability Handbook*.
8. AMCP 706-134, Engineering Design Handbook, *Maintainability Guide for Design*.
9. AR 70-1, *Army Research, Development, and Acquisition*.
10. MIL-D-1000, *Drawings, Engineering and Associated Lists*.
11. MIL-STD-804, *Format and Coding, Tabulation, and Aperture Cards for EDMS*.
12. L. E. Doyle, et al., *Manufacturing Processes and Materials*, Prentice-Hall, Inc., Englewood Cliffs, NJ, 1961.

Downloaded from http://www.everyspec.com

GLOSSARY

A

accessibility. A measure of the relative ease of admission to the various areas of an item.

angle of traverse. 1. Horizontal angle through which a gun or launcher can be turned on its mount. 2. Angle between the lines from a gun or launcher to the right and left limits of the front that is covered by its fire, i.e., the angle through which it is traversed.

artillery (arty). Artillery piece. Gun or rocket launcher, with mounting, too large or too heavy to be classed as a small arm. The lower limit of size or caliber varies somewhat within the Armed Services, but the term is presently applied to any gun or launcher which uses ammunition of a caliber greater than one inch and which is not designed for hand or shoulder use.

automatic breech mechanism. A device that utilizes the energy of recoil, or the pressure of the powder gases, to open the breech, withdraw the fired cartridge case, insert a new cartridge, and close the breech. After firing the first round, the only hand operation necessary for the firing of succeeding rounds is that of continuing to pull the trigger. Present usage of the automatic mechanism is restricted to guns of small caliber that use the small arms cartridge, or fire a projectile weighing not more than a pound. Machine guns have a breech mechanism of the full automatic type.

availability. A measure of the degree to which an item is in the operable and committable state at the start of the mission, when the mission is called for at an unknown (random) point in time.

B

band, rotating. A soft metal band around the projectile near its base. The rotating band centers the projectile and makes it fit tightly in the bore, thus preventing the escape of gas, and by engaging the rifling, gives the projectile its spin.

bore diameter. The interior diameter or caliber of a gun or launching tube.

bore evacuation. Clearing of the bore of propellant gases and extraneous material after firing.

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.

breechblock. The part of a gun, especially a cannon, which closes the breech. The breechblock usually contains the firing pin, and in many types of guns it is also used to chamber the round.

breechblock carrier. Hinged member of one type of breech mechanism which guides and supports the rotating breechblock of cannon.

breechblock, eccentric-screw (Nordenfeld). This breechblock is cylindrical and is threaded on its exterior surface to screw into the breech recess, which is correspondingly threaded. The breechblock is much larger in diameter than the bore, and the axis about which it rotates does not coincide with the axis of the bore. There is a U-shaped off-center opening in the block called the loading recess, which coincides with the bore only when the block is in its open position. The ammunition is inserted into the bore through the loading recess. With ammunition inserted as far as it will go, the breechblock is rotated about its axis approximately a half revolution to close the breech and locate the loading recess away from the bore. The firing mechanism is made so that it properly lines up with the bore in closed position. To open the breech, the block is merely rotated in the opposite direction until the loading recess again comes into alignment with the bore.

Downloaded from http://www.everyspec.com

GLOSSARY (cont'd)

breechblock, interrupted-screw. Also called slotted-screw. A breechblock consisting essentially of a threaded cylindrical block, with longitudinal sectors of the threads removed. The breech recess is likewise threaded, with longitudinal sectors of the threads removed. In both cases there are an even number of sectors and the threads are removed from alternate sectors. The breechblock is made to move longitudinally into the breech recess without turning, the threaded sector in each instance moving into the blank sector of the mating part. Then with a comparatively small turn, the threads of the breech and block are fully engaged, and the block is locked. If the threads were not cut out as indicated, several full turns of the block would be required to attain the same result.

breechblock operating mechanism. A mechanism which unlocks and withdraws the breechblock from the breech, swings the block clear of the breech recess, and then returns it to the firing, or closed, position after loading. There are two types: carrier-supported and tray-supported, according to whether supported by a breechblock carrier or a breechblock tray.

breechblock, sliding-wedge. A breechblock that is rectangular in cross section and slides in a rectangular recess in the breech ring to open and close the breech. Where the motion of the breechblock is vertical, the mechanism is referred to as a vertical sliding-wedge breechblock. Where the motion is horizontal, the block is called a horizontal-sliding wedge breechblock.

breechblock, stepped-thread (Welin). A modification of the breechblock, interrupted-screw. The breech recess and the breechblock are cut with a series of stepped threads, so that when the breechblock is inserted and turned in the breech recess, matching sections of stepped threads engage. By using the stepped type of thread, less rotation is necessary to close the breechblock, and greater threaded surface or holding area is possible. This breechblock is used on modern cannon which fire separate-loading ammunition.

breechblock tray. A tray-like support for the breechblock, hinged to the breech of a large cannon, which supports the breechblock when it is withdrawn and permits it to be swung clear of the breech.

breech bushing. That part of the gun breech on the interior surface of which the threaded and slotted sectors of the breech recess are formed.

breech hoop. A steel jacket for reinforcing the breech end of a built-up cannon. It may contain the breech recess which is threaded to receive the breechblock.

breeching space. The linear distance between the face of the fully closed bolt and the apex of the cone formed by a prolongation of the shoulder taper. This distance, however, is sometimes measured from a datum diameter on the first shoulder.

breech interlock. Safety device used with weapons that are loaded or rammed automatically or in weapons in which the position of the breechblock cannot be readily seen by the loader. It functions to prevent the loading or ramming of a round when the breechblock is not fully open.

breech mechanism. The assembly at the rear of a gun which receives the round of ammunition, inserts it in the chamber, fires the round by detonating the primer, and extracts the empty case. *See also*: **automatic breech mechanism**.

breech operating mechanism. A mechanism used for opening and closing the breech. May be manual, semiautomatic, or automatic in operation. *cf*: **breech mechanism**.

breech preponderance. 1. Unbalance of the tipping parts of a weapon when the weight of the "breech end" exerts a greater moment about the trunnions than does the weight of the "muzzle end". Modern weapons usually have

Downloaded from http://www.everyspec.com

GLOSSARY (cont'd)

a muzzle preponderance because of the trunnions being mounted near the breech end of the tipping parts. Unbalance may be corrected by an equilibrator. 2. The amount of the unbalanced moment.

breech pressure. In interior ballistics, the pressure from the propellant gases, acting against the inner face of the breechblock. Because of the movement of the projectile toward the muzzle, a pressure gradient develops, so that the breech pressure is somewhat greater than the pressure acting upon the projectile.

breech recess. The space at the rear of the barrel assembly of a cannon, formed in the interior of the breech ring to receive the breechblock.

breech reinforce. That part of a cannon in front of the breech and in the rear of the trunnion band.

breech ring. The breechblock housing, screwed or shrunk onto the rear of a cannon, in which the breechblock engages.

breech tray. *See*: **spanning tray**.

C

caliber (cal). 1. The diameter of a projectile or the diameter of the bore of a gun or launching tube. In rifled arms, the caliber is measured from the surface of one land to the surface of the land directly opposite. Often the caliber designation is based on a nominal diameter and represents a close approximation rather than an exact measurement. Caliber is usually expressed in millimeters or inches. Examples: a 105 mm howitzer and a 6-in. gun have calibers of 105 mm and 6 in., respectively. When expressed as a decimal without an indication of the unit, the unit "inches" is understood. For example, a caliber .30 cartridge has a bullet which is approximately .30 in. in diameter. 2. The bore diameter (caliber) of a weapon used as a unit for indicating the length of its bore, measured from the breech face of the tube to the muzzle. For example, a 6-in., 50-caliber gun would have a caliber (bore diameter) of 6 in. and a tube length of 50 calibers or 25 ft.

cannon. A complete assembly, consisting of a tube and a breech mechanism, firing mechanism or base cap, which is a component of a gun, howitzer, or mortar. It may also include muzzle appendages. The term is generally limited to calibers greater than one inch.

case. Short for **case, cartridge**.

case, cartridge. An item designed to hold an ammunition primer and propellant, and to which a projectile may be affixed. Its profile and size conform to that of the chamber of the weapon in which the round is fired except for recoilless rifles.

chamber. 1. Part of a gun in which the charge is placed. In a revolver, it is a hole in the cylinder; in a cannon, it is that space between the obturator or breechblock and the forcing cone. Nominally it is the space occupied by the cartridge case. 2. To insert a round of ammunition in the chamber of a firearm or gun.

charge, base. The base section of a multisection propelling charge, where the sections are not identical.

charge, full. The propelling charge intended to produce full service velocity. The term "full charge" is sometimes used as an identifying designation when more than one type of propelling charge is available for a weapon.

charge, propellant increment. A propelling charge composed of increments, the number of which can be varied to produce the desired muzzle velocity. The item as issued contains the increments required to impart the maximum rated muzzle velocity. Commonly applied to charges for mortars. *See also*: **charge, propelling**.

charge, propelling. A charge of low explosive that is burned in a weapon to propel a projectile from it; propellant; propellant charge.

Downloaded from http://www.everyspec.com

GLOSSARY (cont'd)

Burning of the confined propelling charge produces gases which force the projectile out of the cannon tube.

continuous-pull firing mechanism. This type of firing mechanism is used on weapons firing fixed or semifixed ammunition. Aside from safety devices, the firing lock is not affected by motion of the breechblock. The complete operation of a continuous-pull firing mechanism is affected by one continuous pull of the lanyard. There are three phases in the firing cycle: (1) Cocking Phase. The first part of a pull on the lanyard compresses the firing spring; (2) Firing Phase. The remaining part of the lanyard's movement disengages the sear, thus allowing the spring to expand and force the firing pin against the primer, firing it; and (3) Retracting Phase. The lanyard slacks, and the firing mechanism parts return to their position at rest.

counterrecoil. Forward movement of a gun returning to firing position (battery) after recoil.

crew-served. Of or pertaining to anything served or operated by a crew as distinguished from an individual, e.g., a weapon operated by a crew of two or more persons.

D

DeBange obturator. An obturator in which the gas pressure, due to firing, acts against a mushroom head which compresses an elastic pad. This causes the pad to expand radially against split rings, which in turn expand to make a gas-tight seal against the breech recess wall, thus sealing the breech. *See*: **obturator**.

defilade. 1. Protection from hostile ground observation and fire provided by an obstacle such as a hill, ridge, or bank. 2. Vertical distance by which a position is concealed from enemy observation. 3. To shield from enemy fire or observation by using natural or artificial obstacles.

depression angle. The vertical angle between the horizontal and a line or object pointed downward, as the angle formed by the depression of a gun barrel below the horizontal.

direct fire. Fire delivered on a target in which the sights of a weapon are brought directly on the target.

E

ejection. The process of ejecting an empty cartridge case from small arms and rapid fire guns. Performed by the ejector.

ejector. 1. Mechanism in small arms and rapid fire guns which automatically throws out an empty cartridge case or unfired cartridge from the breech or receiver. *cf*: **extractor**.

elevation quadrant. *See*: **quadrant**.

erosion. *Specif.* The enlargement or wearing away of the bore of a weapon by the movement of high-temperature gases and residues generated from the burning of the propellant, by chemical action, and by friction between the projectile and the bore.

extraction. The process by which the fired cartridge cases are pulled from the chamber of a gun.

extractor. A part in a gun for removing cartridge cases from the chamber.

extractor groove. The groove machined in the base of a cartridge case, a short distance above the head. The groove receives the extractor of the breech mechanism and permits the case to be withdrawn by the extractor. Extractor grooves are used in automatic weapons, in preference to extractor rims (flanges) formed on the cartridge case base. *cf*: **extractor rim**.

extractor pocket. The opening through which the extractor enters the chamber. The extractor pocket may cause extraction difficulties, because of expansion of the case into it.

extractor rim. A rim or flange around the head of a cartridge case to provide a grip for the mechanical extractor of the weapon. *cf*: **extractor groove**.

Downloaded from http://www.everyspec.com

GLOSSARY (cont'd)

F

field gun. A field artillery piece mounted on carriages and mobile enough to accompany infantry or armored units in the field.

fighting compartment. That portion of a fighting vehicle in which the occupants service and fire the principal armament. It occupies a portion of the hull and all of the turret, if any.

firing mechanism. A mechanism for firing a primer. The primer may be for initiating the propelling charge, in which case the firing mechanism forms a part of the weapon. If the primer is for the purpose of initiating detonation of the main charge, the firing mechanism is a part of the ammunition item and performs the function of a fuze.

firing mechanism, electric. A firing mechanism using a firing magneto, battery, or ac power in a circuit with an electric primer. One side of the line is connected by an insulated wire to the primer, and the other side is grounded to the frame of the weapon.

firing mechanism, electric percussion. A firing mechanism which fires the primer electrically or by a percussion blow.

firing mechanism, percussion. A firing mechanism which fires the primer by percussion.

firing mechanism, percussion hammer. A firing mechanism in which a hammer, actuated by a pull of a lanyard, strikes the firing pin and fires the weapon.

fixed ammunition. Ammunition with primer and propellant contained in a cartridge case permanently crimped or attached to a projectile. Loaded into the weapon as a unit. Usually termed a "cartridge". *cf*: **semifixed ammunition, separate-loading ammunition, separated ammunition**.

forcing cone. The 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.

G

gas-check seat. The conical surface in the breech bore of a gun, carefully machined to provide a close fit with the split rings of the obturator.

gun. 1. *General*. A piece of ordnance consisting essentially of a tube or barrel, for throwing projectiles by force, usually the force of an explosive, but sometimes that of compressed gas, spring, etc. The general term embraces such weapons as are sometimes specially designated as gun, howitzer, cannon. (Separate entry.) 2. *Specif*. A gun (sense 1) with relatively long barrel, usually over 30 calibers, with relatively high initial velocity, and capable of being fired at low angles of elevation.

gun launcher. A gun adapted to launching guided missiles or rockets.

H

hammer. The part of the firing mechanism of a gun that strikes the firing pin or percussion cap and fires the gun.

hand rammed. As part of cartridge nomenclature, indicates that the cartridge is intended to be rammed into the gun by hand rather than by power.

handle, breech operating. A handle used for opening and closing the breech.

headspace. The distance between the face of the locked bolt or breechblock of a gun and some specified point in the chamber.

With guns designed for rimless, bottlenecked cartridges, headspace is the space between the bolt face and a specified point on the shoulder of the chamber; with guns using rimmed cartridges, the space between the bolt face and the ridge or abutment in the chamber against which the rim rests; and with guns using rimless straight-case cartridges, the space between the bolt face and the ridge or point in the chamber where the mouth of the cartridge case rests.

Downloaded from http://www.everyspec.com

GLOSSARY (cont'd)

heavy antiaircraft artillery. Conventional antiaircraft artillery pieces larger than 90 mm, the weight of which in a trailed mount is greater than 40,000 lb.

heavy artillery. *Specif.* Artillery, other than antiaircraft artillery, consisting of all howitzers and longer-barreled cannon of a caliber larger than those included in the classification of medium artillery.

howitzer (how). A complete projectile-firing weapon with bore diameter greater than 30 mm. The howitzer is used to deliver curved fire, with projectiles of lower muzzle velocities than those from the gun. The length of bore of a modern howitzer usually lies between 20 and 35 calibers, and the maximum angle of elevation is about 65 deg. The muzzle velocity, hence range and curvature of the trajectory, can be altered by the use of any of several propelling charges or zones, thus permitting a howitzer to reach targets hidden from gunfire. In length, weight, and muzzle velocity the howitzer lies generally between the gun and the mortar. *See also*: **cannon**.

howitzer, heavy, self-propelled. A complete projectile-firing weapon, with a medium muzzle velocity and a curved trajectory, mounted on a self-propelled vehicle. The bore diameter is larger than 200 mm. It is designed for use as a mobile infantry weapon.

howitzer, heavy, towed. A complete projectile-firing weapon with a medium muzzle velocity and a curved trajectory. The bore diameter is larger than 200 mm. It does not have facilities for self-propulsion. *See also*: **howitzer, light, towed** and **howitzer, medium, towed**.

howitzer, light, self-propelled. A complete projectile-firing weapon with a medium muzzle velocity and a curved trajectory, mounted on a self-propelled vehicle. The bore diameter is over 30 mm through 125 mm. It is designed for use as mobile artillery.

howitzer, light, towed. A complete projectile-firing weapon with a medium muzzle velocity and a curved trajectory. The bore diameter is over 30 mm through 125 mm. It does not have facilities for self-propulsion. *See also*: **howitzer, medium, towed; howitzer, heavy, towed**; and **howitzer, pack**.

howitzer, medium, self-propelled. A complete projectile-firing weapon, with a medium muzzle velocity and a curved trajectory, mounted on a self-propelled vehicle. The bore diameter is 125 mm through 200 mm. It is designed for use as mobile artillery.

howitzer, medium, towed. A complete projectile-firing weapon with a medium muzzle velocity and a curved trajectory. The bore diameter is 125 mm through 200 mm. It does not have facilities for self-propulsion. *See also*: **howitzer, light, towed** and **howitzer, heavy, towed**.

howitzer, pack. A complete projectile-firing weapon with a medium muzzle velocity and a curved trajectory. It is designed to be transported by animal or delivered by parachute. It may function as towed artillery.

human engineering. The area of human factors which applies scientific knowledge to the design of items to achieve effective man-machine integration and utilization.

human engineering laboratory (HEL). A DARCOM activity at Aberdeen Proving Ground that prepares anthropometric data and other information concerning the human body for considerations by design agencies in materiel design projects.

human factors. A body of scientific facts about human characteristics. The term covers all biomedical and psychosocial considerations. It includes but is not limited to, principles and applications in the areas of human engineering, personnel selection, training, life support, job performance aids, and human performance evaluation.

hygroscopic. Having a tendency to absorb and hold water, particularly moisture from the air.

Downloaded from http://www.everyspec.com

GLOSSARY (cont'd)

I

increment. An amount of propellant added to, or taken away from, a propelling charge of semifixed or separate-loading ammunition to allow for differences in range. Increments are commonly packed in propellant bags made of cartridge cloth, as for the main propelling charge.

indirect fire. Gunfire delivered at a target that cannot be seen from the gun position.

inertia firing mechanism. This type of firing mechanism, like the continuous-pull type, is used on weapons firing fixed and semifixed ammunition. This mechanism is characterized by a heavy firing pin and guide assembly which moves forward by inertia to strike the primer after the action of the firing pin spring has stopped. The firing pin and guide assembly is retracted by a separate retracting spring. The mechanism cocks when the breechblock is opened and remains cocked during loading and closing of the breechblock. It is fired by pulling a lanyard, striking a lever, or by other mechanical means.

initiator. A device used as the first element of an explosive train, such as a detonator or squib, which upon receipt of the proper mechanical or electrical impulse produces a burning or detonating action. It generally contains a small quantity of a sensitive explosive.

item, interchangeable. One which: (1) possesses such functional and physical characteristics as to be equivalent in performance, reliability, and maintenance, to another item of similar or identical purpose; and (2) is capable of being exchanged for the other item without selection for fit or performance, and without alteration of the items themselves or of adjoining items, except for adjustment.

L

lanyard. A cord, wire, or [illegible] for firing a gun from a distance, giving the gunner protection from recoiling parts.

lay. 1. To direct or adjust the aim of a weapon. 2. Setting of a weapon for a given range, or for a given direction or both.

Not usually applied to shoulder or hand arms in either sense.

light artillery. All guns and howitzers of 105 mm caliber (4.13 in.) or smaller.

loading angle. Angle of elevation specified for loading a particular weapon with its ammunition.

loading tray. Trough-shaped carrier on which heavy projectiles are placed so that they can be more easily and safely slipped into the breech of a gun.

M

maintainability. A characteristic of design and installation which is expressed as the probability that an item will be retained in or restored to a specified condition within a given period of time, when the maintenance is performed in accordance with prescribed procedures and resources.

maintenance, corrective. The actions performed, as a result of failure, to restore an item to a specified condition.

maintenance, preventive. The actions performed in an attempt to retain an item in a specified condition by providing systematic inspection, detection, and prevention of incipient failure.

major caliber. Gun or ammunition 8 in. in caliber, or larger. Navy terminology. No longer used as an Army classification.

maximum depression. The maximum vertical angle below the horizontal at which a piece can be laid and still deliver effective fire.

maximum elevation. The greatest vertical angle at which an artillery piece can be laid. It is usually limited by the mechanical structure of the piece.

medium artillery. Artillery which includes (1) guns of greater caliber than 105 mm but less than 155 mm, and (2) howitzers with calibers

Downloaded from http://www.everyspec.com

GLOSSARY (cont'd)

greater than 105 mm but not greater than 155 mm.

medium caliber, or **intermediate caliber**. Greater than 4 in. and less than 8 in. Navy terminology. No longer used as an Army classification.

O

obturation. 1. The act of, or means for, preventing the escape of gases. 2. In explosive applications, sealing of the breech of a gun to prevent escape of propellant gases.

obturator. An assembly of steel spindle, mushroom head, obturator rings, and a gas-check or obturator pad of tough elastic material used as a seal to prevent the escape of propellant gases around the breechblock of guns using separate-loading ammunition, and therefore not having the obturation provided by a cartridge case.

obturator pad. A pad of tough elastic material, forming part of an obturator.

obturator rings. Accurately machined and fitted rings forming part of an obturator.

obturator spindle. The part of the breechblock assembly of a gun which fires separate-loading ammunition. It extends through the breechblock and holds in position the various parts of the obturator, while permitting the breechblock independent rotation about these parts.

P

pressures, gun. Pressures within a gun tube or barrel, as used in design practices.

Because of the wide variations in size, wall ratios, heat dissipation, required factors of safety, etc., design practices vary for the different types of weapons. Some pressure terms having significance in the design of (a) all tubes and barrels, (b) cannon tubes, (c) recoilless rifle tubes, and (d) small arms barrels follow:

1. *For All Tubes and Barrels:*

chamber pressure. The pressure existent within the gun chamber at any time as a result of the burning of the propellant charge. This pressure normally varies from atmospheric pressure at the time of ignition to a peak pressure which is attained when the projectile has traveled a very short distance, decreasing steadily until the projectile emerges from the muzzle. It then drops quickly to atmospheric pressure again.

2. *For Cannon Tubes:*

elastic strength pressure (ESP). Computed true internal gas pressure in a gun at any given cross section thereof that will stress the metal at the inner layer of the wall at that section tangentially up to the minimum elastic limit of the metal from which the inner layer is made. Normally required to be a least 1.5 times the computed maximum pressure.

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

computed maximum pressure (CMP). The value of maximum pressure computed by means of interior ballistic formulas and which it is desired will be developed when a new gun of the particular type is fired under standard conditions, with a propelling charge which will give the projectile its rated muzzle velocity.

rated maximum pressure (RMP). The value of maximum pressure specified in the propellant specifications 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. Normally about 2000 psi above the computed maximum pressure, subject to determination at the time of development.

Downloaded from http://www.everyspec.com

GLOSSARY (cont'd)

lower acceptable mean maximum pressure (LAMMP). The value of the maximum pressure specified in the propellant specifications as the lower limit for the average of the maximum pressures developed by acceptable propellant in propelling charges that will impart the specified muzzle velocity to the specified projectile. Normally about 4000 psi under the computed maximum pressure, subject to determination at the time of development.

permissible mean maximum pressure (PMMP). The value which should not be exceeded by the average of the maximum pressures developed in a series of rounds fired under any service condition. Normally established as 1.08 times the rated maximum pressure.

permissible individual maximum pressure (PIMP). Values which should not be exceeded by the maximum pressure developed by any individual round under any service condition. Normally established as 1.15 times the rated maximum pressure.

primer, artillery. The term applied to a primer provided to effect ignition of the propellant charge of an artillery weapon. In ammunition employing a cartridge case, the primer is contained in the cartridge case. For separate-loading ammunition the primer is inserted in the breechblock. It consists of a charge of heat producing material, such as black powder, together with means for igniting the charge, and a metal housing to permit it to be handled as a unit. Artillery primers are classified by the method of initiation, as percussion, electric, friction, and combination percussion-electric.

primer seat. The chamber in the breech mechanism of a gun that use separate-loading ammunition into which the primer is set.

Q

quadrant. 1. One of the four parts into which a plane is divided by two perpendicular axes. 2. Instrument with a graduated scale used in laying the piece for elevation. It measures the vertical angle which the axis of the bore makes with the horizontal. When attached to the elevating mechanism as a part thereof, it is called elevation quadrant if graduated in mils or degrees, or range quadrant if graduated in range units. When it consists of a separate unattached instrument for hand placement on a reference surface, it is called a gunner's quadrant.

quadrant elevation. The vertical angle between horizontal and axis of bore of gun which exists just prior to firing; quadrant angle of elevation.

R

rammer. 1. A device for driving a projectile into position in a gun. It may be hand or power operated. 2. A tool used to remove live projectiles from the bore of a gun.

rate of fire. The rapidity with which rounds are fired per minute from a weapon or groups of weapons.

reaction propulsion. A propulsion system in which a forward motion or thrust is produced by the expulsion of propellant gases through nozzles or a venturi, generally longitudinally opposed to the intended line of travel.

recoil brake. That part of the recoil mechanism that actually absorbs the energy of recoil and stops the rearward movement of the recoiling parts.

recoiling parts. Those parts of a weapon which move in recoil. This usually includes the tube, breech housing, breechblock assembly, and parts of the recoil mechanism.

recoil operated. Of an automatic of semiautomatic firearm: that utilizes recoil to throw back or unlock the bolt or slide and actuate the loading mechanism. Applies especially to certain locked-breech firearms. Recoil operated weapons are classified as long recoil when the

Downloaded from http://www.everyspec.com

GLOSSARY (cont'd)

barrel and breechblock or bolt recoil the entire distance together, and as short recoil when the breechblock or bolt is unlocked and the barrel is stopped after only a short distance of recoil together.

reliability. The probability of a device performing its purpose adequately for the period of time intended under the operating conditions encountered. For a system with independent components the overall reliability is based on the product of the individual reliabilities; e.g., three independent components with a 90% reliability each will have an overall reliability of 0.9 × 0.9 × 0.9 or 72.9%. Similarly, 100 components with a 99% reliability will have an overall reliability of only 36.5%.

rifling. The helical grooves cut in the bore of a rifled gun tube, beginning at the front face of the gun chamber (origin or rifling) and extending to the muzzle; also the operation of forming the grooves in the gun tube. The purpose of rifling is to impart spin and stability to the projectile, so that the projectile will travel nose first to the target.

Engagement of the projectile with the rifling is generally accomplished by using a rotating band on projectiles greater than about 0.60 in. in diameter, and on smaller projectiles, by providing a soft bullet or, if a hard cored projectile is necessary, by the use of a relatively soft jacket.

The gun bore diameter is determined by the ridges between the rifling grooves. These ridges are referred to collectively as the lands, and the sides of the lands are called edges.

When the projectile or bullet starts to move under the force exerted by the propellant gases, the rotating band or jacket is engraved by the rifling which forms a reverse replica in the band or jacket. This engraving is accomplished partly by cutting and partly by forming.

In recoilless ammunition the force required to accomplish engraving of the band would interfere with accomplishment of the recoilless feature, and the projectiles for this ammunition are preengraved; i.e., the grooves corresponding to the rifling are made in the rotating band at the time of manufacture. Provision is made to ensure that the projectile will be inserted in the recoilless rifle in proper relationship to the rifling.

The twist of rifling at any point is the inclination of a groove to the element of the bore. It is expressed as the number of calibers of length in which the helix makes one complete turn, for example, one turn in 40 calibers. The direction of rifling is usually right hand, causing the projectile to rotate in a clockwise direction, as viewed from the base. This is known as right-hand twist. If rotated in the opposite direction, it would be called left-hand twist.

The present practice is to provide rifling of uniform twist, i.e., rifling in which the angle of the helix to an element of the bore is constant.

Opinion relative to the desirability of uniform twist of rifling as opposed to increasing twist of rifling has apparently become settled in favor of the uniform twist. Considerations of production were important factors in this decision. Under the increasing twist system, the twist may start either at zero or at some low value and then increase according to some function of the travel, either to the muzzle, or to some point short of the muzzle at which point the twist would become uniform to the muzzle. Increasing twist is also known as gain-twist.

rocket, boosted. A rocket contained in a cylindrical-shaped case, one end of which is fitted with a primer and propelling charge for imparting initial velocity to the rocket, usually launched from a cannon.

S

safety lock. The locking device that prevents a weapon from being fired accidentally.

Downloaded from http://www.everyspec.com

GLOSSARY (cont'd)

scavenging. 1. The sweeping out of engine cylinder, by piston movement or a blast of air, of all or most of the gaseous products of the preceding fuel combustion. 2. The sweeping out by a blast of air, of the gaseous products resulting from the firing of a gun. Provided for in some fixed or turret installations.

scavenger system. 1. A device for clearing smoke and gases from the chamber and bore after firing. Also known as "gas ejector system".

sear. 1. An item so designed as to retain the firing mechanism of a gun in the cocked position. 2. A variety of lockwork in the firing mechanism of a cartridge actuated device which prevents motion of the firing pin until released.

semifixed ammunition. Ammunition in which the cartridge case is not permanently fixed to the projectile, so that the zone charge within the cartridge case can be adjusted to obtain the desired range; loaded into the weapon as a unit. *cf*: **fixed ammunition, separate-loading ammunition, separated ammunition**.

separated ammunition. 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 fixed ammunition.

separate-loading ammunition. Ammunition in which the projectile, propellant charge (bag loaded), and primer are handled and loaded separately into the gun. No cartridge case is utilized in this type of ammunition.

setback. 1. The relative rearward movement of component parts in a projectile, missile, or fuze undergoing forward acceleration during its launching. These movements, and the setback force which causes them, are used to promote events which participate in the arming and eventual functioning of the fuze. 2. Short for "setback force". *See also*: **setback force**.

setback force. The rearward force of inertia which is created by the forward acceleration of a projectile or missile during its launching phase. The forces are directly proportional to the acceleration and mass of the parts being accelerated. *See also*: **setback**.

sliding block. *See*: **breechblock, sliding-wedge**.

sliding-wedge breechblock. *See*: **breechblock, sliding-wedge**.

slotted-screw breechblock. *See*: **breechblock, interrupted-screw**.

spanning tray. A removable hollowed tray on which the elements of separate-loading ammunition slide when being inserted in the breech of a cannon.

T

tank, combat, full-tracked. A self-propelled, heavily armored, offensive vehicle having a fully enclosed revolving turret with one major weapon. It may mount one or more machine guns. Excludes self-propelled weapons.

time, down (downtime). That element of time during which the item is not in condition to perform its intended function.

towed artillery. Artillery weapons designed for movement as trailed loads behind prime movers. Some adjustment of the weapon is necessary to place it in firing position.

traverse. Movement to right or left on a pivot or mount, as of a gun, launcher, or radar antenna.

trigger. A mechanism which when pulled, as with the finger, releases another mechanism, as in the trigger of a gun; likewise, a mechanism which pressed does the same thing, as in the trigger of a control stick used to fire a gun.

trigger, electrical. A mechanism to provide for remote control of the electric gun firing solenoid for automatic guns.

trigger fork. That part of a firing lock which bears against the firing pin holder sleeve and is engaged to the trigger shaft so that rotation of

Downloaded from http://www.everyspec.com

GLOSSARY (cont'd)

the latter part causes the fork to force the sleeve forward and compress the firing spring.

trigger pull. The resistance offered by the trigger of a rifle or other weapon; force which must be exerted to pull the trigger. Usually expressed in pounds.

trigger shaft. The shaft which passes transversely through the breechblock and firing lock, and whose arm is actuated by the firing mechanism. Movement of the arm rotates the shaft and thus imparts movement to the trigger fork of the firing lock.

trunnion. 1. One of the two pivots supporting a piece of artillery on its carriage and forming the horizontal axis about which the piece rotates when it is elevated. 2. One of the two supporting pivots for holding an instrument on its mount.

tube, cannon. A cylindrical metallic item which is that part of a cannon which controls the initial direction of the projectile. The bore may be rifled and must have a diameter of 37 mm or larger.

turret (trt). Dome-shaped or cylindrical armored structure containing one or more guns located on forts, warships, airplanes, and tanks. Most turrets are built so that they can be removed.

turret gun. Gun mounted in a turret.

W

weapon system. In logistic use: A total entity consisting of an instrument of combat (a single unit of striking power), such as a bomber or a guided missile, together with all related equipment, supporting facilities, and services, required to bring the instrument upon its target or to the place where it carries out the function for which it was built.

Welin breechblock. *See*: **breechblock, stepped-thread** (Welin).

Z

zone. An area in which projectiles will fall when a given propelling charge is used and the elevation is varied between the minimum and the maximum. Use of the term is generally limited to howitzer and mortar firings.

zone charge. The number of increments of propellant in a propellant charge of semifixed rounds, corresponding to the intended zone of fire; e.g., zone charge 5 consists of 5 increments of propellant. *See also*: **increment**.

Downloaded from http://www.everyspec.com

INDEX

Downloaded from http://www.everyspec.com

INDEX (cont'd)

Downloaded from http://www.everyspec.com

INDEX (cont'd)

Downloaded from http://www.everyspec.com

ENGINEERING DESIGN HANDBOOKS

These Handbooks are available to Department of the Army activities by submitting an official requisition form (DA Form 17, 17 Jan 70) directly to the Commander, Letterkenny Army Depot, ATTN: SDSLE–AJD, Chambersburg, PA 17201. "Need to know" justification must accompany requests for classified Handbooks. Requestors—DOD, Navy, Air Force, Marine Corps, non-military Government agencies, contractors, private industry, individuals, universities, and others—who are registered with the Defense Documentation Center (DDC) and have a National Technical Information Service (NTIS) deposit account may obtain these Handbooks from the DDC. To obtain classified documents from the DDC, "Need to Know" must be established by the submission of DD Form 1540, 1 Jul 71. Requestors, not part of the Department of the Army nor registered with the DDC, may purchase unclassified Handbooks from the National Technical Information Service, Department of Commerce, Springfield, VA 22161. All Handbooks carry the prefix AMCP 706- unless otherwise indicated.

Handbook No. 706-	Document No. (Used by DDC and NTIS)		Title	NTIS Price
100	AD-890 839	**	Design Guidance for Producibility	$13.00
101†	—		Army Weapon Systems Analysis, Part One	—
102†	—	*	Army Weapon Systems Analysis, Part Two	—
104	AD-894 478		Value Engineering	$ 6.00
106	AD-830 272		Elements of Armament Engineering, Part One, Sources of Energy	$ 6.50
107	AD-830 287		Elements of Armament Engineering, Part Two, Ballistics	$ 9.50
108	AD-830 288		Elements of Armament Engineering, Part Three, Weapon Systems and Components	$ 9.25
109	AD-903 967		Tables of the Cumulative Binomial Probabilities	$19.00
110	AD-865 421		Experimental Statistics, Section 1, Basic Concepts and Analysis of Measurement Data	$ 9.00
111	AD-865 422		Experimental Statistics, Section 2, Analysis of Enumerative and Classificatory Data	$ 5.25
112	AD-865 423		Experimental Statistics, Section 3, Planning and Analysis of Comparative Experiments	$ 6.00
113	AD-865 424		Experimental Statistics, Section 4, Special Topics	$ 6.50
114	AD-865 425		Experimental Statistics, Section 5, Tables	$ 8.00
115	AD-784 999		Environmental Series, Part One, Basic Environmental Concepts	$ 9.25
116	ADA-012 648		Environmental Series, Part Two, Natural Environmental Factors	$25.00
117	ADA-023 512		Environmental Series, Part Three, Induced Environmental Factors	$17.50
118	ADA-015 179		Environmental Series, Part Four, Life Cycle Environments	$17.50
119	ADA-015 180		Environmental Series, Part Five, Glossary of Environmental Terms	$12.50
120	AD-889 588		Criteria for Environmental Control of Mobile Systems	$ 9.00
121	AD-901 533		Packaging and Pack Engineering	$13.00
123	AD-884 519		Hydraulic Fluids	$11.00
124	ADA-025 665		Reliable Military Electronics	$15.00
125	AD-865 109		Electrical Wire and Cable	$ 9.25
127	AD-763 495		Infrared Military Systems, Part One	$16.25
128 (S)	ADC-001 857		Infrared Military Systems, Part Two (U)	—
130	AD-830 262		Design for Air Transport and Airdrop of Materiel	$12.00
132	ADA-021 390		Maintenance Engineering Techniques (MET)	$20.00
133	ADA-026 006		Maintainability Engineering Theory and Practice	$17.50
134	AD-754 202	**	Maintainability Guide for Design	$13.00
136	AD-655 861	**	Servomechanisms, Section 1, Theory	$ 9.50
137	AD-830 263	**	Servomechanisms, Section 2, Measurement and Signal Converters	$ 7.25
138	AD-830 274		Servomechanisms, Section 3, Amplification	$ 9.25
139	AD-830 283		Servomechanisms, Section 4, Power Elements and System Design	$ 9.25
140	AD-830 264		Trajectories, Differential Effects, and Data for Projectiles	$ 5.25
150	AD-462 060		Interior Ballistics of Guns	$ 8.00
158†	—	*	Dynamics of Ballistic Impact, Part One	—
159 (S)†	—	*	Dynamics of Ballistic Impact, Part Two (U)	—
160	AD-389 219		Elements of Terminal Ballistics, Part One, Kill Mechanisms and Vulnerability	$15.00
161	AD-289 318		Elements of Terminal Ballistics, Part Two, Collection and Analysis of Data Concerning Targets	$ 7.00
162 (SRD)	AD-389 372		Elements of Terminal Ballistics, Part Three, Application to Missile and Space Targets (U)	—
163 (C)†	ADC-013 060		Basic Target Vulnerability (U)	—
165	AD-853 719		Liquid-Filled Projectile Design	$ 7.50
170 (S)	AD-530 822		Armor and Its Applications (U)	—
175	AD-830 265		Solid Propellants, Part One	$ 7.25
177	AD-764 340	**	Properties of Explosives of Military Interest	$13.25
179	AD-777 482		Explosive Trains	$ 9.50
180	AD-900 260		Principles of Explosive Behavior	$13.00
181	ADA-003 817		Explosions in Air, Part One	$10.50
182 (SRD)	ADC-004 269		Explosions in Air, Part Two (U)	—
185	AD-817 071		Military Pyrotechnics, Part One, Theory and Applications	$10.75
186	AD-830 371		Military Pyrotechnics, Part Two, Safety, Procedures and Glossary	$ 5.25
187	AD-830 394		Military Pyrotechnics, Part Three, Properties of Materials Used in Pyrotechnic Compositions	$12.50
188	ADA-000 821		Military Pyrotechnics, Part Four, Design of Ammunition for Pyrotechnic Effects	$11.00
189	AD-803 864		Military Pyrotechnics, Part Five, Bibliography	$ 6.00
191	AD-884 151		System Analysis and Cost-Effectiveness	$13.25
192	AD-767 826		Computer Aided Design of Mechanical Systems	$12.00
193†	—		Computer Aided Design of Mechanical Systems, Part Two	—
196	ADA-027 370		Development Guide for Reliability, Part Two, Design for Reliability	$12.50
197	ADA-032 105		Development Guide for Reliability, Part Three, Reliability Prediction	$10.50
198	ADA-027 371		Development Guide for Reliability, Part Four, Reliability Measurement	$15.00
199	—	*	Development Guide for Reliability, Part Five, Contracting for Reliability	—
200	ADA-027 372		Development Guide for Reliability, Part Six, Mathematical Appendix and Glossary	$12.50

*UNDER PREPARATION—not available
**REVISION UNDER PREPARATION

***Limited Documents are not for sale by NTIS
† DARCOM-P 706-

Downloaded from http://www.everyspec.com

ENGINEERING DESIGN HANDBOOKS (cont'd)

Handbook No. 706-	Document No. (Used by DDC and NTIS)	Title	NTIS Price
201	ADA-022 007	Helicopter Engineering, Part One, Preliminary Design	$17.50
202	ADA-033 216	Helicopter Engineering, Part Two, Detail Design	$20.00
203	AD-901 657	** Helicopter Engineering, Part Three, Qualification Assurance	$12.00
204	AD-785 000	Helicopter Performance Testing	$10.75
205	ADA-020 020	Timing Systems and Components	$17.50
210	AD-889 245	Fuzes	$ 9.25
211	AD-389 295	Fuzes, Proximity, Electrical, Part One	$ 4.75
212 (S)	AD-389 331	Fuzes, Proximity, Electrical, Part Two (U)	—
213 (S)	AD-389 330	Fuzes, Proximity, Electrical, Part Three (U)	—
214 (S)	AD-389 333	Fuzes, Proximity, Electrical, Part Four (U)	—
215	AD-389 296	Fuzes, Proximity, Electrical, Part Five	$ 6.25
235	AD-864 910	Hardening Weapon Systems Against RF Energy	$10.75
238	ADA-023 513	Recoilless Rifle Weapon Systems	$20.00
240 (C)	AD-386 896	Grenades (U)	—
242	AD-801 509	Design for Control of Projectile Flight Characteristics	$ 7.25
244	AD-830 290	Ammunition, Section 1, Artillery Ammunition—General, with Table of Contents, Glossary, and Index for Series	$ 6.00
245	AD-389 304	Ammunition, Section 2, Design for Terminal Effects	$12.50
247	AD-830 296	Ammunition, Section 4, Design for Projection	$ 9.00
248	AD-830 284	Ammunition, Section 5, Inspection Aspects of Artillery Ammunition Design	$ 4.50
249	AD-830 266	Ammunition, Section 6, Manufacture of Metallic Components of Artillery Ammunition	$ 5.25
250	AD-830 303	Guns—General	$ 6.00
251	AD-838 748	Muzzle Devices	$ 7.25
252	AD-830 297	** Gun Tubes	$ 6.50
253†	—	* Breech Mechanism Design	—
255	AD-818 532	Spectral Characteristics of Muzzle Flash	$ 6.50
260	AD-868 578	Automatic Weapons	$12.00
270	ADA-016 716	Propellant Actuated Devices	$12.50
280	AD-840 582	** Design of Aerodynamically Stabilized Free Rockets	$ 9.25
281 (SRD)	AD-389 352	Weapon System Effectiveness (U)	—
283	AD-830 377	Aerodynamics	$ 6.00
284	AD-389 298	Trajectories	$ 6.50
285	AD-861 082	Elements of Aircraft and Missile Propulsion	$21.25
286	AD-830 267	Structures	$ 6.00
290	AD-501 329	Warheads—General	$12.50
300	AD-905 372	*** Fabric Design (Limited Document)	—
312	ADA-013 178	Rotational Molding of Plastic Powders	$15.00
313	ADA-015 181	Short Fiber Plastic Base Composites	$12.50
327	AD-830 809	Fire Control Systems—General	$15.25
329	AD-879 465	Fire Control Computing Systems	$15.00
331	AD-830 275	Compensating Elements	$ 6.50
340	AD-830 276	** Carriages and Mounts—General	$ 4.50
341	AD-830 277	** Cradles	$ 5.25
342	AD-830 281	** Recoil Systems	$ 6.00
343	AD-830 393	** Top Carriages	$ 4.50
344	AD-830 396	** Bottom Carriages	$ 4.50
345	ADA-003 347	** Equilibrators	$ 4.75
346	AD-830 301	** Elevating Mechanisms	$ 4.50
347	AD-830 291	** Traversing Mechanisms	$ 4.50
350	AD-881 357	Wheeled Amphibians	$13.25
355	AD-830 268	The Automotive Assembly	$15.25
356	AD-817 023	Automotive Suspensions	$14.50
357	AD-873 103	Automotive Bodies and Hulls	$13.25
358†	ADA-035 445	Analysis and Design of Automotive Brake Systems	$15.00
360	AD-783 697	Military Vehicle Electrical Systems	$16.50
361	ADA-013 769	Military Vehicle Power Plant Cooling	$20.00
410†	ADA-038 803	Electromagnetic Compatibility (EMC)	$22.50
411 (S)	ADC-008 827	Vulnerability of Communication-Electronic and Electro-Optical Systems (Except Guided Missiles) to Electronic Warfare, Part One, Introduction and General Approach to Electronic Warfare Vulnerability (U)	—
412 (C)	ADC-008 828	Part Two, Electronic Warfare Vulnerability of Tactical Communications (U)	—
413 (S)	ADC-008 829	Part Three, Electronic Warfare Vulnerability of Ground-Based and Airborne Surveillance and Target Acquisition Radars (U)	—
414 (S)	ADC-008 830	Part Four, Electronic Warfare Vulnerability of Avionics (U)	—
415 (S)	ADC-008 831	Part Five, Optical/Electronic Warfare Vulnerability of Electro-Optic Systems (U)	—
416 (S)	ADC-008 832	Part Six, Electronic Warfare Vulnerability of Satellite Communications (U)	—
417 (S)†	—	Vulnerability of Guided Missile Systems to Electronic Warfare (U)	—
445	AD-903 789	Sabot Technology Engineering	$11.00
470†	ADA-029 902	Metric Conversion Guide	$ 9.00

*UNDER PREPARATION—not available
**REVISION UNDER PREPARATION

***Limited Documents are not for sale by NTIS
† DARCOM-P 706-

☆ U. S. GOVERNMENT PRINTING OFFICE : 1979 O - 280-964 (1165)

Downloaded from http://www.everyspec.com

(DRCMT)

FOR THE COMMANDER:

ROBERT L. MOORE
Brigadier General, USA
Chief of Staff

OFFICIAL:

G. J. HAROLD
LTC, GS
Adjutant General

DISTRIBUTION:
Special